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Chart Review and Factor Analysis Examining Poorer-Than-Expected Word Recognition Scores

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ABSTRACT

CHART REVIEW AND FACTOR ANALYSIS EXAMINING POORER-THAN-EXPECTED WORD RECOGNITION SCORES

Katherine Allen, B.A

The purpose of this study was to examine commonalities between patient case history complaints, diagnoses, and test results, and cases presented in the literature. Patient files of individuals seen for audiological testing at the Towson University Institute for Well Being were reviewed. The total number of active, inactive, and archived audiology patient files totaled 2,554. Patients with a diagnosis of sensorineural hearing loss and poorer-than-expected word recognition scores, compared to Dubno et al. (1995), met study criteria. The number of patient files that met study criteria, and were included in statistical analysis, was 231 after exclusions (n = 163). Data were analyzed to determine any numerical (i.e., PTA, WRS) or case history complaints (i.e., difficulty in noise) significantly predicted poorer-than-expected word recognition scores. Patient pure-tone average (average of 500 Hz, 1000 Hz, and 2000 Hz) was the only significant predictor of poor word recognition scores. Individuals with sudden sensorineural hearing loss appeared to have markedly decreased word recognition scores, and individuals with OAE notches ≥15 dB appeared to have better word recognition scores, on average, compared to the individuals who did not present with this case history; however, inferential statistics were not calculated on this sub-population due to the small sample size. Future research should focus on a prospective study to determine statistical significance of case history variables, and additional rehabilitation options for individuals with poor word recognition abilities.

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KEY TO ABBREVIATIONS

APD: Auditory Processing Disorder

OAD: Obscure Auditory Dysfunction

KKS: King-Kopetzky Syndrome

WRS: word recognition score

SRT: speech recognition score

CHL: conductive hearing loss

SNHL: sensorineural hearing loss

dB: decibel

HL: hearing level

IHC: inner hair cell

DL: difference limen

Hz: Hertz

F0: fundamental frequency

VOT: voice onset time

TFS: Temporal Fine Structure

STM: short-term memory

LTM: long-term memory

WM: working memory

PTA: pure-tone average

HFPTA: high-frequency pure-tone average

OME: otitis media with effusion

MLV: monitored live voice

OAE: otoacoustic emissions

DPOAE: distortion-product otoacoustic emissions

TEOAE: transient evoked otoacoustic emissions

UCL: uncomfortable level

ANSD: Auditory Neuropathy Spectrum Disorder

DR: dynamic range

CANS: Central Auditory Nervous System

SNR: signal-to-noise ratio

QoL: quality-of-life

CHAPTER 1

Introduction

Hearing loss is a growing health concern worldwide that affects between 1 and 3 out of 1000 infants and is one of the most common health issue affecting individuals aged 65 years and older in the United States (Dubno et al., 2013; Hilgert, Smith, & Van Camp, 2009). Individuals experiencing even a slight hearing loss are likely to experience impediments in their communicative abilities, education, psychosocial development, and overall quality of life. Additionally, there is a small population with normal hearing, characterized by normal audibility, that suffer from perceptual effects similar to those associated with hearing loss (Haggard, Saunders, & Gatehouse, 1987; Higson, Haggard, & Field, 1994: Hinchcliffe, 1992; Pryce, Metcalfe, Hall, & Claire, 2010). Many of these individuals will have poor speech discrimination abilities in conjunction with normal audibility; and because they are not candidates for traditional amplification they will likely go without answers or rehabilitation for their complaints (Cianfrone, Turchetta, Mazzei, Bartolot, & Parisi, 2006; Keith, 1999; Stach, 2007). Thus, the field of audiology is presented with a patient population that goes untreated. This retrospective case review aimed to identify common case history complaints, audiological test results, and previous diagnoses among patients with poorer than expected word recognition scores; and provide the audiologist with ways to identify and treat this unique population.

Previous research has examined the psychophysical aspects of hearing as well as the word recognition portion of the comprehensive audiological evaluation (Dilley, Wieland, Gamache, McAuley, & Redford, 2013; Dobie & Van Hemel, 2005; Dubno, Lee, Matthews, & Lam, 1995; Fogery, 2013; Gelfand, 2009; Katz et al., 2009; Mackersie, Prida, & Stiles, 2001; Moore, 2012; Stach, 2007; Thibodueau, 2007; Thornton & Raffin, 1978). Such research has touched upon the differences between phonetically-balanced (containing sounds at the same rate as they occur in spoken language) and phonemically-balanced (consonant-vowel-consonant format) word lists, the importance and effects of presenting full versus shortened lists, the differences in scores between monitored live voice and recorded material, and the impact presentation level has on an individual's word recognition abilities (Boothroyd, 1968, 1984; Dubno et al., 1995; Guthrie & Mackersie, 2009; Martin, Champlin, & Perez, 2000; Runge & Hosford-Dunn, 1985; Stach, 2007; Wiley, Stoppenbach, Feldhake, Moss, & Thordardottir, 1995). Other research has focused on specific disorders related to poor word recognition abilities and the complaints patients with these disorders present to the clinic (Cianfrone et al., 2006; Keith, 1999; Pryce et al., 2010; Saunders, Field, & Haggard, 1992). These disorders include hearing loss and more unique disorders such as Auditory Neuropathy Spectrum Disorder, Auditory Processing Disorder, and Obscure Auditory Dysfunction/King-Kopetsky Syndrome (combination of various physical and psychological factors contributing to perceptual hearing difficulties in the presence of a normal audiological evaluation) (Cianfrone et al., 2006; Higson et al., 1994; Keith, 1999; Pryce et al., 2010; Saunders, Field, & Haggard, 1992). Individuals with these disorders have common complaints which include difficulty understanding speech, especially in noise, and the ability to hear but not understand.

The present study is a retrospective case review and analysis of patients who presented with poorer-than-expected word recognition relative to their pure-tone

audiometric findings. The hypothesis was that individuals with poorer-than-expected word recognition would present with similar case history complaints, family histories of otologic conditions, and previous or current diagnoses similar to those found in previous research. A comprehensive retrospective review was used to extract indicators of disorders. This research has practical implications in the field of audiology to provide information regarding psychoacoustics and the psychological nature of an at-risk population that otherwise goes untreated.

CHAPTER 2

Literature Review

Hearing loss can be caused by multiple genetic and environmental factors; therefore, individuals with hearing loss consist of a large heterogeneous group (Dubno, Eckert, Lee, Matthews, & Schmiedt, 2013). In the United States, individuals 65 years of age and older (approximately 30% of the population) report hearing loss as a chronic impairment affecting day-to-day life (Dubno et al., 2013). Additionally, after the age of 60 years, hearing declines at an average rate of 0.7-1.23dB at each frequency per year (Jenstad & Souza, 2007). For adults, decreased hearing acuity leads to decreased quality-of-life and, cognitive, and emotional states (Agrawal, Platz, & Niparko, 2008).

In children, hearing loss affects the development of communication which can result in poor education performance. Hearing loss can also negatively impact the development of social skills, which can lead to impaired relationships (Niskar et al., 2009). Hearing loss is the most common birth defect in industrial nations, estimated to include more than 7 million children between the ages of 6 and 19 years having at least a slight degree of hearing loss (Hilgert et al., 2009; Niskar et al., 2015). The population of newborns with bilateral sensorineural hearing loss greater than a mild degree is 1/500. As age increases, prevalence increases to as much as 3.5/1000 by adolescence (Hilgert et al., 2009). The most common environmental cause of hearing loss, congenital cytomegalovirus (CMV), has a prevalence of 0.64%, whereas 70% of newborns with no exposure to environmental causes are born with non-syndromic, hereditary hearing loss (Hilgert et al., 2009).

Due to exponential growth of the decibel (dB), a change as small as 1dB can severely impact an individual's hearing abilities (Niskar et al., 2009). Essentially this gives a range of 25dB (-10dB HL – 15dB HL) for normal hearing. Someone with audiometric frequencies at -10dB HL might have fewer hearing difficulties than someone with thresholds at 15dB HL, yet despite both are considered to have no hearing impairment. Therefore, hearing and speech comprehension can differ among people categorized as having normal hearing. There is a small subgroup of individuals with normal hearing and poorer-than-expected word recognition abilities. Individuals within this subgroup might fall into various diagnoses such as auditory processing disorder (APD) or obscure auditory dysfunction (OAD)/King-Kopetzky syndrome (KKS). Associated with these diagnoses comes the common complaint of difficulty understanding speech in the presence of background noise. In order to understand individual psychophysiological differences in hearing ability, a core understanding of speech perception is necessary.

Processes Underlying Speech Perception

Speech consists of three broad features: frequency, duration, and intensity (Dobie & Van Hemel, 2005). Speech processing consists of perceiving physical properties of the signal and deriving meaning through processes such as cognition and working memory (Dobie & Van Hemel, 2005). Physical information such as frequency, duration, and intensity are coded by the inner hair cells (IHCs) of the cochlea and the cochlear branch of the auditory nerve, which then sends this information to the brainstem and auditory cortex (Dobie & Van Hemel, 2005). Both the basilar membrane of the cochlea and the auditory nerve are tonotopically organized. Different fibers are responsible for coding different frequencies and intensities characteristic of a stimulus (Dobie & Van Hemel, 2005). This tonotopic organization extends throughout the auditory cortex in the brain. Successful processing of both physical and cognitive elements of speech contributes to an individual's successful interpretation and perception of a signal.

Intensity and loudness perception. One portion of the signal that is transmitted through the auditory pathway is intensity. Human ears have a dynamic range of 140dB, meaning the ear can detect intensities ranging from 0dB SPL to 140dB SPL. There are difference limens (DL) for the intensity of signals. These differences are based on the concept of Weber's Law, which states that the ratio between the DL and starting intensity level (known as Weber's Fraction) is constant (Gelfand, 2009). For pure tone stimuli, Weber's Fraction decreases with increasing intensity, such that at 5dB SPL the DL is 1.7dB and decreases to 0.5dB SL at 80dB SPL; these DLs remain constant between 10-40dB SL and do not appear to be affected by frequency (Gelfand, 2009). Although intensity plays an important role in audibility, pitch and timing information tends to be more important for speech perception, as these factors convey information including semantic, lexical, syntactic, and emotional features of the stimulus (Dilley et al., 2013).

Loudness is the psychoacoustic correlate to the perception of intensity, such that sounds with less intensity are perceived to be not as loud as those with higher intensities. The level of loudness is based on equal loudness contours, meaning how loud a tone of a particular frequency must be to reach perceived equal loudness of a 1000Hz tone. Equal loudness of a 1000Hz tone is measured in phons, whereas loudness growth relative to a 1000Hz tone at 40dB SPL is measured as one sone (Moore, 2012). For example, a 125Hz tone must be 60dB SPL to reach equal loudness of a 40dB SPL 1000Hz tone. These differences decrease as intensity increases (i.e., the same 125Hz tone need only be 5dB SPL louder than the 1000Hz tone at 100dB SPL in order to be perceived as equally loud) (Moore, 2012).

The spectral energy for speech sounds that are vowels is higher in intensity than spectral energy of consonants (Moore, 2012). Lower frequency sounds are perceived as softer than higher frequency sounds, but grow in perceived loudness at a faster rate than high frequency sounds (Gelfand, 2009). Moreover, if the intensity of a signal is increased 10-fold (or changed by 10dB), the perceived loudness of that sound will double. For example, a 1000Hz tone at 40dB SPL is one sone, and a 1000Hz tone at 50dB SPL is two sones (Moore, 2012).

Characteristics of speech are such that vowels are more recognizable than consonants and contribute to the intensity of the signal, whereas consonants contribute to increased clarity and intelligibility (Meyer, Dentel, & Meunier, 2013). Vowels are produced by constant voicing and are characterized by the filtering properties of the vocal folds, physiological characteristics of the vocal tract, as well as articulatory characteristics of the oral cavity (i.e., tongue placement or lip rounding) (Gelfand, 2009). Another vowel characteristic is 'tenseness', or amount of muscular constriction, which contributes to the intensity and, therefore, perceived loudness of a vowel. An example of a tense vowel is the phoneme /i/ (articulated as "ee"). Tense vowels are higher in intensity than non-tense vowels. An example of a non-tense vowel is the schwa /ə/, an unstressed syllable found in words such as bord/ə/m (Gelfand, 2009).

True vowels are those which stand alone and are produced in the oral cavity with certain amounts of tongue elevation or lip rounding. Other sounds known as 'nasals' (/m/,

/n/, and /ng/) and semi-vowels (/w/, /j/, /l/, and /r/) have less intensity than their true vowel counterparts. Nasals are not considered true vowels due to their lower fundamental frequency (F0) and nasal murmur caused by the addition of the nasal cavity as a resonator. Semivowels are also not considered true because the place of articulation changes during transition from one vowel sound to another (Gelfand, 2009).

Consonants are varying interruptions of voicing characteristics of a signal and are distinguished from vowels by a disturbance in air flow within the oral cavity, characterized as place of articulation (Gelfand, 2009). Consonants can be divided into two general categories: voiced or voiceless, depending on whether the vocal folds are vibrating during articulation. During production of a voiced consonant, the vocal folds vibrate. As a result of this vibration, voiced consonants are louder than voiceless consonants. The vocal folds remain inactive during the production of voiceless consonants, and air expenditure from the lungs is built up behind the place of articulation (Gelfand, 2009).

Frequency and pitch perception. Identification of specific frequency characteristics of speech sounds are necessary for successful understanding. Human hearing has a frequency range from 20Hz to 20,000Hz and is most sensitive to the frequency range of 2000 to 5000Hz (Gelfand, 2009). Depending on the frequency, DLs will be shorter or longer in duration. In general, the DL increases with increasing frequency. For example, with a presentation of 40dB SL, a DL of 1Hz can be detected for low frequency stimuli (<1000Hz). To perceive differences in high frequency tones the difference between frequencies must be greater. The DL is about 16Hz for frequencies near the 4000Hz region and 68Hz for frequencies near 8000Hz (Gelfand, 2009).

Simply stated, speech production is characterized by the F0. This F0 provides information regarding the age and sex of the speaker (Watson & Schlauch, 2008). Average F0s for a males are between 100 and 150Hz, between 200-220Hz for females, and in the range of 400Hz for children (Abrams & Kraus, 2009; Skuk & Schweinberger, 2014). The F0 categorizes the acoustic components of a speaker’s voice and separates them from other speakers. This becomes increasingly important for speech perception in challenging listening environments (Fogerty, 2013; Mackersie, Prida, & Stiles, 2001). Subsequent to the F0 are the frequency components F1, F2, and F3. These frequencies are determined by points of articulation within the oral cavity and contribute to recognition of vowels within speech stimuli (Gelfand, 2009).

The psychoacoustic manifestation of frequency is the perceived pitch of an acoustic signal. As F0 increases or decreases different pitches are perceived (i.e., as the F0 increases the listener hears one pitch until a considerable enough difference is reached, causing the listener to perceive a different pitch) (KÖhler, 1987). Low frequencies are perceived as low pitched tones and high frequencies as high pitched tones (Gelfand, 2009). Though the intensity of the stimulus does contribute somewhat to varying pitch perception, the effects are minimal. For speech stimuli, pitch is equivalent to the F0 of the utterance, with contributions from formants up to and including F5 (Gelfand, 2009).

Perception of speech-related frequency. Successful detection of changes in a speech signal occurs when consonants are perceived as different phonemes. When consonants are not perceived as different, changes in the signal are undetected. This phenomenon is referred to as *categorical perception* (Gelfand, 2009; Moore, 2012). The feature influencing phonemic separation is the voice onset time (VOT). VOT is defined as, "… the relation between the [brief interval of high intensity noise] and the onset of pulsing [of the vocal cords]" (Lisker & Abramson, 1967, p. 2). VOT is used to distinguish voiced from voiceless stop consonants in initial position (the first phoneme of a word) and fricative consonants. Voiced consonants have shorter VOTs than voiceless consonants (Gelfand, 2009)

Vocalizations with short VOTs are perceived as one phoneme (i.e., /d/) and longer VOTs are perceived as a phoneme of a higher pitch (i.e., /t/). As VOT increases a boundary, termed the *categorical boundary*, is reached. For example, VOT increases until reaching the categorical boundary, at which point the phoneme /d/ is instantly perceived as the phoneme /t/ and is not misconstrued as any other consonant (Gelfand, 2009). A diagram of this relationship can be seen in Figure 1. Categorical perception represents the relationship between duration and frequency in an individual's ability to perceive frequency information of a speech signal.

Duration and temporal perception. Detection of a signal by a listener is dependent on the duration of the signal. The time it takes for speech to reach a listener is characterized by pressure waves occurring over time (Dobie & Van Hemel, 2005). Amplitude modulation of a signal is used to determine the envelope and temporal fine structure (TFS) of a signal. The distinction between temporal envelope and temporal fine structure can be seen in Figure 2.

The modulation of the timing-intensity relationship of a stimulus is the temporal envelope of a speech signal, and is arguably the most important aspect to speech perception. The envelope of a stimulus represents generalized changes in amplitude of

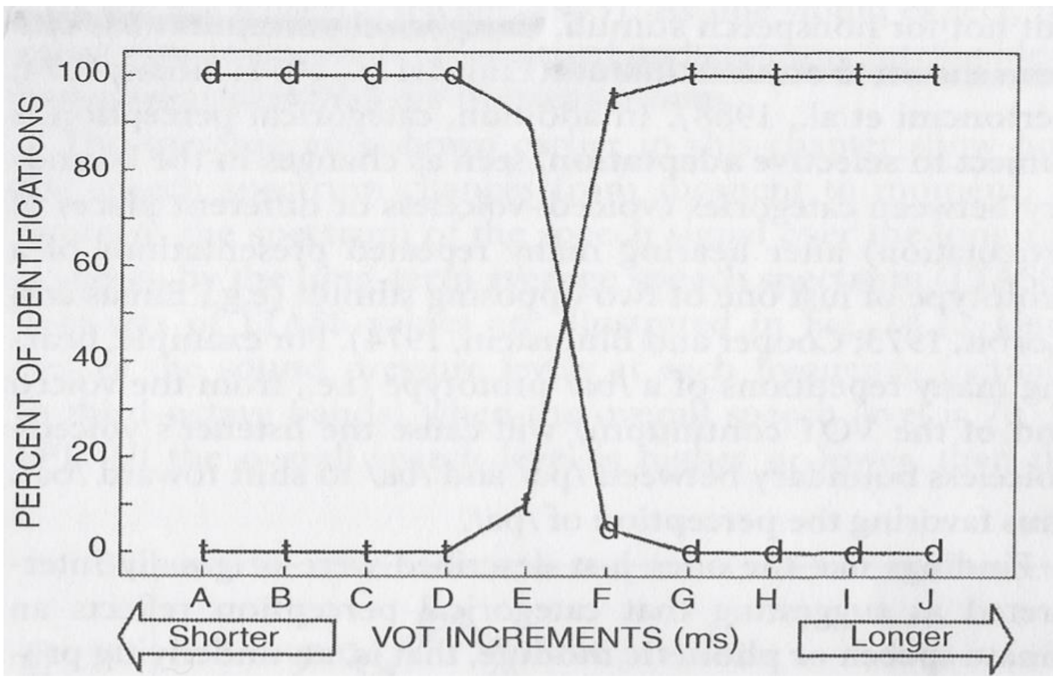


Figure 1. The relationship between VOT and correct identification of the phonemes /d/ and /t/. From *Hearing: An introduction to psychological and physiological acoustics* (p. 263), by S. Gelfand, 2009, New York: Informa Healthcare.

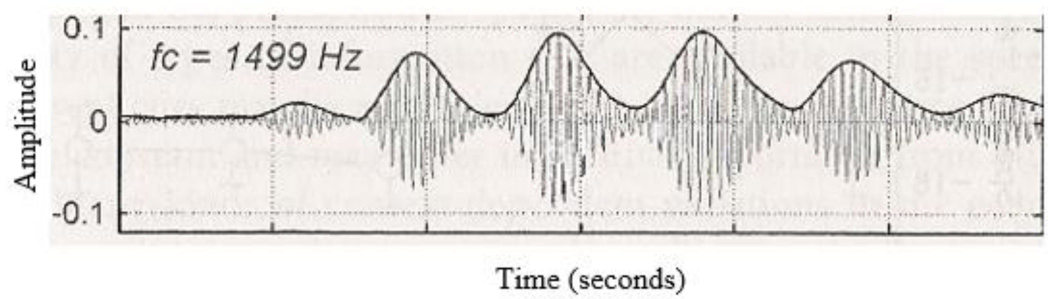


Figure 2. The relationship between the waveform envelope and temporal fine structure. The bold line outlining the top waveform represents the overall shape of the tone, and is the temporal envelope; whereas the lines within the envelope represent individual cycles of the tone, and is the temporal fine structure of the waveform. From *An Introduction To The Psychology of Hearing* (p. 341), by B.C. Moore, 2012, United Kingdom, Emerald Group Publishing Limited.

the stimulus over time (amplitude modulation); it carries syllabic and rhythmic data that provides information necessary for identification of voicing and manner of speech (Jenstad & Souza, 2007; Moore, 2012; Rimmele, Sussman, & Poeppel, 2015).

Vowels represent intonation and intensity, and best preserve the temporal envelope. Identification of the temporal envelope is crucial when listening in challenging environments (Fogerty, 2013). Individuals in a quiet setting can successfully understand speech with as few as 4 to 16 bands (related frequency bands which have been altered to contain envelope information only). This success deteriorates in the presence of background noise, however, indicating that envelope cues are only adequate in quiet environments (Moore, 2012).

TFS of a signal corresponds to the rate of the signal as it relates to the center frequency (Moore, 2012). TFS is an important factor for understanding speech in the presence of background noise. Studies have found that SRTs decrease with increasing amounts of TFS present in a signal (Moore, 2012). Both temporal envelope and fine structure information are important for speech perception, especially in challenging environments (Fogerty, 2013).

Temporal resolution is another important speech characteristic for successful identification of constantly varying speech signals. Temporal resolution "refers to the shortest period of time over which the ear can discriminate two signals", and can be measured using changes in modulation rate and depth (Gelfand, 2009, p. 175). The higher the rate of modulation, the closer together in time fluctuations will occur. High modulation rates represent high frequency stimuli, whereas low modulation rates represent low frequency stimuli. Depth of modulation refers to the deepness of fluctuation. For example, 0 dB is equivalent to 100% modulation. Changes in modulation can be detected at 5% (-25dB) for low frequency tones and between 20 to 50% (-15 to -5dB) for higher frequencies up to 1000Hz. The human ear, however, is most sensitive to temporal changes in the low frequencies up to and including 100Hz (Gelfand, 2009).

Time is the perceptual quality of duration. The DLs for temporal discrimination, in general, increase with increasing duration of a signal and are unaffected by intensity (Gelfand, 2009). DLs for longer duration (100-960ms) stimuli range from 10 to 50ms, whereas DLs decrease to about 0.5ms for short duration (less than 1ms) stimuli (Gelfand, 2009). Typically, a stimulus takes approximately 9 to 10ms to travel through the auditory pathway and reach the auditory cortex (Näätänen & Winkler, 1999).

Memory. When information reaches the auditory cortex, the brain weighs the information and determines the most probable match based on the individual's previous experiences. This is especially true if background noise interferes with the speech signal, causing breaks in the speech stream (Watson & Schlauch, 2008). The complex process of filling in the gaps involves various memory capacities (Rimmele et al., 2015).

There are various types of memory; however, memory is generally categorized by short-term memory (STM), long-term memory (LTM), and working memory (WM). Short-term auditory memory allows for storage of the loudness summation, backward masking, and timing information of the stimuli. Long-term auditory memory is responsible for storing the temporal order of speech (Rimmele et al., 2015). WM facilitates the storage of temporal and phonological features into LTM and is easily interrupted by irrelevant content (Gabriel et al., 2012; Meister et al., 2013). According to a study conducted by Ingvalson, Dhar, Wong, & Liu (2015), WM is correlated with speech perception abilities in normal hearing, older adults. Additionally, a larger WM is associated with increased academic performance and language learning (Ingvalson et al., 2015).

The *episodic theory of speech perception* states that speech is stored as a memory trace related to individual features of a signal and its source. When novel speech information is heard, the brain searches memory stores for relevant information based on previous experiences, thus creating an understanding of the information (Trude et al., 2014). These episodic memory traces (or temporal-spatial experiences stored in memory) represent auditory sensory memory, and last anywhere between 2 to 20 seconds (Näätänen & Winkler, 1999; Tulving, 1972). Auditory memory is termed ‘echoic memory’ and is fundamental to speech perception because it is responsible for maintaining the spectral-temporal aspects of a signal in the auditory cortex for further analysis (Calabrese, 2012). This memory process is considered a bottom-up process and is necessary for language learning.

Speech understanding is defined as “how well the listener receives and comprehends the speech signal” (Gelfand, 2009, p. 266) and combines both bottom-up and top-down processing (Gelfand, 2009). Access to the mental lexicon (databank of an individual’s word representations or mental “dictionary”) after acoustic input must take place for speech understanding, and therefore, word recognition plays an important role in speech understanding (Lowe, 1990). Bottom-up processing incorporates spectral and phonetic qualities of a speech utterance. The initial phonetic cues prime the lexicon to create a pool of phonetically appropriate matches. At this point, remaining acoustic cues are used to narrow the initial pool of word candidates extrapolate a single word; this is referred to as top-down processing (Lowe, 1990). A schematic of bottom-up and top-down processes can be found in Figure 3.

In circumstances where bottom-up processing of acoustic information is disrupted, the brain will incorporate top-down processing for further analysis by accessing the listener's past acoustic experiences (i.e., grammar and lexicon) to correctly interpret the message (Calabrese, 2012). This process is fundamental to speech understanding (Calabrese, 2012; Näätänen & Winkler, 1999). The ability to attend to multiple speakers simultaneously and code switch between contexts suggests speech perception processes adapt at incredible speeds (Trude, Duff, & Brown-Schmidt, 2014). Increased redundancy of a stimulus and added context (sentences versus words) increases the likelihood of intelligibility. However, manipulations of a signal, such as filtering and increased time compression, negatively affect speech understanding (Gelfand, 2009).

Assessment of Speech Perception

Assessment of speech perception is accomplished through a comprehensive audiologic evaluation. This evaluation consists of air conduction, bone conduction, speech recognition, and word recognition testing. Air conduction examines the entire auditory pathway, broadly representing abilities of the middle ear cavity, inner ear (cochlea), central auditory pathways, and auditory cortex.

Assessing audibility. Pure-tone air conduction thresholds are measurements of the lowest intensities a listener can detect. Increased thresholds (in dB) represent a loss of audibility to the listener and is typically a result of damage to the outer hair cells of the cochlea (Bharadwaj Verhulst, Shaheen, Liberman, & Shinn-Cunningham, 2014; Noonan, Redmond, & Archibald, 2014). Air conduction thresholds are typically not influenced by

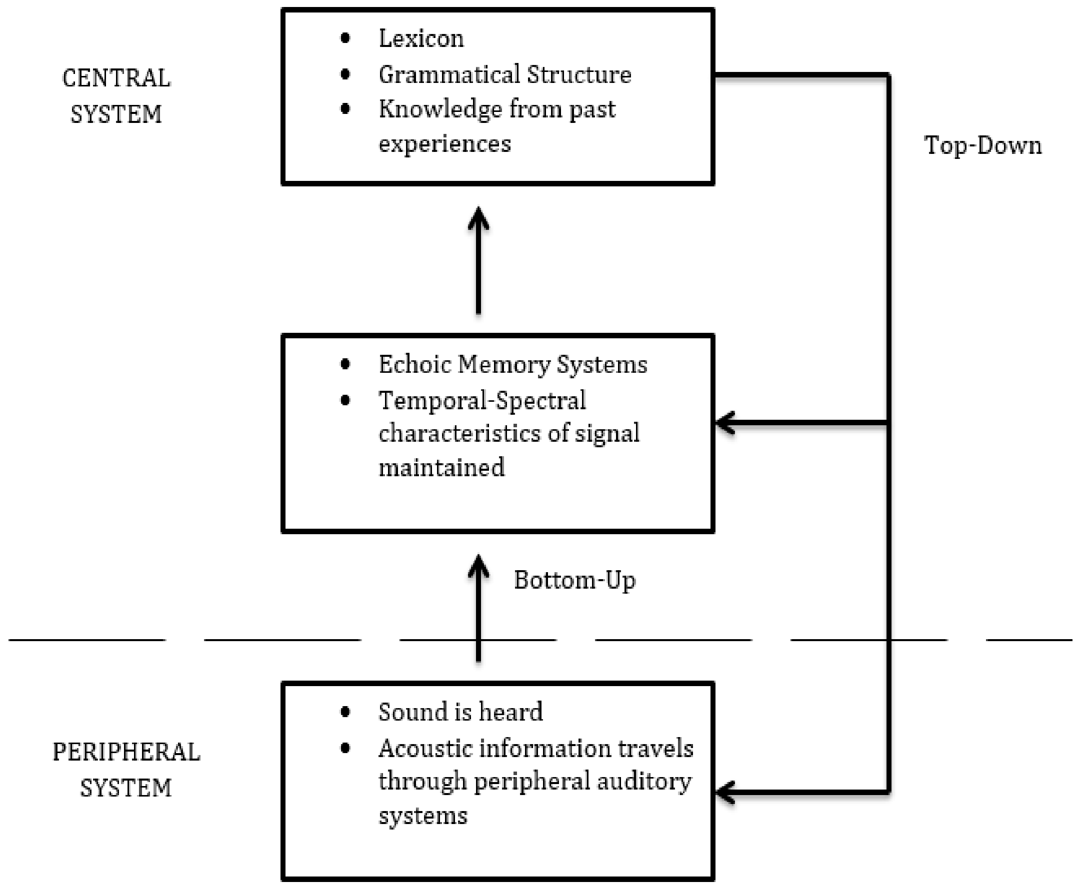


Figure 3. A schematic representation of the relationship between bottom-up and top-down processes contributing to speech perception.

significant levels of deafferentation or, to a certain extent, inner hair cell loss (Bharadwaj, Masud, Mehraei, Verhulst, & Shinn-Cunningham, 2015; Strelcyk, 2009). It is possible that a loss of up to 90% of auditory nerve fibers will not result in elevated pure tone thresholds (Strelcyk, 2009). The degree of hearing loss evidenced by the results provides a general representation of handicap experienced by the individual (Katz & White, 2001).

Normal hearing is characterized by pure-tone air conduction thresholds of ≤15 dB HL. The degrees of hearing loss, from least to greatest severity, are as follows: 16-25 dB HL (slight), 26-40 dB HL (mild), 41-55 dB HL (moderate), 56-70 dB HL (moderately-severe), 71-90 dB HL (severe), and >90 dB HL (profound) (Stach, 2010). These threshold measurements, however, are not exact because, due to time constraints of clinical practices, pure tone air-and-bone conducted thresholds are measured in 5 dB increments.

Air conduction thresholds are supplemented by bone conduction testing which bypasses the middle ear cavity, directly stimulating the cochlea and higher structures. These results indicate the type of hearing loss, either conductive, sensorineural, or mixed (Stach, 2010).

Assessing speech perception. Speech perception tests include the speech recognition threshold (SRT) and word recognition score (WRS). The SRT uses spondaic words (words containing two syllables that have equal stress) to measure a broad generalization of communicative difficulty. The score is measured as the intensity level at which the patient identifies 50% of the presentations. This score represents the lowest intensity level a listener is aware of speech and general auditory abilities for speech material (Ramkissoon, Estis, & Flagge, 2014; Stach, 2010).

Results are used as a reference point for suprathreshold word recognition testing and as an overview of the patient's response reliability (Chien et al., 2006; Katz et al., 2009). Response reliability is a cross-check principle. The SRT should be in good agreement with the three-frequency pure-tone average (PTA) of air conduction thresholds (the two measures should agree to within ≤6 dB, considered "good" agreement). PTA-SRT agreement between 7-11 dB is considered "fair", and discrepancies >11 dB represent "poor" agreement (Katz et al., 2009).

The WRS evaluates how many words an individual can correctly identify in a quiet environment when the stimulus is sufficiently loud (i.e., 40dB SL re: SRT), and provides insight into the relationship between air conduction thresholds and WRS (Dubno et al., 1995; Katz et al., 2009). There are four levels of processing. From least taxing to highest level of cognitive function, they are: awareness, discrimination, recognition, and comprehension. Due to the nature of word recognition testing, in which a patient repeats a word presented at a suprathreshold level, it is considered a test of comprehension (Thibodueau, 2007). The WRS, therefore, does not assess an individual's understanding of content, nor does it account for "real-world" environmental phenomena, such as competing noise. Results of the WRS aim to identify poor cochlear reserve (the overall integrity of the cochlea) (Abdelghaffar, Fakhry, & Fawzy, 2010; Katz & White, 2001; Thibodueau, 2007). This test is sensitive to peripheral dysfunction and does not asses complete auditory abilities (Stach, 2007). Test of word recognition are important to a comprehensive evaluation because patients with similar hearing loss can differ in word recognition abilities (Dubno et al., 1995; Katz et al., 2009; Stach, 2007; Thibodueau, 2007). The suprathreshold WRS is an important diagnostic factor for determining site of lesion, and has implications for rehabilitation (Dubno et al., 1995; Thibodueau, 2007).

The word recognition test is typically administered with the patient seated in a sound-treated audiological test suite. Test material is typically open-set list of monosyllabic, extrinsically non-redundant words in a consonant-vowel-consonant format (i.e., NU-6 word list); it is scored as a percent correct (Gelfand, 2009; Stach, 2007). Word recognition tests can be administered and scored using phoneme recognition (Modified Rhyme Test [MRT], keyword recognition within sentences (City University of New York [CUNY] Sentences), or phonemic word lists (such as the isophonemic lists created by Boothroyd [1968 and 1984]). The most commonly used materials, however, are monosyllabic words in quiet (Boothroyd, 1968, 1984; Katz et al., 2009). Common monosyllabic word lists for adults include the Phonetically-Balanced 50 (PB-50), CID Auditory Test W-22 (W-22), and Northwestern University Test No. 6 (NU-6). The PB-50 and W-22 are phonetically balanced whereas the NU-6 word list is phonemically balanced and takes into account coarticulatory factors of the spoken words. Examples of word recognition tests for children include the Word Intelligibility Picture Identification (WIPI) (ages 4-5 years), and Northwestern University Children’s Perception of Speech (NU-CHIPS) (ages 3-4 years) (Katz et al., 2009).

According to evidence-based practice, patients should be presented a 50-word list, or enough words to obtain a “true score”. A true score is the number of words repeated correctly from the original test list (Thornton & Raffin, 1978). A study by Runge and Hosford-Dunn (1985) was conducted to determine if shorter word lists could be used clinically and remain valid. They obtained word recognition scores using the W-22 ordered-by-difficulty word list at a presentation level 40 dB SL above the participant's SRT. Scores were obtained using 50-word (full list), 25-word (half list), and 10-word lists. Following the results, researchers recommended scoring ordered-by-difficulty lists as follows: (a) if the patient responds correctly to the first 10 words cease testing; (b) if one or more errors occur in the 10-word list then 25 words should be presented; and (c) if there are more than four errors within the 25-word list then continue with the full 50-word list (Runge & Hosford-Dunn, 1985). Recent surveys determined that full 50-word lists are rarely presented; that 25-word lists are used most often, regardless of the number of incorrect responses (Wiley et al., 1995).

WRSs are shown as a percent correct. To determine a patient's WRS the amount of correct responses is divided by the total amount of presentations. Therefore, if the patient responded incorrectly to one word out of 10 total presentations they would receive a score of 90% (9 ÷ 10 = 0.9 x 100 = 90%). If the patient responded incorrectly to five out of 25 words, the score would be 80% (20 ÷ 25 = 0.8 x 100 = 80%), and so on. WRSs are indicative of hearing loss if the patient scores less than 90% correct (Runge & Hosford-Dunn, 1985).

Individuals with normal hearing will obtain excellent WRS at relatively low presentation levels (i.e., 30dB SL re: SRT) (Katz et al., 2009). Individuals diagnosed with conductive hearing loss (CHL) will obtain excellent WRSs if the presentation level is sufficiently loud enough to bypass the conductive pathology (Katz et al., 2009). A study conducted by Dubno and colleagues (1995), examined the word recognition scores of 212 participants with sensorineural hearing loss (SNHL). They tested word recognition at various stimulus intensities above the participants' PTAs using a NU-6, 25-word list. The researchers found that a phonetically balanced maximum score (PBmax) of 100% could be achieved with sensorineural hearing losses (SNHL) in the mild to moderate range. However, presentation levels yielding the best WRS vary across individuals (Guthrie & Mackersie, 2009). Additionally, WRSs of patients with SNHL vary widely depending on the degree and configuration of hearing loss (Dubno et al., 1995).

Guthrie and Mackersie (2009) evaluated the effects of different presentation levels on word recognition scores. Five presentation levels were evaluated for 40 participants with precipitously sloping, high-frequency SNHL ranging from mild to moderately-severe/severe. Results from this study determined that a presentation of UCL-5 dB yielded optimal WRS for all degrees of hearing loss. The authors acknowledged, however, that UCL-5 dB was not optimal for patients with rollover and, therefore, audiologists should determine the presentation level which best fits their patients' needs.

A common theme within clinical audiology is to use a 40dB SL re: SRT presentation level, however this level may exceed uncomfortable levels (UCL) for patients with an SRT of 35 dB HL or poorer, and can result in varying levels of PBmax across patients (Guthrie & Mackersie, 2009; Wiley et al., 1995). Presenting test material at multiple presentation levels is recommended. For example, testing the WRS at various presentation levels can show diagnostic patterns representative of retrocochlear (both neural and central) pathologies (Katz et al., 2009; Wiley et al., 1995). In the presence of a neural retrocochlear pathology, such as a vestibular schwannoma, the WRS will decrease considerably when tested at intensity levels above PBmax. This is termed "rollover". Other diagnostic patterns of neural retrocochlear pathology include asymmetrical pure-tone air conduction results, asymmetrical WRS results, and overall disproportionately poor WRSs compared to the pure tone configuration of hearing loss (Katz et al., 2009). Additionally, presentation levels which do not yield a PBmax score can alter treatment decisions (Wiley et al., 1995).

A patient's score should fall within a predetermined 95% confidence interval (Dubno et al., 1995). A score within this 95% confidence limit indicates an expected score in relation to the degree of hearing loss (Thibodueau, 2007). If the WRS falls outside of this 95% confidence limit, the score is considered poorer than expected compared to the degree of hearing loss established by air conduction thresholds. A result disproportionately poor score implies that the patient experiences impaired communication abilities beyond difficulties caused by audibility alone (i.e., retrocochlear or central dysfunction) (Dubno et al., 1995). In situations where the word recognition score is poorer than expected, speech audiometry should be altered to examine subtle disorders (Stach, 2007).

Disadvantages of the WRS consist of differing forms of administration, including number of test items, mode of presentation (monitored live voice [MLV] versus recorded material), and presentation level (Wiley et al., 1995). It is well understood that an inverse relationship exists between the number of words presented and test score variability. Such evidence is presented in a widely used clinical reference (the binomial model) crafted by Thornton and Raffin (1978). Variability in test scores can lead to large discrepancies in interpretation of the results and, therefore, impact patient management. These discrepancies lessen test sensitivity (Wiley et al., 1995). For example, if an individual scores 80% on a 50-word list, the range of scores possible to maintain clinical non-significance (p <.05), meaning the score has not changed a significant amount since the last evaluation, is 64 to 92%. Conversely, if an individual scored 80% on a 10-word list, the range of clinical non-significance widens to 40 to 100% (Thornton & Raffin, 1978).

Whether the test is presented via MLV or recorded material can also have considerable effects on patients' WRSs. When material is presented MLV, the test inadvertently includes factors such as speaker gender, dialect, and rate of speech (Wiley et al., 1995). Similarly, use of multiple test presenters creates variability in test results due to the inadvertent variability in the intensity of presentation across clinicians. Such discrepancies can be avoided by using recorded speech material by either male or female speakers and using the same test material consistently.

Factors That Impact Speech Perception

Communication difficulties caused by hearing loss vary according to degree, configuration, and type of loss. Complex and challenging listening situations create a difficult environment for successful word intelligibility (Eckert et al., 2008).

Hearing status. Normal hearing is characterized by auditory pure tone thresholds ≤15 dB HL and excellent word recognition ability (Stach, 2010). Individuals with normal hearing identify speech information under adverse conditions by using additional acoustic cues. Such acoustic cues are lost for those with hearing loss (Ortmann, 2012). The population diagnosed with slight hearing loss (air conduction thresholds between 15 to 25 dB HL from 250 Hz to 4000 Hz), comprises 17% of the adult population (Haggard, Saunders, & Gatehouse, 1987). Individuals with mild hearing loss (air conduction thresholds between 26 to 40 dB HL) have difficulties with temporal resolution (Larsby & Arlinger, 1999). More severe hearing losses, such as mild-to-moderate high frequency hearing loss, will present with increased SRTs and masked thresholds, and poorer than expected speech recognition.

Symptoms and complaints can differ in patients with the same diagnosis. Both temporal and spectral resolution abilities vary in people with equivalent auditory sensitivity. These differences account for difficulties experienced by some individuals in the presence of speech-in-noise, but not others; and can be attributed to structural changes in spiral ganglion cells and decreased gray matter volume in the auditory cortex. This is particularly true for mild-to-moderate hearing loss and/or high-frequency hearing loss (Eckert, Cute, Vaden, Kuchinsky, & Dubno, 2012; Larsby & Arlinger, 1999). A study conducted by Haggard, Saunders, and Gatehouse (1987), tested 60 participants with normal hearing, and found that one-third of these participants complained of auditory difficulties despite their normal hearing sensitivity. According to Ruggles, Bharadwaj, and Shinn-Cunningham (2011), these individual differences could be caused by noise exposure resulting in temporary insult to the auditory system; these temporary shifts eventually lead to permanent reduction in spiral ganglia cells necessary for coding acoustic signals. Auditory nerve fibers are reduced after exposure to loud sounds resulting in a temporary threshold shift. Similarly, damage can be caused by moderate exposure to loud sounds over extended periods of time. Noise-induced neuropathy contributes to normal variability in hearing (Bharadwaj et al., 2015).

Pure-tone thresholds can remain stable with up to a 90% reduction in spiral ganglion cells, however, the cell count generally decreases with age and hearing loss. Individuals with normal hearing may have as few as 20,000 spiral ganglia cells, whereas this number diminishes to about 10,000 in individuals with moderate to moderately-severe hearing loss (Noonan et al., 2014; Otte, Schuknecht, & Kerr, 1978). Though pure-tone thresholds can remain unaffected, a lack of spiral ganglion cells negatively affects speech discrimination. Research conducted by Otte et al. (1978), found that at least 10,000 spiral ganglion cells were necessary for successful speech understanding, with at least 3,000 of the total 10,000 cells originating from the apical region of the cochlea. Due to low frequency contributions to speech perception, conservation of apical cells (responsible for coding low frequencies) is important (Otte et al., 1978). Damage to spiral ganglia leads to less redundant speech signals (Ruggles et al., 2011).

Normal hearing individuals that have poor speech perception abilities are less effective at deducing acoustic signals, such as temporal fine structure, but will have less difficulty hearing than individuals with hearing loss (Buss, Hall, & Grose, 2004). Increased degrees of SNHL and decreased speech understanding are related to the inability to encode temporal information of a stimulus (Buss et al., 2004). Difficulties processing TSF are caused by the inability of the auditory cortex to phase-lock to a signal (Strelcyk, 2009). These difficulties will be more pronounced in the presence of background noise (Eckert et al., 2012; Ortmann, 2012; Strelcyk, 2009).

Specifically, individuals with more severe hearing loss have impaired discrimination of high-frequency fricatives (Dimitrijevic, Pratt, & Starr, 2013). Previous studies have found that in individuals between the ages of 40 and 80 years, with moderate-to-severe hearing loss, had decreased speech recognition scores relative to previous results (Dubno et al., 1997). The added challenge of hearing loss impacts the ability to detect a signal; in such a circumstance the individual with hearing loss might require longer periods of silence to successfully detect voicing of plosive consonants

(Mackersie, 2007). Temporal-intensity cues in conversational speech are not always clear; and comprehension is easier for individuals with normal hearing because they have access to more acoustic cues within speech signals than individuals with hearing loss. Individuals with hearing loss might not have access to additional cues and, therefore, must rely more heavily on distorted temporal-intensity cues for comprehension (Ortmann, 2012).

***Effects of hearing loss on psychoacoustic properties*.** The effects of hearing loss on perceived intensity and perceived loudness are relatively straightforward. With an increase in threshold, sound needs to be louder for an individual with hearing loss to detect it, compared to someone with normal hearing. Increasing volume is needed to overcome more severe hearing loss. Average conversational speech takes place at an intensity of 50 dB HL Therefore, an individual with a mild degree of hearing loss will have difficulty perceiving conversational speech. For persons with thresholds ≥50 dB HL, however, speech comprehension is further impacted by the increased need for greater audibility (Martin & Jerger, 2005).

Similarly, an increase in hearing loss usually creates an increase in recruitment, (i.e., reduced dynamic range [DR] for hearing sensitivity) (Moore & Glasberg, 1993). The dynamic range is the difference between the measurable upper limits of hearing and the individual’s threshold at any one frequency (i.e., 140 dB HL – 60 dB HL [threshold at 2000Hz] = 80 dB DR). As stated previously, the dynamic range for humans is 140 dB. Therefore, an individual with mild hearing loss will have a larger DR and less recruitment than an individual with moderate-to-severe hearing loss. Recruitment effects loudness perception. Someone with a decreased DR will perceive loudness to increase at a much faster rate than for someone with a larger DR (Moore & Glasberg, 1993).

Intensity and frequency effects on speech perception are often interrelated. The nature of hearing loss is that audibility is reduced for certain frequencies. A study conducted by Egan and Wiener (1946) found that decreasing the bandwidth of a signal, or varying the bandwidth above or below 1500 Hz, decreased intelligibility. Conversely, increasing the bandwidth (up to 3000 Hz) increased intelligibility. Furthermore, the researchers found that for decreased bandwidth condition, the intensity of the signal needed to be increased to produce speech recognition scores equivalent to the participants' scores prior to manipulation of the signal. These results demonstrate the relationship between frequency and intensity for speech perception (Egan & Wiener, 1946). Additionally, previous research has demonstrated that when high-frequency or low-frequency information is omitted from a speech signal, using low-pass and high-pass filtering, respectively, the ability to understand speech diminishes considerably (Gelfand, 2009). If hearing loss (i.e., precipitously sloping high frequency hearing loss) is viewed as a sort of bandpass filter of speech information, a reduction in speech perception abilities is not surprising.

The effects of hearing loss on duration are less established (Moore & Glasberg, 1987). According to the literature, it appears that temporal abilities, evidenced by a reduction in gap-detection scores, are reduced in elderly individuals with hearing loss (Martin & Jerger, 2005; Moore & Glasberg, 1993; Phillips, Fitzgibbons, & Yeni-Komshian, 2000). Effects of aging on gap-detection and temporal resolution are associated with a decline in central auditory processing due to natural aging processes (Phillips et al., 2000).

Background noise. Though speech-in-noise is not the focus of this literature review, it is important to mention briefly. The ability to decipher speech in noise involves spectral and temporal processing in older adults; and hearing loss exacerbates the effects of noise from the acoustic environment (Anderson, White-Schwoch, Parbery-Clark, & Kraus et al., 2013). Background noise consisting of complex stimuli negatively affects cognitive processes and memory (Ljung Israelsson, & Hygge, 2013). More cognitive resources are necessary for successful interpretation of a signal in the presence of noise. For example, research conducted by Strelcyk (2009) found that acceptable word recognition in quiet conditions can be achieved by relying solely on envelope cues of a stimulus, whereas TFS cues are crucial for speech understanding in background noise. The need to use additional cognitive resources limits working memory capabilities and causes difficulties with free recall of information within a stimulus (Ljung et al., 2013; Zekveld, Festen, & Kramer, 2013).

Cognitive status. In addition to peripheral dysfunction, individuals may undergo central deficits. The central auditory nervous system (CANS) is responsible for analyzing and processing neural information from each ear and transmitting this information to the primary auditory cortex (Stach, 2007). Higher-level dysfunction is caused by decreased structural integrity of the temporal lobes due to increased age, leading to reliance on non-auditory brain regions to complete word recognition tasks (Eckert et al., 2008). Subtle insults to the brainstem and cortex will not affect peripheral auditory tests; more sensitive testing is needed to detect damage within the higher level auditory systems (Eberwein et al., 2007).

Impairments to higher level processes, such as working and short-term memory, have an effect on speech perception. Individuals with hearing loss expend more energy in order to focus on a signal (McCoy et al., 2005). This energy can reduce the effectiveness of higher-level memory processes which would otherwise contribute to signal processing. For example, if an individual has an impairment in working memory, they will lack the necessary top-down contributions to process a signal. Top-down processes likely effected include lexical and syntactical word identification (McCoy et al., 2005). Likewise, short-term memory contributions are an important component of speech comprehension and language processing, and also contribute to top-down processing (Martin, 1993). Patients with impairments to short-term memory abilities have difficulty storing phonological and syntactical information, leading to an inability to identify relationships within a sentence (Martin, 1993).

Language status. In addition to physiological changes causing poorer-than-expected word recognition, individuals who acquired English as a second language present with similar hearing complaints. Language proficiency is a predictor of English word recognition abilities in quiet (Shi, 2013). According to Shi (2013), language skills are defined by how well an individual can use language rather than whether they have the ability to use language. For bilingual speakers with English as a second language, age of English acquisition determined verbal and written English proficiency. Bilingual speakers who learned English at an earlier age had better performances on English word recognition tests than those who acquired English later in childhood (Shi, 2013). The study found that the average word recognition score, obtained using NU-6 word lists, for native English speakers was better than bilingual English speakers who acquired English in infancy; and those who acquired English at ages older than three years performed more poorly than individuals who acquired English before three years (Shi, 2013; Shi & Zaki, 2014).

The same study also found that English-dominant bilingual listeners had the capacity to perform as well as monolingual English listeners when there was a high signal-to-noise ratio (SNR). At low SNRs, however, performance of bilingual listeners was reduced. In contrast, non-English dominant listeners performed considerably more poorly than English monolingual speakers regardless of SNR. Using the highest level SNR (+18 dB), the non-English dominant groups' highest score was 80% correct. This showed a shallow psychometric function and early plateau compared to English-dominant controls, who reached ceiling effects at 100% correct at the same level (Shi & Zaki, 2014). Studies such as these provide evidence for the importance of recognizing that bilingual individuals should not be tested with traditional English word lists, and should be tested using their native language (Shi, 2013).

Disordered Speech Perception

Symptoms. Common situations that cause considerable difficulty for individuals with hearing loss include the presence of excessive amounts of background noise (i.e., a restaurant setting) and longer complex conversation or dialogue. The human brain is adept in overcoming degraded or distorted speech signals, however, auditory processing becomes increasingly more challenging in the presence of competing signals (Meyer et al., 2013; Stach, 2007). Difficulties experienced in settings such as parties or restaurants are categorized as spatial hearing deficits, and in such environments localization becomes problematic (Stach, 2007). In noisy listening situations, the noise spectrum consists of low-amplitude stimuli which reduces the speech spectrum (Ortmann, 2012).

Difficulties understanding longer complex conversation or dialogue can be explained by suprathreshold coding deficits, since speech processing includes the interaction between acoustic processes and higher-level cognition (Bharadwaj et al., 2014; Ortmann, 2012). According to the auditory approach to speech perception, functioning auditory and cognitive facilities are necessary for phonemic and lexical recognition (Ortmann, 2012). Therefore, individuals with various levels of auditory or cognitive deficits will have increased difficulty following complex conversation.

Speech Perception Disorders

Conditions which might cause poorer-than-expected word recognition include auditory neuropathy/auditory dys-synchrony (ANSD), auditory processing disorder (APD), and obscure auditory dysfunction/King-Kopetzky syndrome (OAD/KKS).

Auditory Neuropothy/Auditory Dys-synchrony (ANSD). In addition to sensory or central contributions to the auditory system, hearing loss can be caused by neural elements. Individuals with sensory losses have atrophy of cochlear hair cells, atrophy of the stria vascularis, or subtle lesions in the midbrain. Subtle sensory lesions result in mild, low-frequency hearing loss (Dubno et al., 2013; Stach, 2007). Conversely, neural hearing loss is due to a loss in spiral ganglion neurons (Dubno et al., 2013). Inner hair cells within the cochlea are synapsed by 10 to 30 auditory nerve fibers. Fibers with high-spontaneous rates are likely responsible for recognizing sounds in quiet, whereas neurons with low-spontaneous rates are resistant to noise and are, therefore, necessary for deciphering speech in competing environments (Bharadwaj et al., 2014). These auditory nerve fibers send acoustic information to the brain. A reduction in the amount of auditory nerve fibers creates an inability to detect temporal fine structure and waveform envelopes of speech stimuli. Individuals differ in the amount of auditory nerve fibers present in the auditory pathway, regardless of hearing status. A reduction in auditory nerve fibers is caused by many factors including genetic inheritance and noise exposure (Bharadwaj et al., 2014).

A minority of individuals suffering from neural deficits will present clinically with normal hearing and complaints similar to those with sensory hearing loss (Gates, Feeney, & Mills, 2008; Stach, 2007). These individuals present with variable pure tone thresholds and poorer-than-expected word recognition scores based on the 95% confidence limit. Word recognition scores will dramatically decline in the presence of noise. These patients are characterized with having auditory neuropathy or dyssynchrony (ANSD) (Cianfrone et al., 2006). This condition is likely caused by demyelination of the auditory nerve or a reduction in the total number of auditory nerves contributing to the response. This damage is present in either the inner hair cells, within the synapses between inner hair cells and auditory nerves, or directly on the auditory nerve (Draper & Bamiou, 2009).

Auditory Processing Disorder (APD). According to the American Speech and Hearing Association (ASHA), APD “refers to difficulties in the perceptual processing of auditory information in the CNS as demonstrated by poor performance in one or more [auditory] skills” (American Speech-Language-Hearing Association [ASHA], 2005). This disorder is characterized as a functional deficit of the CANS caused by disease, damage, or degradation in the pathway from the eighth cranial nerve to the auditory cortex (Stach, 2007). Common causes include: aging, dementia, stroke, head injury, neoplasms, and disturbances in development. APD is a heterogeneous disorder and is comorbid with populations where prematurity, language disorders, learning disability, dyslexia, and attention deficit hyperactivity disorder (ADHD) are suspected (Demanez, 2007). Estimated prevalence is 2 to 3% of children and 17 to 90% of the aging population, and is more common in males (Demanez, 2007; Hind et al., 2011). Prevalence of APD increases with age (Gates, Anderson, Feeney, McCurry, & Larson, 2007).

Individuals with APD will present with normal hearing, and normal receptive and expressive language. Patients with APD, however, will have deficits in one or more of the following: localization, auditory discrimination, auditory memory, and understanding speech in noise, rapid speech, or accented speech (Keith, 1999). Comorbidities include poor listening skills, reading problems, poor spelling, poor handwriting, and constant need for repetition (Keith, 1999). Additionally, histories of otitis media with effusion (OME) are highly correlated with APD diagnoses (Hind et al., 2011). According to the American Academy of Audiology (AAA), APD is a deficit in the processes which combines the CANS with bottom-up and top-down processing, such as language, attention, and memory (American Academy of Audiology [AAA], 2010).

Obscure Auditory Dysfunction (OAD) and King-Kopetzky Syndrom (KKS). A condition with similar clinical presentations to APD is defined as obscure auditory dysfunction (OAD). This term is a descriptive label to identify the 5 to 10% of individuals in ear, nose, and throat (ENT) and audiology offices who have normal hearing but severe subjective symptoms (Higson et al., 1994). A patient presenting with OAD is described as “an individual aged between 15 to 55 years who had gained referral to an ENT or audiology department after complaining of auditory difficulties, but who has clinically normal hearing and has no other obvious likely cause for his/her difficulties” (Saunders, Field, & Haggard, 1992, p.33). Approximately 80% of normal individuals experience unexplained physical symptoms at any one time (Ullas, McClelland, & Jones, 2013). This statistic accounts for 20 to 27% of medically unexplained symptoms presenting in primary care offices. Somatic events may occur after stressful experiences or in patients suffering from increased anxiety (Ullas et al., 2013). People with OAD vary in social and educational backgrounds (Higson et al., 1994).

Both auditory and psychological factors contribute to these perceived symptoms. Individuals with OAD differ from normal controls in their psychology, cognition, and psychoacoustic processing. The role of psychological versus organic factors in OAD is unknown (Ullas et al., 2013). Within this subpopulation, male patients with suspected OAD are more likely to present with personality differences versus women, who, when compared to controls, were more likely to present with true psychoacoustic difficulties (Saunders & Haggard, 1992). In a study conducted by Higson et al. (1994), which compared 59 individuals with OAD to 50 controls, the authors found a higher prevalence of females in their early thirties presenting with symptoms. The researchers stated that, according to scores on a Crown Crisp Experimental Index (CCEI), significant differences were present in areas such as stress, somatic anxiety, and depression.

The researchers also noted that individuals in the OAD groups reported difficulties learning to read and write, middle ear issues extending into adulthood, tinnitus, and family history of otologic conditions (Higson et al., 1994). Additionally, individuals with childhood histories of otologic problems such as OME were more likely to present with subtle low-frequency threshold differences. OAD groups present with difficulties understanding speech in noise associated and poor frequency resolution unrelated to noise exposure (Saunders & Haggard, 1989). Similar findings were reported by King and Stephens (1992), who found that OAD was associated with mild cochlear dysfunction accompanied by psychological factors exacerbated by stressors such as academic examinations, marital separation, and death of a relative. Compared to normal controls, these patients reported higher incidences of previous ear-related problems, family history of hearing disorders, lower linguistic abilities, and higher levels of anxiety. In addition, the OAD group reported higher levels of loneliness and poor coping strategies (King & Stephens, 1992).

Multiple studies have investigated OAD groups using behavioral and objective measures. King and Stephens (1992) tested 20 patients with OAD (mean age 30.3 ± 10.7 years) compared to 20 normal controls (mean age 27.9 ± 9.1 years). The results were that, though the OAD groups' thresholds fell within the normal range (thresholds ≤15 dB HL or not exceeding 30 dB HL at any one frequency), they had worse average pure-tone thresholds across all frequencies (categorized as the average threshold across 250-8000 Hz). These differences were as much as 3.3 to 6.2 dB. For example, at 6000 Hz, the average threshold for the OAD group was 18.2 dB HL, whereas the average threshold for the control group was 12.0 dB HL. This resulted in an unexplained difference of 6.2 dB.

This difference does not appear to be substantial and both thresholds were categorized as normal hearing by criteria set in the study (King & Stephens, 1992). However, if one considers a more conservative criteria for “normal” hearing (≤15 dB HL), the control group remains as having normal hearing. The OAD group, however, would be categorized as having a slight hearing loss. This overall poorer audibility reduced the DR leading to a need for increased volume, and contributes to poor frequency resolution (King & Stephens, 1992). Another study, conducted by Strelcyk (2009), compared six normal hearing listeners ranging in age from 21 to 55 years to two participants with OAD. The findings suggested that individuals suffering from OAD have more difficulties understanding less redundant speech and struggle to process low-frequency information.

Other measures separating OAD groups from normal controls include: poor speech perception threshold in noise (PSRTN), considerable differences between documented hearing ability and the patients’ subjective estimate of ability (PS-DIS), poor masked thresholds, and poor performance on dichotic listening tasks (Saunders et al., 1992). Deficits on these measures implies a level of cognitive dysfunction, in terms of a reduction in speed of processing, along with psychological impairments (Higson et al., 1994). Additionally, King and Stephens (1992) found poor frequency resolution, measured by notched noise testing at 2000 Hz, in the right ear of the OAD group compared to normal controls. Notches create gaps of missing frequency information within a signal, leading to misinterpretation of speech sounds (i.e., phoneme). In addition, patient groups with OAD have been found to have action potential tuning curves (APTCs) with elevated peaks, flatter curves, or peaks shifted to lower frequencies (Centre, 1988). Testing which did not yield any significant differences between OAD groups and normal controls included otoacoustic emissions (OAEs) and acoustic reflex thresholds (ARTs) (Higson, Morgan, Stephenson, & Haggard, 1996; Ostergaard, 1992). In the study that reviewed the relationship between OAEs and OAD, however, only 50 participants were tested (Ostergaard, 1992).

King-Kopetzky Syndrome (KKS). KKS is a term coined by Hinchcliffe (1992) to described hearing difficulties in the presence of normal hearing sensitivity (Pryce et al., 2010). It is another term for OAD, and patients present with the same or very similar difficulties, psychological factors, and objective and behavioral test results. (Demanez, 2007; Pryce et al., 2010). KKS is a group of normal hearing individuals that cannot be diagnosed with APD, but experience similar acoustic challenges (Bharadwaj et al., 2014). In addition, individuals with suspected KKS tend to seek medical attention rather immediately, which differs from individuals with typical hearing loss who wait, on average, up to 10 years to address their hearing difficulties. Similar to individuals with hearing loss, however, people with suspected KKS also experience similar levels of social isolation and decreased quality of life (Pryce, et al., 2010). Research investigating this population has presented additional information regarding this subgroup of patients.

Many tests within a standard audiometric battery do not have the sensitivity to show subtle dysfunction present in KKS (Stephens & Zhao, 1999). A test yielding more sensitive results is the audioscan test. This test covers the frequency range between 125 and 16,000 Hz, including 64 frequencies per octave. The purpose of the audioscan is to detect narrow notches in octave frequencies between those tested in conventional audiometry. Results of audioscan tests revealed notches in the frequency range between 500 and 3000 Hz in individuals with KKS. In this study, a decrease in threshold with a depth of 15 dB in relation to adjacent frequencies was considered noteworthy (Zhao & Stephens, 1999). From these results researchers concluded that cochlear lesions may be concentrated to this low- to- mid frequency region. While not necessarily constituting abnormal hearing, these notches indicated a genetic predisposition to cochlear deprivation in this population (Zhao & Stephens, 1999). Individuals with genetic hearing impairment also show audioscan notches within this frequency range, further supporting the reported cases of family history in patients with KKS (Stephens & Zhao, 2000; Zhao & Stephens, 1999).

In conjunction with audioscan notches, notches were found within distortion product otoacoustic emissions (DPOAEs) in the same frequency range (Zhao & Stephens, 2000). These results, however, were only found in individuals presenting with audioscan notches; significant differences between control and KKS participants were not found in individuals who did not present with significant audioscan results (Zhao & Stephens, 2000). The relationship between audioscan notches and a lack of robust DPOAE amplitudes in the frequency range of 500 to 3000 Hz is indicative of early signs of cochlear pathology, such as a dominant genetic condition (Borg & Stephens, 2003; Stephens & Zhao, 2000).

Zhao & Stephens (2000), presented six potential causes of KKS according to site of lesion. These include (a) subclinical cochlear dysfunction; (b) central deficits; (c) poor lip-reading abilities; (d) emotional instability (supported by patient report); (e) difficulties acquiring a second language; and (f) unknown causes. Central deficits were referred to as deficits specific to the medial olivocochear efferent system (MOCS), which could be measured by transient otoacoustic emissions (TEOAEs) with contralateral auditory stimulation (CAS), or the staggered spondaic word list (SSW). (Zhao & Stephens, 2000; Zhao & Stephens, 2007). Additionally, the aforementioned causes explain the combined physiological and psychological manifestations of KKS (Zhao & Stephens, 2007).

Impact of disordered speech perception. There are many common complaints between individuals with hearing loss, ANSD, APD, and those suspected of OAD/KKS. Individuals with hearing loss report overall difficulty understanding speech and the ability to hear but not understand. The phenomena of hearing speech but not understanding its contents stems from the hearing loss configuration and acoustic stimuli. For successful detection of a signal (i.e., vowels and voiced consonants), the intensity of a stimulus must increase as severity of the hearing loss increases (Ortmann, 2012).

All conditions reported in this review report the common complaint of perceived difficulty understanding speech-in-noise, regardless of normal hearing sensitivity (Higson et al., 1994; Keith, 1999; Saunders et al., 1992; Wilson, Heine, & Harvey, 2004). Other similarities between APD and OAD/KKS included reading and language difficulties in childhood, understanding in situations with low-redundancy speech, disordered temporal processing, dichotic listening difficulties, understanding speech with acoustically distorted signals (i.e., reverberation and rapid or competing speech), and poor lip-reading abilities (Demanez, 2007; Keith, 1999; Saunders & Haggard, 1989; Stach, 2007; Wilson et al., 2004). Patients with similar frustrations and experiences will present these wide range of complaints.

Hearing difficulties in everyday situations can have a negative impact on an individual’s quality of life (QoL). People suffering from any degree of hearing loss, or those with normal hearing but disordered speech perception, can experience severe reductions in QoL in the form of reduced participation in social activities, feelings of dependence, and depression (Midha & Malik, 2015; Mulrow, Tuley, & Rhodes, 1990). Someone struggling to follow day-to-day conversations may start to experience a lack of confidence in their speech understanding abilities. This, in-turn, leads to feelings of exclusion and low self-esteem. Additionally, misinterpreting dialogue can lead to embarrassing situations and cause an individual to avoid similar incidences in the future (Higson et al., 1994). Many adults with hearing loss experience fatigue due to the need for higher-level, non-auditory compensatory strategies, which can lead to feelings of frustration (Eckert et al., 2008). A large systematic database review of QoL in the elderly associated with hearing loss, conducted by Ciorba, Bianchini, Pelucchi, & Pastore (2012), found that hearing loss was often associated with emotional reactions (loneliness, dependence, depression, and anxiety), behavioral reactions (social withdrawal and blaming others for their circumstances), and cognitive effects (confusion and lack of self-esteem). This same study reported that, of the population of normal hearing individuals, 68% experienced good QoL compared to only 39% of individuals with hearing loss (Ciorba et al., 2012).

Treatment of disordered speech perception. Based on the current literature review, auditory processing evaluations, auditory evoked potentials (AEPs), transient evoked otoacoustic emission (TEOAE) suppression testing, audioscan and DPOAE testing, and extended high-frequency audiometry are warranted as additional testing considerations for the minority populations with normal hearing but disordered speech perception. These tests could also find subtle disorders in individuals with hearing loss but poorer-than-expected word recognition (Bharadwaj et al., 2014; Demanez, 2007;

Murdin & Davies, 2008; Shaw, Jardine, & Fridjhon, 1996; Zhao, Stephens, & Meyer-Bisch, 2002). Tests for APD should include low-redundancy speech tests, dichotic listening tasks, tests of temporal processing, and tests of binaural interaction (Demanez, 2007). Additionally, Murdin and Davies (2008), reported that TEOAE suppression is more suppressed in children with APD compared to normally functioning controls.

Audioscan notches are defined as significant if they are ≥15 dB in depth. Significant notches within the frequency range of 500 to 3000 Hz is likely related to dominant genetic factors (Zhao et al., 2002). High frequency hearing sensitivity is necessary for successful temporal resolution. Patients with OAD have been found to have elevated thresholds within the frequency range between 10,000 and 20,000 Hz compared to normal controls. These differences could account for difficulties differentiating speech in background noise (Shaw et al., 1996).

Due to normal hearing or appropriate audibility but poor word recognition, traditional treatment and management options (i.e., hearing aids) are not appropriate, or may not provide functional benefit to these patients. Other forms of treatment have been proposed, including frequency modulated (FM) devices to improve SNR or other assistive listening devices (ALDs) (Stach, 2007). For patients' with poorer-than-expected WRSs, aural rehabilitation can help the brain reorganize acoustic cues and, thus, improve speech perception (Tremblay, 2003). Management strategies for APD include acoustical environment modification, and perceptual, compensatory, and cognitive training (Keith, 1999). For the OAD/KKS group, psychological management has been reported as having the most benefit. Pryce et al. (2010) proposed a psycho-social management approach for this population. Cognitive behavioral therapy treatment of psychological disorders has also been recommended (Ullas et al., 2013). In general, any form of counselling that targets the patients’ individual difficulties, whether acoustic, psychological, or personality based, and addresses realistic expectations regarding personal demands and communication strategies is most beneficial (Borg & Stephens, 2003; Saunders & Haggard, 1989).

Study Rationale and Purpose

The purpose of the study was to conduct a retrospective case review to examine commonalities between patient cases (i.e., case history, symptoms, and diagnoses) and cases presented in the literature. The research question was, “what factors contribute to poorer than expected word recognition?” This research sought to establish clinical red flags for a subgroup of patients with poor listening abilities that often go undertreated (Cianfrone, Turchetta, Mazzei, Bartolot, & Parisi, 2006; Keith, 1999; Stach, 2007). In addition, previous research stated a need for long-term follow-up of patients with disorders such as OAD/KKS; this follow-up might reveal that the source of the symptoms progresses to a less elusive pathology (such as SNHL of hereditary origin). Such a revelation could allow for identification of early case history complaints often reported by this population (Saunders et al., 1992). Knowledge clinical red flags will alert audiologists to the potential for additional testing and less traditional rehabilitation options. A heightened awareness of the needs of this clinical population with poorer-than-expected WRSs will assist audiologists in providing proactive and comprehensive health care.

CHAPTER 3

Methods

This study was a retrospective case review investigating all available patient files, including archived files, of any patient seen for audiologic services at the Towson University Institute for Well-Being (IWB) Hearing and Balance Center in Towson, Maryland. Study approval was granted by the Towson University Institutional Review Board (IRB). Access to patient files by the researcher was permitted based on Doctor of Audiology (Au.D) student status and patient consent to use test results for educational purposes. Health Insurance Portability and Accountability Act (HIPAA) requirements were met based on the need for keycard access into the IWB building as well as the individual floors containing health records, which were provided by Au.D clinical director Dr. Amanda Kozlowski, Au.D, CCC-A, and thesis advisor of this study, Dr. Stephanie Nagle, Ph.D, CCC-A. Data acquisition took place in January, 2016 by a HIPAA certified Au.D student in their third year of study.

Classification criteria. To determine initial study criteria, patient files were divided into separate factors of interest according to age, PTA, word recognition list administered, the number of words presented, and most importantly, WRS. Age was examined first. Criteria consisted of three groups: (a) adults 18 years of age or older; (b) children 7 to 18 years; and (c) children birth to 6, 11 years. The latter group was excluded from analysis based on diagnostic criteria for APD and limitations of comprehensive audiologic testing at younger ages. Secondly, WRSs and whether or not it was tested at patients' baseline evaluations determined preliminary inclusion to the study.

Secondary criteria. Of the remaining patient files, baseline audiograms were examined for type of hearing loss, and details of testing such as the calculated PTA (average of thresholds at 500 Hz, 1000 Hz, and 2000 Hz), calculated high-frequency PTA (average of thresholds at 2000 Hz, 4000 Hz, and 6000 Hz), and word list used for word recognition testing (Clark, 1981). Lastly, WRSs were compared to the Dubno et al. (1995) criteria for expected WRS based on PTA, if applicable.

Therefore, patients with normal hearing or a diagnosis of sensorineural hearing loss were included in the study. Those diagnosed with hearing loss other than sensorineural hearing loss, such as conductive or mixed hearing losses, were excluded from the study. In some cases, there was potential for missing data. For example, word recognition testing was performed but the number of words presented to the patient was not indicated on the audiogram or report. Information from these cases were included in analysis for other factors, but were not analyzed regarding the number of words presented. Additionally, in patient files in which a different PTA was calculated (i.e., a two-frequency PTA), both a three-frequency PTA and a high-frequency PTA (HFPTA) were calculated and further examination determined. This limited exclusion from the study and ensured a sizable sample.

WRSs were then be examined. Remaining charts were divided into three groups according to word list used: (a) those tested using the NU-6 ordered-by-difficulty; (b) those tested with the W22 word list; and (c) individuals tested with a word list other than the two aforementioned lists (i.e., PB-50). Lastly, PTA was compared to the WRS and Dubno et al. (1995) criteria, when applicable, to determine if scores fell within the expected range or were disproportionately poor. Figure 4 provides a visual representation and chronological display of inclusion and exclusion criteria.

Final variables. The remaining data were obtained from children (7-17 years) and adults (≥18 years). Patient files were examined based on patient case history complaints, previous diagnoses, and diagnoses made at the preliminary evaluation. A comprehensive list of factors of interest are displayed in Table 1. Patient complaints of interest included

- hearing but not understanding;
- difficulty hearing in noise;
- the constant need for repetition or difficulty listening;
- considerable stress or anxiety; and
- family history of otologic conditions.

Further analysis of abnormal test results included

- notches of ≥15 dB on TEOAE or DPOAE results, if applicable. A notch was defined as a decrease in response amplitude ≥15 dB with a recover ≥5 dB at the adjacent frequency (Taylor & Emanuel, 2013); and
- poor scores on speech-in-noise tests, if applicable.

Previous diagnoses or patient reports of particular interest included

- noise exposure;
- language and learning disorders;
- dyslexia;
- attention deficit hyperactivity disorder (ADHD); and
- chronic OME.

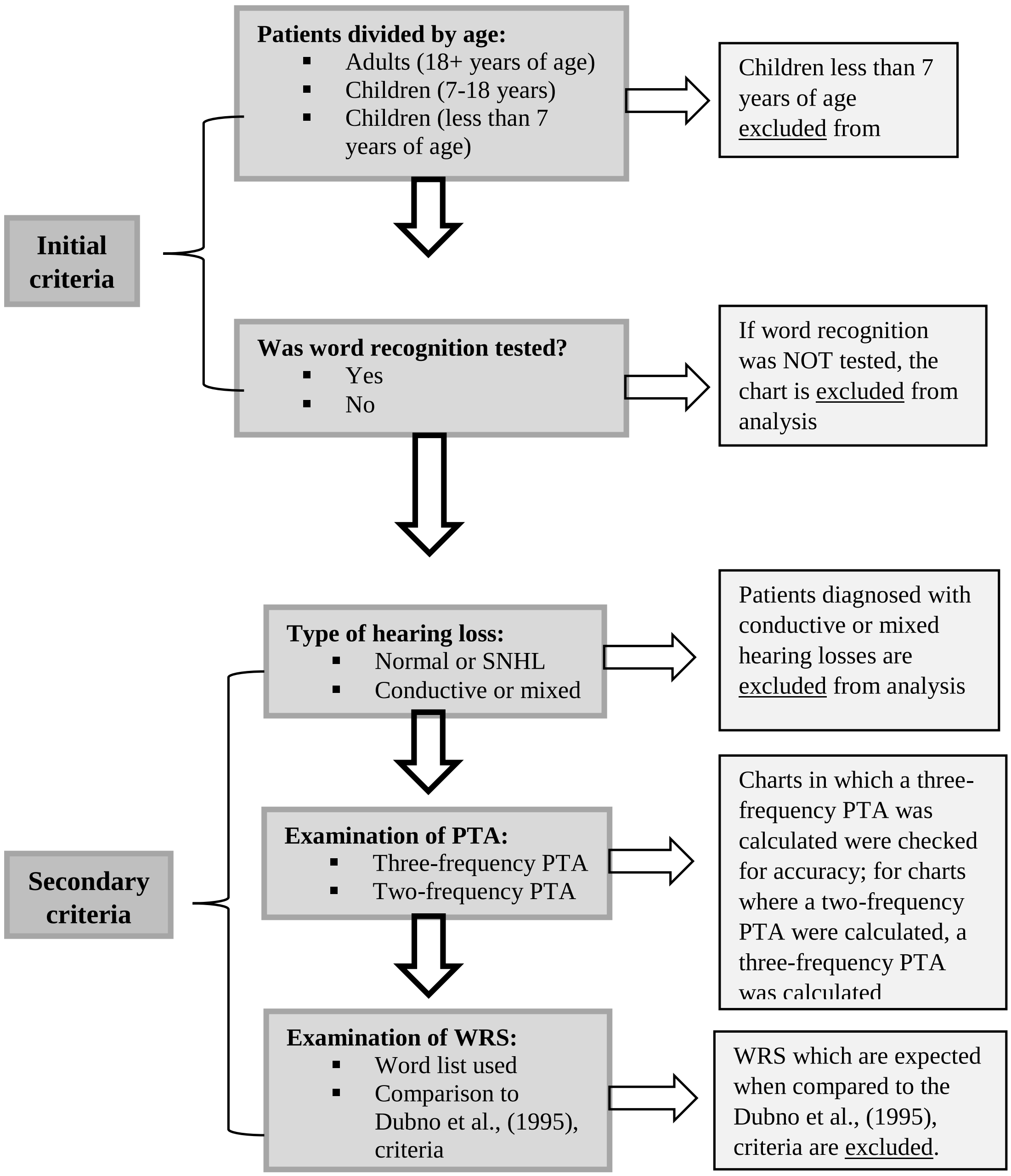


Figure 4. The sequence of initial and secondary exclusion criteria in chronological order for the proposed retrospective case analysis.

Table 1

The Variables Used To Organize Chart Data Based On Similar Patient Complaints, Test Results, Previous Diagnoses, and Numerical Values

Variables of Interest				
Patient Complaints	***Abnormal Test Results***	***Previous Diagnoses/Reports***	***Numerical Values***	***Test Procedure***
Can hear but cannot understand	Notches ≥15dB on TEOAE/DPOAEs	Language and/or learning disorders	PTA	MLV versus recorded
Difficulty hearing in noise	Poor speech-in-noise results	Dyslexia	SRT	Number of words presented
Need for repetition/difficulty listening		ADHD	High-frequency PTA	
Stress or anxiety		Chronic OME	WRS	
Family history of otologic conditions		Noise exposure	Presentation level	
			Number of words presented	

Statistical analysis

Distribution of the sample populations are displayed in histograms. Data associated with patients' PTAs and WRSs are displayed in scatterplots to compare differences between variables by ear (Field, 2009). Exploratory inferential statistics were performed to determine differences between variables and the levels of variables. Tests of statistical significance included a correlation matrix of numerical variables, factor analysis, stepwise regression, analysis of covariance (ANCOVA), and chi square test. These analyses were used to determine associations between audiological test results, patient complaints, abnormal test results, and previous diagnoses, as well as the relationship of the WRS to these categories.

CHAPTER 4

Results

A retrospective case review investigating all available patient files, including archived, inactive, and active files of any patient seen for audiologic services at Towson University's IWB Hearing and Balance Center in Towson, Maryland was conducted from January through February, 2016. Data were extracted for patients between 7 and 100 years with sensorineural hearing loss and poorer-than-expected WRS compared to Dubno et al. (1995). Figure 5 provides a file summary. Examination of this figure indicates 2,554 audiology files were reviewed. Of these files, 1,433 were active patient files, 357 were inactive (<7 years prior to the patient's last audiological visit to the Towson University IWB), and 764 were archived (>7 years since patient had been seen). Three hundred and ninety-four patient files met study criteria, including 207 males and 187 females.

Exclusions

Upon review of the patient data relative to study criteria, one patient file was eliminated on the basis of incorrect calculation of the word recognition score by the examiner (i.e., a score of 29% from a 25-word list). Similarly, for another patient file, the right ear was excluded for an incorrect calculation. For several patients' files (n = 208), neither the audiogram nor the written report included the number of words presented for the word recognition score. In these circumstances it was assumed, based on general trends in the Towson University IWB and overall field of audiology, that a 25-word list was presented. After this assumption was made, the word-recognition scores of two patient files were WNL and were excluded from further analysis. For cases in which two word lists were used and one of the lists was a 10-word list, the WRS associated with the

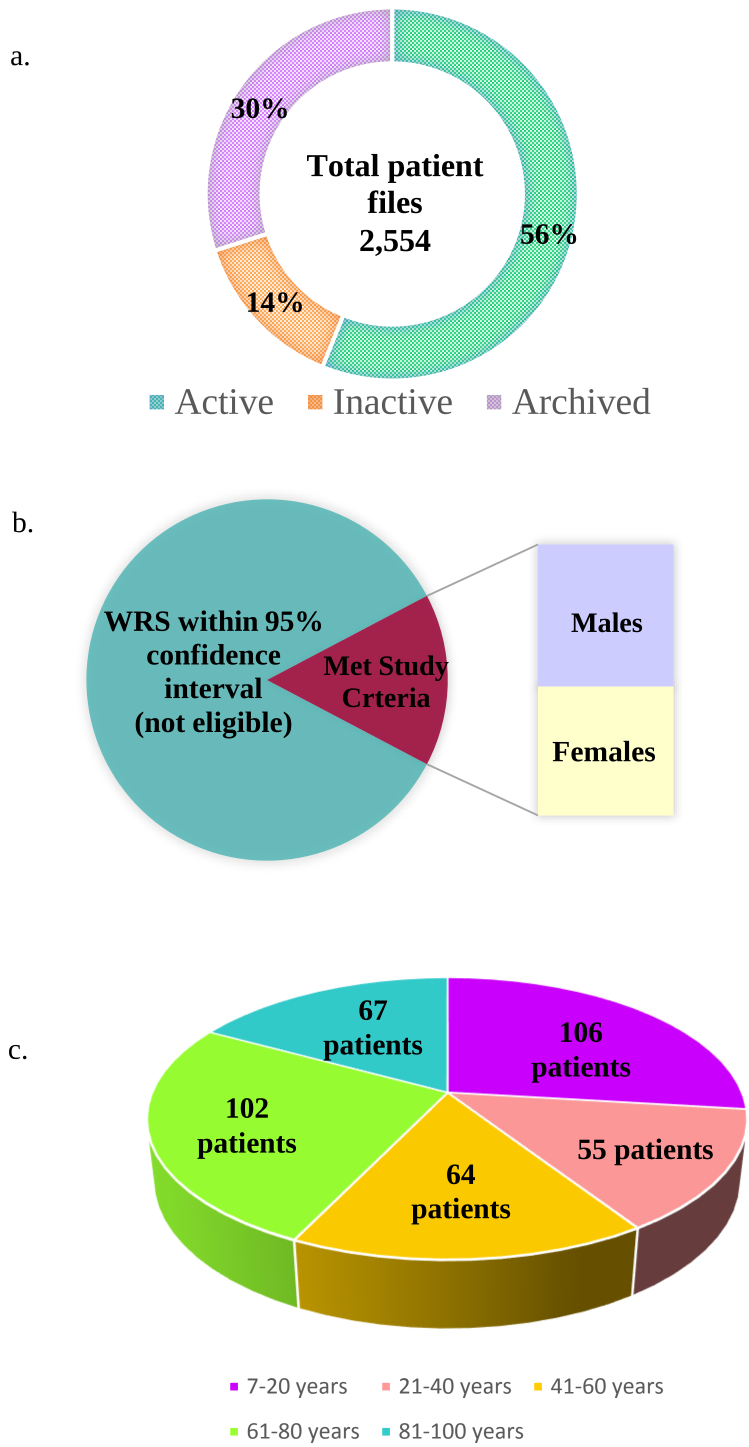


Figure 5. Breakdown of (a) all patient charts at the Towson University IWB Hearing and Balance Center; (b) those which met study criteria and the breakdown of males and females; and (c) the total number of charts by age.

10-word lists were coded as missing data. This decision was made because Dubno and colleagues (1995) did not include normative data resulting from the use of a 10 word list. The final sample equaled 391 patient files consisting of 207 males and 184 females. The original data sheet including all scores for each file can be found in Appendix B.

Preliminary Analysis: Patient Demographics

Select patient demographic data were extracted from patients' files and are shown in Table 2 and Figure 6. Mean age of the patients (n =391) was 48.97 years with a range of 7 to 96 years. Average PTA was 24.75 dB HL for the right ear and 24.28 dB HL for the left ear. Average word recognition scores were 71.51% and 71.98% for right and left ears, respectively. The histogram presented in Figure 6 shows a relatively bimodal distribution, with modes centered around 20 and 73 years with a distinct resurgence at 40 years.

The scatterplots presented in Figure 7 show right and left PTA by age. Examination of these figures indicates an apparent curvilinear relationship between age and PTA, with a cluster of normal PTAs associated with lower ages (<35 years) and several data points for each ear (n=7 right, n=6 left) that were far removed from the estimated model, with high PTA associated with 30-40 year old patients. These points represented 1.8% (right) and 1.5% (left) of the patient files analyzed (n=391) and approximately 0.3% (right) and 0.2% (left) of the total number of patients files reviewed (n=2,554).

Children and young adults (<40 years). To remove the apparent curvilinear relationship between PTA and age created by the different profiles of patients under 40 years and those over 40 years, these two age groups were examined separately.

Table 2

Descriptive Statistics Examining Charts Analyzed From Towson University Institute for Well Being

			Right Ear			
Age ***(years)***		**PTA**	**HFPTA**	**SRT**	**WRS**	**PL** ***(dB HL)***
48.97	**Mean**	24.75	44.50	23.26	71.51	61.39
28.99	**SD**	24.24	29.31	22.97	29.00	19.66
7-96	**Range**	-5-111.7	-8.3-98.3	-10-95	0-100	20-115
			Left Ear			
	Mean	24.28	45.77	23.03	71.98	61.31
	SD	23.13	29.31	21.74	29.56	19.07
	Range	-6.7-85	-10-103.3	-5-95	0-100	30-105

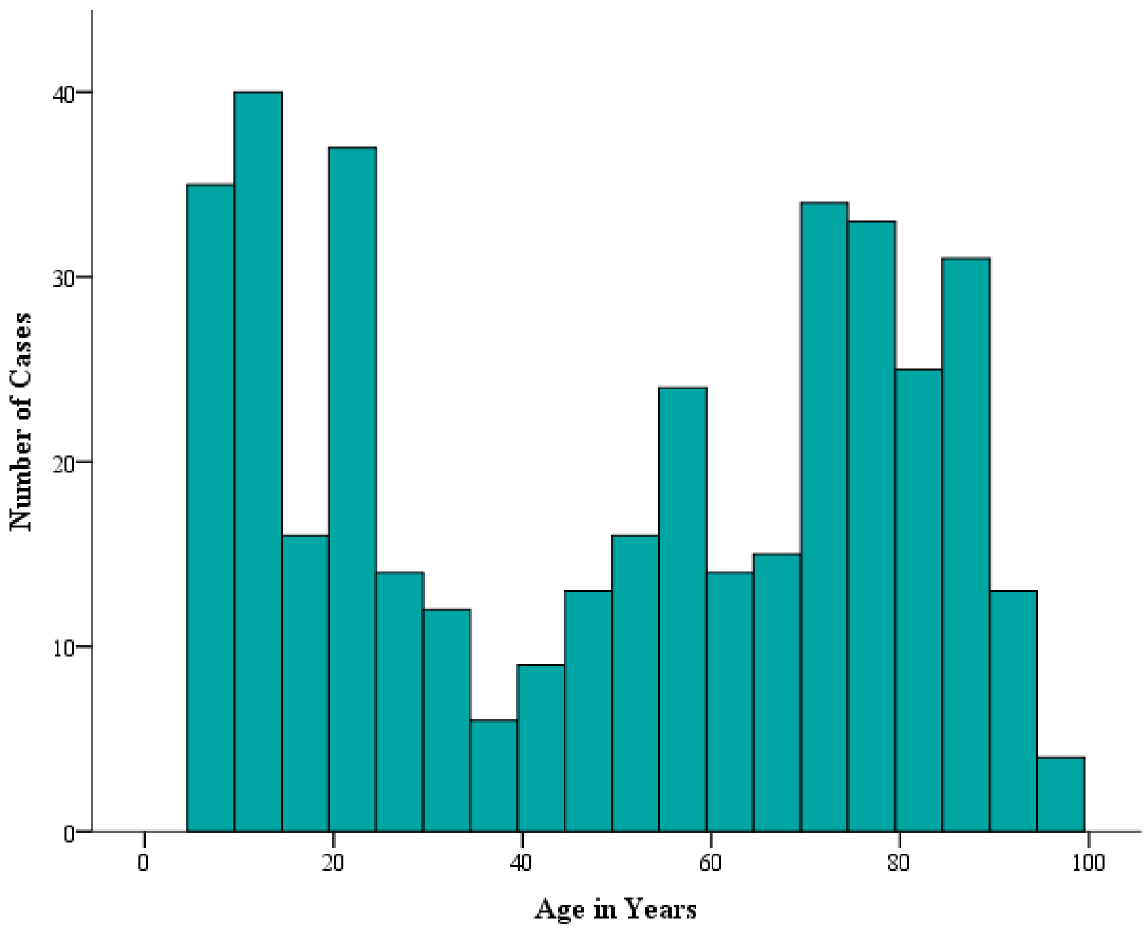
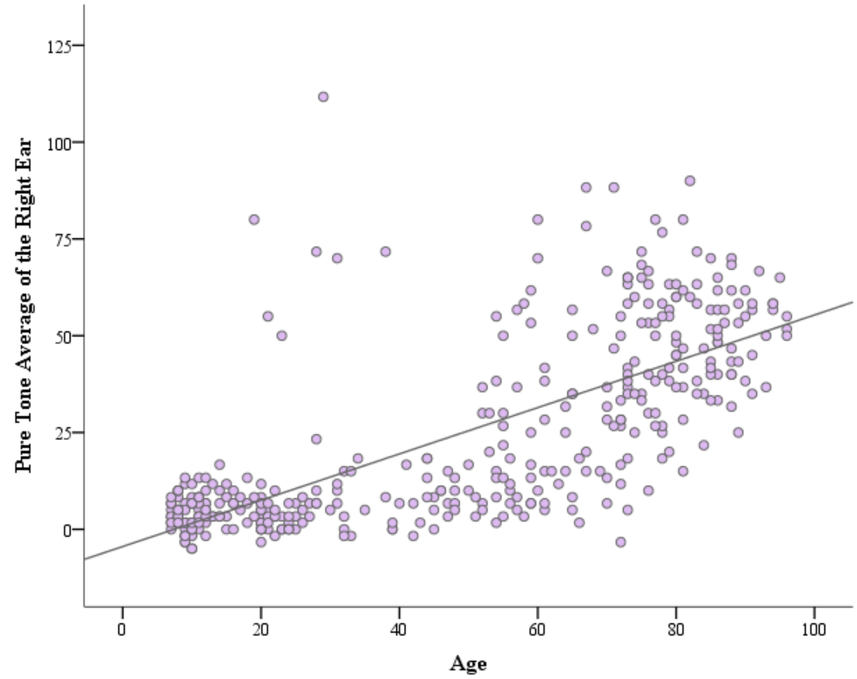


Figure 6. Distribution by age of patients seen at the Towson University Institute for Well Being.

a.



b.

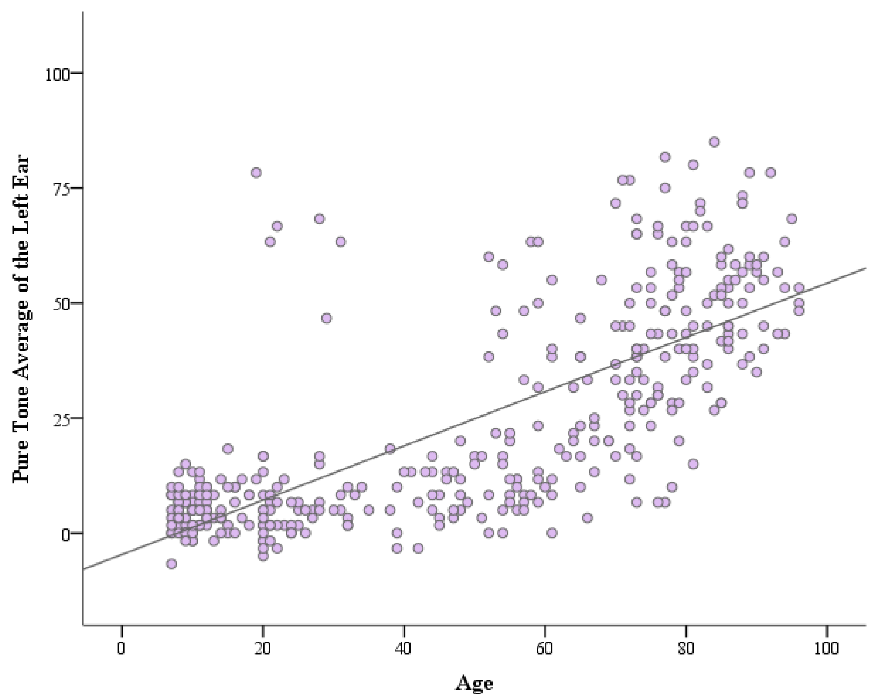


Figure 7. The relationship between increasing age and increasing PTA in the right ear (a) and the relationship between increasing age and increasing PTA in the left ear (b).

Examination of demographics of the under 40 year population (n = 160), based on data displayed in Table 3, indicated mean age was 17.43 years with a range from 7 to 39 years. Based upon examination of PTAs, 92% had normal hearing (PTA ≤15dB HL in both ears). Average word recognition scores were excellent (>90% correct) for both right and left ears. A 10-word lists was used for 31 patients, 30 of whom exhibited normal hearing. The number of patients with a diagnosis of APD was 15; four of these were tested using a 10-word list. The number of patients with a PTA ≥15dB HL was 13 (8%). Eight of the 13 patients had a PTA >25 dB HL in at least one ear and 5 had a PTA <25dB HL in at least one ear. These trends exemplified particularly high performance of the group overall.

Neither the number of words presented nor a diagnosis of APD were a focus of the research. In addition, the majority of the population examined by Dubno et al. (1995), who created the table from which the current research is based, were adults 60 years and older. Due to these factors, and the overall performance of the group, which clearly represents two sub-populations, it was concluded that the patient files for individuals under 40 years of age would affect the validity of the results and were, therefore, excluded from further analysis.

Adult subgroup (>40 years). Demographics for patients >40 years (n = 231) are shown in Table 4. Mean age was 70.82 years and the range was from 40 to 96 years. Average air conduction thresholds across all patients indicated a mild sloping to moderately-severe SNHL and poor WRS bilaterally.

Overall trends from data extracted from patient files >40 years are shown in Figures 8 and 9. The histogram presented in Figure 8 indicates these data appeared to be

Table 3

Descriptive Statistics Examining Charts <40 years of age Analyzed from Towson University Institute for Well Being

Right Ear						
Age ***(years)***		**PTA**	**HFPTA**	**SRT**	**WRS**[a]	**PL** ***(dB HL)***
17.43	**Mean**	7.72	11.98	7.04	90.25	46.96
8.53	**SD**	15.27	20.64	11.73	15.67	10.16
7-39	**Range**	-5-111.7	-8.3-98.3	-10-85	0-100	20-90
Left Ear						
		7.31	14.13	7.59	91.62	46.09
		12.67	22.33	10.40	13.59	9.66
		-6.7-78.3	-10-103.3	-5-75	0-100	30-90

Note. n = 160.
[a]The mean scores when ears that were WNL according to Dubno et al. (1995) were excluded were 86.69(16.91) and 87.56(15.43), respectively, with a range of 0-96 in both ears.

Table 4

Descriptive Statistics Examining Patient Charts > 40 Years of Age Analyzed From Towson University Institute for Well Being

			Right Ear			
Age ***(years)***		**PTA**	**HFPTA**	**SRT**	**WRS**	**PL** ***(dB HL)***
70.82	**Mean**	36.74	56.05	33.63	52.88	71.14
14.27	**SD**	22.13	22.81	22.40	29.42	17.62
40-96	**Range**	-3.3-90	-5-98.3	0-95	0-96	35-105
			Left Ear			
		35.87	56.67	32.65	49.70	73.64
		21.46	22.81	21.43	28.65	17.68
		-3.3-85	-1.7-96.7	0-95	0-96	35-105

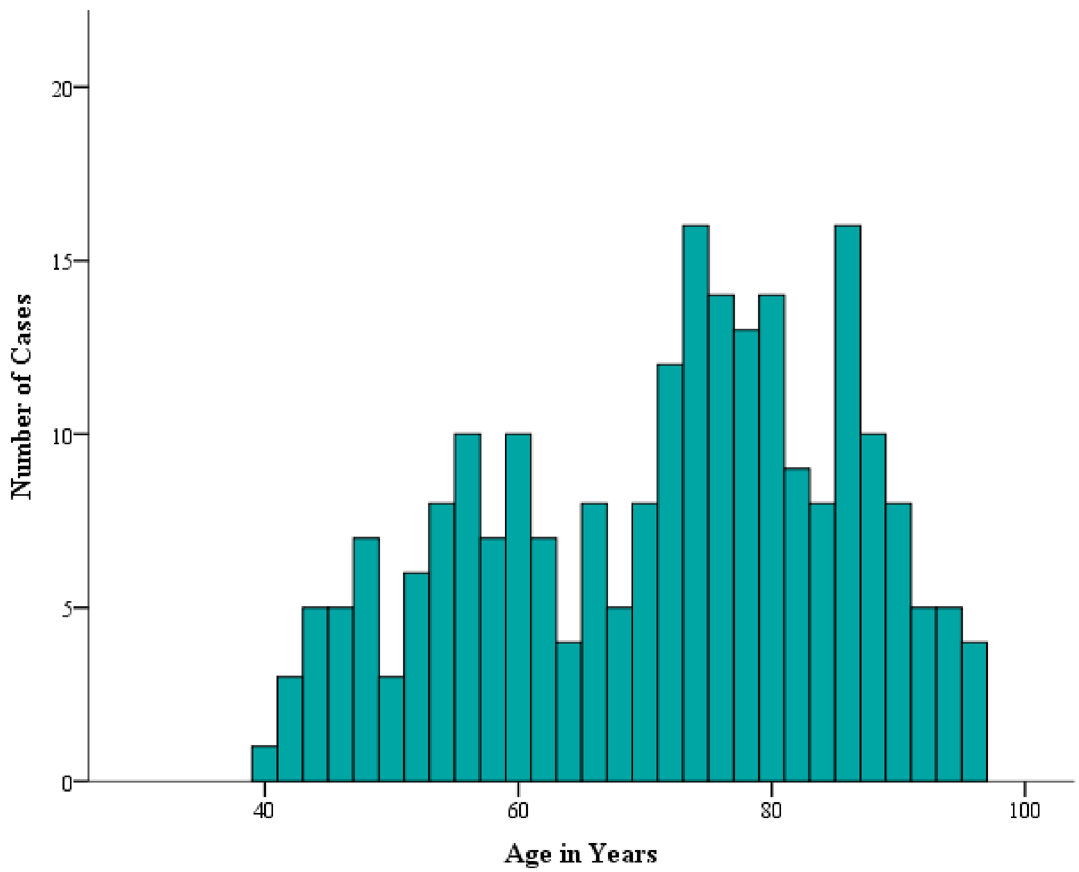


Figure 8. The distribution of the older subgroup of patients seen at the Towson University Institute for Well Being.

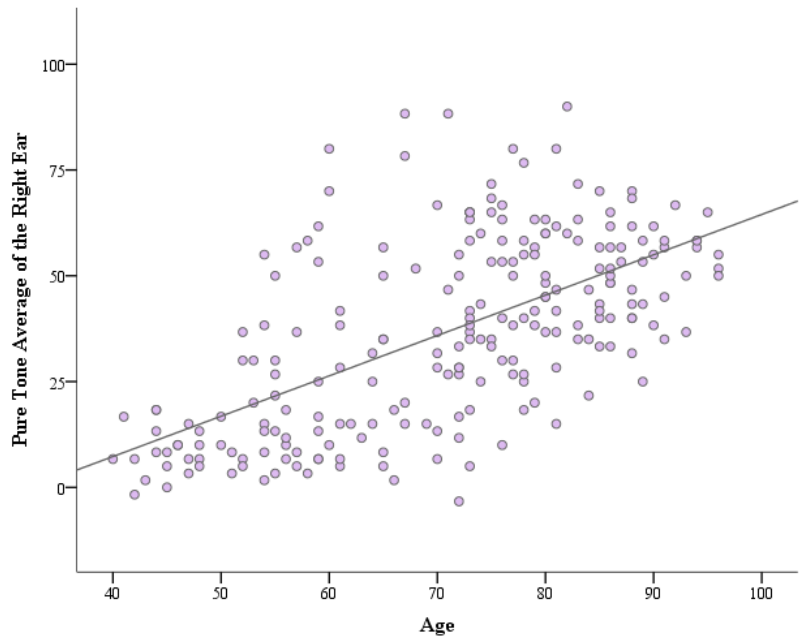
normally distributed. Scatterplots provided in Figure 8 display the relationship between PTA and age and show that the relationship appeared more linear once the <40 group had been eliminated, thus confirming the appropriateness of this subgroup for further analyses as a way to examine the linear relationship (Field, 2009).

Secondary Analysis

Dependent t-test. A paired samples t-test was used to examine the differences between WRS of the right ear and WRS of the left ear. Results indicated WRSs between ears were not significantly different, $t(214) = .385$, $p = .701$, $r = .03$. This means there was not a significant difference between WRS between the right and left ears. Because this study was designed to examine poorer than expected WRSs, all patients with one ear that met this description and one ear that fit the 95% confidence limit, were included only for the poorer ear; in these cases the “good” ear was coded as missing data.

Correlation. A correlation matrix of all numerical variables was conducted to determine which variables were strongly related to one another. The correlation matrix indicated there was a significant relationship among all numerical variables, $p < .05$. The correlation matrix with significance values for all variables is presented in Appendix C. This suggests that these variables, if used as predictor variables, will overlap in the variance that is explained.

Factor Analysis. To determine if any factors were distinct, a principle component analysis (PCA) was performed. The component matrix is presented in Table 5. The analysis showed three components had eigenvalues greater than Kaiser’s criterion of 1. Due to the high correlation of these components, percent variance could not be calculated. Examination of Table 5 indicates that all variables of interest loaded onto one a.



b.

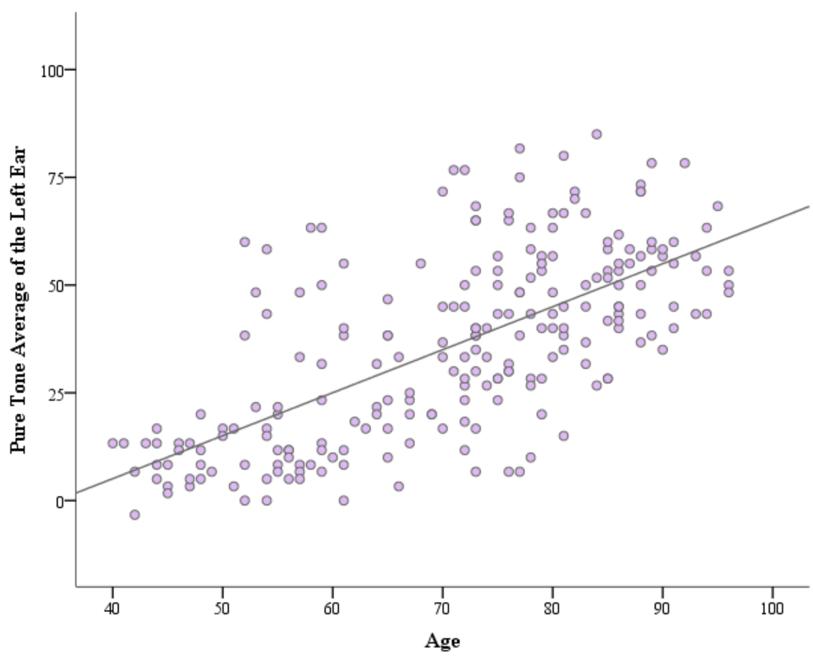


Figure 9. The relationship between increasing age and increasing PTA in the right ear (a) and the relationship between increasing age and increasing PTA in the left ear (b) for the >40 years of age subgroup.

Table 5

Component Matrix for Numeric Data Indicating All Variables Load Most Appropriately on A Single Factor.

	Component		
	1	2	3
PTAL	.954	-.200	
PTAR	.931	-.249	-.176
T1000L	.910	-.284	
WRSL	-.905	.112	
HFPTAR	.890	.351	-.140
T2000L	.884	.250	-.170
WRSR	-.880	.190	
T2000R	.865	.144	-.338
T1000R	.856	-.360	-.108
SRTL	.845	-.413	
T3000R	.838	.434	-.196
HFPTAL	.835	.517	
SRTR	.835	-.468	
T8000R	.796	.258	.272
PLR	.794	-.138	
T500R	.791	-.541	
PLL	.784	-.106	
T4000R	.778	.453	-.106
T6000R	.761	.368	
T500L	.757	-.530	.170
T8000L	.754	.458	.256
T6000L	.721	.579	.239
T3000L	.719	.563	-.102
T4000L	.709	.614	
Age	.708	-.158	.398
T250R	.691	-.515	.101
T250L	.674	-.519	.263
Words Presented	-.125	.449	.634

factor. This was consistent with results from the correlation matrix, indicating, again, that the variance seen in the WRSs was not uniquely explained by the variables, which overlapped in the variance that they predicted.

Stepwise Regression. To determine the hierarchy of predictor variables of WRS, a stepwise regression was conducted. Rather than average across multiple components to create a single factor, the commonly studied variables of age and PTA were chosen as representative predictor variables. Table 6 indicates that PTA of the right ear predicts a significant proportion of the variances of the WRS of the right ear, $R^2 = .871$, $t(146) = -31.23$, $p < .01$, and PTA of the left ear predicts the WRS of the left ear, $R^2 = .866$, $t(155) = -31.59$, $p < .01$. Once PTA was removed from the model, age did not predict a significant amount of the additional variance for either right ($p = .738$) or left ($p = .297$) ears.

A second stepwise regression analysis was conducted to determine if any categorical variables significantly predicted the WRS. Table 7 indicates that difficulty in noise was a significant predictor of WRS for the right ear, $R^2 = .173$, $t(153) = -2.16$, $p < .05$, whereas difficulty understanding, presentation of the material (MLV or recorded), language or learning disorders, and OME were all significant predictors of WRS for the left ear, $R^2 = .141$, $p = .000$. Based on these results, it was determined that difficulty understanding (either in quiet or noise), whether the test material was presented MLV or recorded, presence of a language or learning disorder, and a history of OME significantly predicted WRS for poorer than normal scores. Equivalent mean scores of 50% were obtained when test material was presented MLV and recorded. Therefore, both modes of administration significantly contributed to poorer-than-expected WRSs.

Table 6

Results of Stepwise Regression Analysis of Age and PTA Predicting WRS

	B	SE B	ß
		Right Ear WRS[a]	
Constant	97.95	1.68	
Right Ear PTA[b]	-1.25	0.40	-.93*
		Left Ear WRS[a]	
Constant	97.02	1.72	
Left Ear PTA[b]	-1.24	0.04	-.93*

[a]Dependent variable
[b]Predictor variable
[c]An asteric (*) indicates significance at the level of $p < .01$.

Table 7

Results of Stepwise Regression Analysis of Categorical Variables Predicting Poor Word Recognition

	B	SE B	ß
		Right Ear WRS[a]	
Constant	70.23	8.37	
Difficulty in Noise[b]	-10.56	4.89	-.17
		Left Ear WRS[a]	
Constant	27.17	32.70	
Difficulty Understanding[b]	13.72	4.48	.23
Test Administration	-0.04	0.02	-.19
Language or Learning Disorder	-25.39	11.18	-.17
OME	24.41	11.10	2.20

[a]Dependent variable
[b]Predictor variables
[c]An asteric (*) indicates significance at the level of $p < .01$.

When all variables (both numerical and categorical) were included in the regression model together, however, only PTA was selected as a significant predictor for right (R^2 = .834, p = .000) and left (R^2 = .867, p = .000) ears. The case history categories were not significant (test administration, p = .624; OAE notches, p = .939; poor SIN score, p = .483; language or learning disorder, p = .656; OME, p = .890; noise exposure, p = .865; difficulty understanding, p = .895; difficulty in noise, p = .273; stress or anxiety, p = .542; and family history, p = .684), indicating a shared variance between PTA and the case history results. In other words, degree of hearing loss was clearly the determining factor in the WRS and, similar to the WRSs, the case history findings were likely related to the PTA.

Analysis of covariance (ANCOVA). As another way to examine the relationship among the categorical variables, age, and PTA, an ANCOVA was conducted using age as a covariate and PTA as the outcome variable. As expected, results of this analysis indicated that the covariate, age, was significantly related to the patients' PTA for the right, F(1, 199), 127.91, $p < .01$, and left ears, F(1, 199), 135.40, $p < .01$. With age controlled for, there were no significant effects of the aforementioned categorical variables on PTA of either ear. This indicates, as with the regression analysis, that age, PTA, and WRS are highly correlated but once the variance explained by one of these is removed when explaining either of the other two, then the case history data do not provide any additional significance as predictors.

Further trends. To determine if any categorical variables with assumed relationships were significantly related, a chi-squared analysis was performed. Significant relationships were found between a history of noise exposure and gender, $\chi^2(1) = 50.74$, p

< .01, as well as difficulty understanding and difficulty in noise, $\chi^2(1) = 4.62$, $p < .05$. These results indicate that the gender of the patient is related to their incidence of noise exposure.

The case history data included a few medical issues that may have impacted the WRS, but that were not common enough to warrant their inclusion in the regression model. Some of the more common of the rare reports were used to create boxplots. These boxplots, presented in Figure 10, indicate WRS scores for patients who exhibited these factors compared with the remainder of the sample. The factors responsible for 2% or more of the overall sample (n= 231) included: (a) Sudden SNHL (3.46%); (b) Brain tumor or brain surgery (2.6%); (c) transient ischemic attack (TIA) or stroke (7.36%); (d) Head trauma (3.03%); (e) Alzheimer’s disease or dementia (2.16%). In addition, the test result of OAE notches >15dB in the right ear (3.46%) was also graphed. Figure 9 shows a distinct difference in the distribution of the WRS for the factors of SSNHL and OAE notches (left ear only).

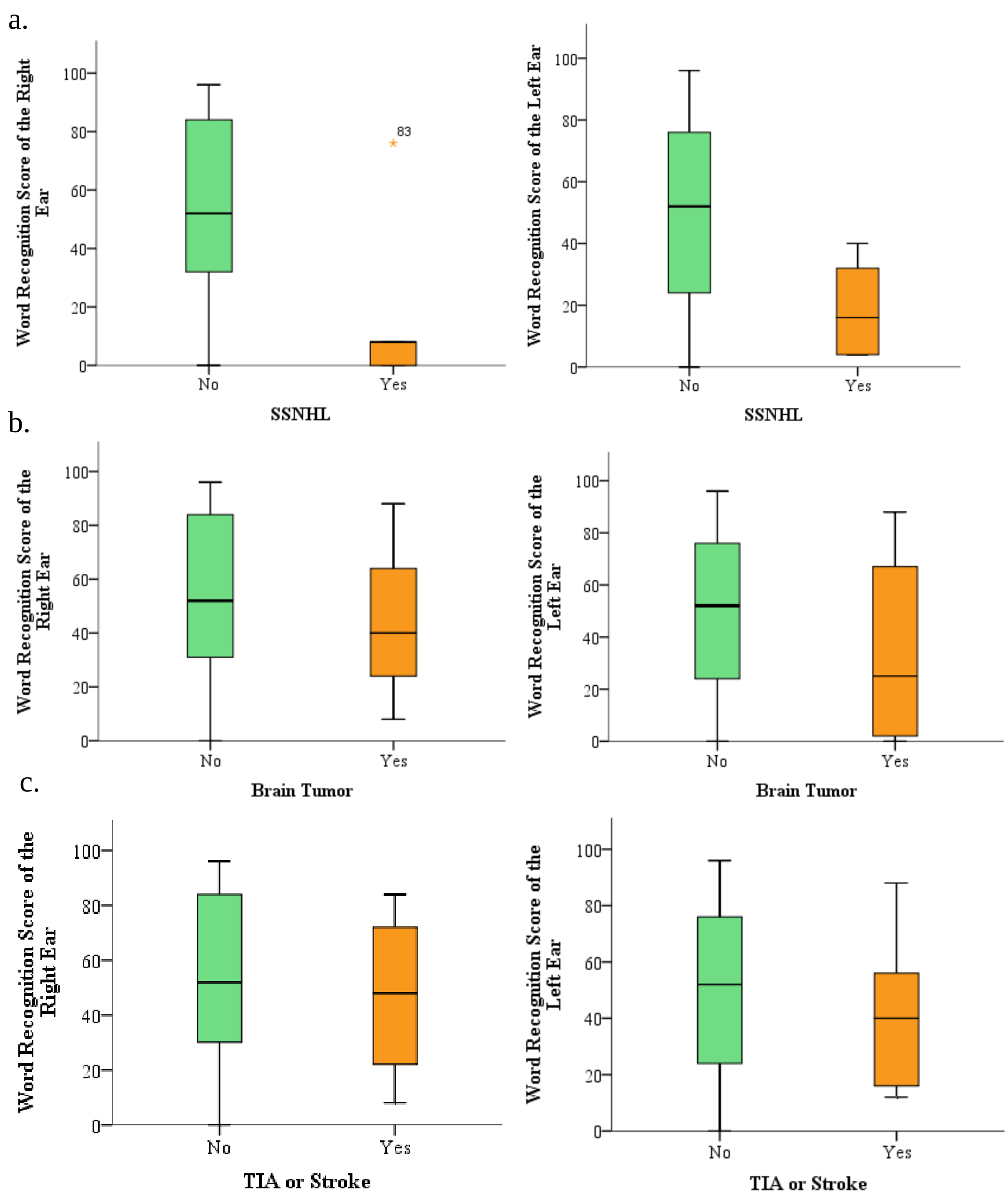


Figure 10. Examination of the difference in WRS between individuals exhibiting (a) SSNHL; (b) brain tumor or surgery; (c) TIA or stroke, and individuals who did not exhibit these factors.

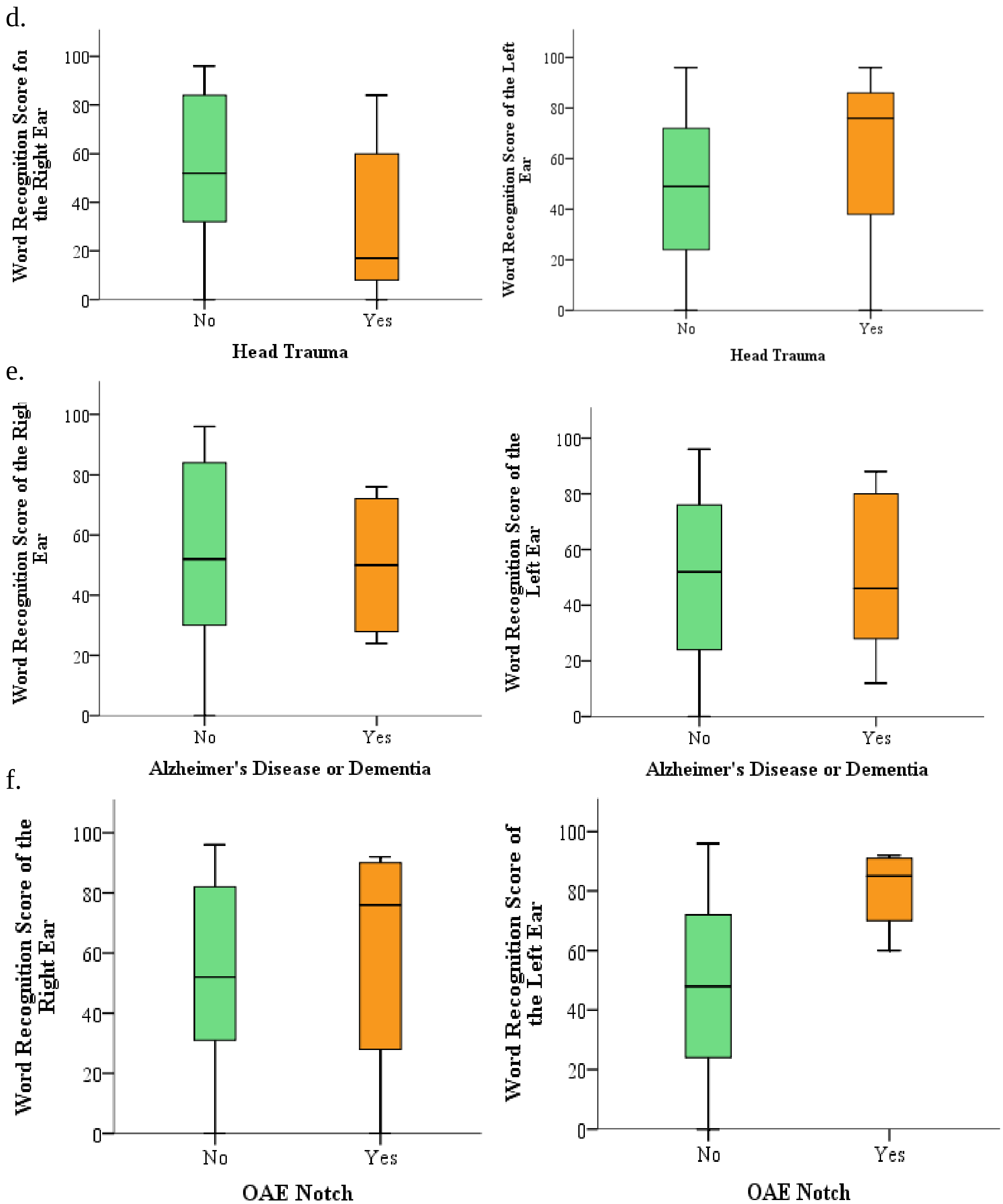


Figure 10 continued. Examination of the difference in WRS between individuals exhibiting (d) head trauma; (e) Alzheimer’s disease or dementia; and (f) notches in OAE results, and individuals who did not exhibit these factors.

CHAPTER 5

Discussion

The study by Dubno et al. (1995) was conducted to determine 95% confidence limits for WRS using both 25- and 50-word NU-6 lists to ensure a patient's WRS is consistent with the degree of SNHL established by the PTA. These 95% confidence limits defined lower boundaries for degree of hearing loss and, therefore, a score lower than the 95% confidence limit is considered poorer-than-expected. The sample population consisted of individuals ranging in age from 21 to 81 years (n = 212), the majority of whom were over 60 years of age (n= 156) (Dubno et al., 1995). The current study was conducted to examine the number of patients seen for audiological testing at the Towson University IWB Hearing and Balance Center in Towson, Maryland who had poorer-than-expected WRS compared to the Dubno et al. (1995) 95% confidence limits, and to determine if any patient case history complaints or audiological test procedures could predict WRSs for the patients with poorer than expected scores.

There were no patient complaints, abnormal test results, previous diagnoses, or test administration procedures that significantly predicted WRS once PTA had been accounted for in the prediction model. Therefore, the null hypothesis was not supported. Results of the stepwise regression indicated patients' PTA underlies different variables and is the only significant predictor of WRS, accounting for 87% of the variance. No other predictor variables accounted for more than 13% of the variance and were not significant.

When a stepwise regression of categorical variables was conducted, difficulty understanding in quiet and noise, presence of a language or learning disorder, history of chronic OME, and test administration were significant predictors of WRSs. Though these variables were not significant once PTA was accounted for, they are potential predictors of the WRS. For a patient with considerable hearing loss, a report of difficulty understanding in quiet or noise is not surprising; this complaint, however, is also common among individuals with APD or perceived deficit in the presence of normal hearing (Bharadwaj et al., 2014; Keith, 1999; Saunders & Haggard, 1989). Language and learning disorders, and history of chronic OME are also associated with APD diagnoses and word discrimination problems (Brown, 1994; Hind et al., 2011; Keith, 1999). In addition, the use of both MLV and recorded material significantly affected WRSs. The use of recorded test material is recommended to ensure consistent voice intensity and to avoid variability among speakers (ASHA, 1988; Wiley et al., 1995). Use of MLV, however, often allows for more flexibility in testing. (ASHA, 1988). For example, MLV might be more appropriate for a patient requiring increased response time, or to keep a patient engaged in the task. The use of MLV can also provide educational benefit to students by allowing them to practice becoming familiar with the audiometer and presenting test material. Because these variables were significantly related to word recognition score when PTA was unaccounted for, and because they are highly associated with conditions with known word discrimination deficits, they should be of particular interest and importance for future studies investigation their relationship to the WRS.

Based on these results, it is reasonable to assume that an increase in age and PTA will result in decreased WRS and a concomitant increase in case history complaints such as difficulty understanding in quiet and/or noise. The relationship between increased age and increased PTA with poor word recognition abilities is well established (Katz &

White, 2001; Liu & Yan, 2007; Phillips et al., 2000). As age increases, prevalence of hearing loss increases. Hearing loss is a commonly reported chronic health condition among elderly individuals in the United States (Dubno et al., 2013; Liu & Yan, 2007). The number of elderly individuals is expected to increase exponentially, potentially reaching 60 million Americans by 2025 (Liu & Yan, 2007). If this projection is correct, a patient population necessitating audiological services will increase dramatically; and audiologists will need to be equipped to provide efficient and appropriate care.

This study sought indicators within the case history that might assist audiologists in prediction of the WRS, beyond those already known (i.e., type of hearing loss, PTA, and etiology) (Cambell & Klemens, 2000; Katz et al., 2009; Katz & White, 2001; Liu & Yan, 2007; Phillips et al., 2000). This study indicated none of the commonly reported symptoms significantly predicted WRSs. Although one rare case history finding (SSNHL) and one diagnostic finding (OAE notch > 15 dB in the left ear) were associated with large deviations in WRSs relative to patients without these issues, the small sample did not allow for inferential statistical analysis. It is well known that SSNHL often results in extremely poor WRSs (Campbell & Klemens, 2000). There appears to be no current research indicating that an OAE notch > 15 dB is associated with significantly increased WRS, so this may require further study.

Case history complaints significantly related to one another included noise exposure and gender, and difficulty understanding in quiet and in noise. Established research states that noise exposure is typically more common in males than females (Dubno et al., 2013; Gates, Feeney, & Mills, 2008). In addition, a patient experiencing difficulty understanding in quiet might also experience difficulty in noise and vice-a-versa.

The current projections of the increasing elderly population in the United States underlies the importance of finding significant contributors to a poorer-than-expected WRS and understanding relationships within patients' test results. Such information can provide audiologists with case history 'red flags' to alert them of patients at risk for obtaining a poorer-than-expected WRS, or the potential for communicative difficulties even if not verbally expressed throughout the case history interview.

Understanding these relationships may assist audiologists in seeing the 'bigger picture' as it relates to their patients by giving insight into additional tests to perform. If a poorer-than-expected WRS is obtained, it is recommended that the examiner alter testing (i.e., increase the presentation level, increase the number of words, evaluate for rollover) to deduce nuances associated with the patient's hearing abilities (Dubno et al., 1995; Stach, 2007). By understanding the complexities of the patient's hearing loss, the provider will be more equipped to provide comprehensive treatment with a wider variety of rehabilitation options.

Results of this study were also valuable in validating the results obtained by Dubno et al. (1995), in which the researchers determined confidence intervals for WRSs by comparing the WRS to the participants' degree of hearing loss (PTA). The current study found PTA to be the strongest predictor of WRS. This finding validates the function of PTA in determining a disproportionate score. Dubno and colleagues also highlighted the importance of determining patients' PBmax, the effects of test administration on WRSs, and diagnostic and rehabilitative implications of the WRS; and speculated that other factors other than PTA contributed to WRSs. Though the current study did not find case history variables that significantly predicted poor WRSs, it emphasized the importance of testing at multiple intensity levels and consistent test administration; and stressed the need for further study to determine additional contributing factors.

In addition, considering the original sample population of this study (n = 391), the Dubno et al. (1995) criteria had an 85% confidence limit for determining disproportionate WRSs (391/2,554). It was speculated this was due to many patients not achieving WNL scores by one or two incorrect words. Post hoc analysis of the original sample tested with 25- or 50-word lists revealed the percent of patients not achieving a WNL score by one incorrect word in at least one ear was 41%. If the criteria was increased to two words away from an expected score in at least one ear, the percentage increased to 63%. This pattern is likely a result of the clinic often testing word recognition at one intensity level (i.e. 40 dB SL re: PTA), which is common practice in the field. Dubno and colleagues, however, likely reached a higher confidence criteria by testing at multiple intensity levels. In the Dubno et al. (1995) study, they tested at 30 dB SL re: SRT, and increased the presentation level by 10 dB, 15 dB, or 20 dB increments until PBmax was achieved (Dubno et al., 1995). Therefore, a patient’s WRS might not always represent their full potential, and thus reiterates the importance of expanding test procedures.

Limitations

Limitations of the present study included lack of control over consistency of test procedures, differences in reporting styles, and lack of generalizability. Because of the nature of a retrospective study, the audiograms and reports being examined were from previous testing and thus had potential for inconsistencies over time. In addition, information was obtained through case history interviews conducted and interpreted by many outside examiners, potentially leading to areas of misinterpretation during data collection. The Towson University IWB Hearing and Balance Center employs many audiologists who each teach multiple student practitioners. Students attending Towson University are given strong foundations in evidence based practice, and taught skills to provide care to a variety of patients. Potential differences in case history questions asked, interpretation of case history reports, and test administration are likely the result of clinical judgements based on patient needs (i.e., culture, native language, mental status, and response speed).

In addition, this study is not generalizable to the greater community. The sample population consisted only of individuals seen for audiological testing at one clinic in Towson, Maryland, United States. Results of future studies will be more generalizable if data are collected from multiple audiological evaluation sites from various areas of the country and/or world. Future studies might also consider examining differences in word recognition abilities and the incidence of specific case history variables across a more ethnically diverse population. In addition, future studies could control for effects of age and increased PTA when evaluating the significance of the effect of case history variables on the WRS.

Future Research

It is possible that a prospective study instituting consistent case histories across patients could further clarify the possible relationships between case history reports and symptoms. Results of potential future studies could supply audiologists with important information regarding the best course of treatment/rehabilitation in regards to patients' hearing loss and poor word recognition abilities. Further insights into patients' case history information could provide audiologists with added guidance as they work with their patients to determine appropriate intervention strategies. Individuals with similar degrees and configurations of hearing loss can differ widely in their word recognition abilities and overall QoL (Midha & Malik, 2015; Thibodueau, 2007). Therefore, increased information of the subtleties of patients' hearing difficulties can alert the attentive audiologist to further testing (i.e., AEPs) and expanded treatment options, such as ALDs or auditory rehabilitation therapy (Bharadwaj et al., 2014; Stach, 2007; Tremblay, 2003).

Appendix A

TOWSON UNIVERSITY

EXEMPTION NUMBER: 16-X053

To: Katherine Allen
From: Institutional Review Board for the Proctection of Human Subjects Devon Dobrosielski
Date: Wednesday, December 09, 2015
RE: Application for Approval of Research Involving the Use of Human Participants

Thank you for submitting an application for approval of the research titled,

Chart Review and Factor Analysis Examining Poorer-Than-Expected Word Recognition Scores

to the Institutional Review Board for the Protection of Human Participants (IRB) at Towson University.

Your research is exempt from general Human Participants requirements according to 45 CFR 46.101(b)(3). No further review of this project is required from year to year provided it does not deviate from the submitted research design.

If you substantially change your research project or your survey instrument, please notify the Board immediately.

We wish you every success in your research project.

CC: S. Nagle
File

Appendix B

Subject	Gender	Age	250R	500R	1000R	2000R	3000R	4000R	6000R	8000R
A1	1	88	65	50	60	75	75	100	115	NR
A2	2	15	5	5	5	0	DNT	5	15	0
A3	2	61	10	5	5	5	DNT	20	DNT	10
A4	1	73	10	5	10	0	15	30	40	50
A5	1	23	5	0	0	0	DNT	0	DNT	10
A6	1	10	5	5	10	5	DNT	5	-5	-10
A7	1	67	15	20	10	30	DNT	45	DNT	55
A8	2	25	0	0	0	0	DNT	10	DNT	0
A9	2	86	40	30	25	45	60	75	DNT	80
A10	2	77	15	25	40	50	DNT	70	DNT	95
A11	2	56	15	10	10	10	15	15	10	0
A12	1	61	15	15	40	70	80	80	65	55
A13	2	60	65	70	70	70	65	90	90	NR
A14	1	73	30	25	35	65	65	70	70	75
A15	1	11	5	10	10	5	10	10	10	0
A16	1	44	10	15	20	5	DNT	10	20	25
A17	2	22	5	15	10	5	DNT	-5	DNT	5
A18	2	86	55	45	45	55	105	105	NR	NR
A19	1	8	5	5	5	5	DNT	0	DNT	0
A20	2	27	20	10	5	5	DNT	10	DNT	10
B1	1	80	20	35	60	85	DNT	100	DNT	NR
B2	1	80	35	35	50	60	DNT	70	70	85
B3	2	52	35	40	35	35	30	35	40	25
B4	2	85	45	55	60	55	75	85	85	85
B5	1	32	15	15	15	15	20	15	DNT	15
B6	2	47	0	10	5	5	DNT	15	DNT	20
B7	2	20	0	0	5	5	DNT	0	DNT	10
B8	1	45	5	5	5	5	DNT	0	DNT	5
B9	2	35	5	5	10	0	DNT	5	DNT	-5
B10	1	55	20	20	20	40	DNT	45	35	20
B11	1	25	10	5	5	10	10	25	10	20
B12	2	20	5	5	5	5	DNT	5	20	15
B13	2	9	10	5	-5	-5	DNT	-5	DNT	-10
B14	1	22	5	0	0	-5	DNT	0	5	10
B15	2	9	15	5	-5	5	DNT	0	DNT	10
B16	2	9	5	15	10	10	DNT	10	DNT	15
B17	2	48	5	10	15	15	15	15	5	5
B18	2	10	15	10	15	10	DNT	10	DNT	10
B19	1	24	5	5	10	5	DNT	0	0	5
B20	1	16	10	10	10	10	5	0	0	0

Appendix B continued

B21	1	57	75	60	55	55	80	85	DNT	100
B22	1	94	30	40	55	80	90	105	NR	NR
B23	1	86	60	55	55	60	55	55	65	90
B24	2	70	10	10	10	20	DNT	30	45	55
B25	2	25	5	5	5	0	DNT	0	DNT	-5
B26	1	15	10	15	5	15	DNT	15	DNT	0
B27	2	75	50	55	70	80	70	65	75	100
B28	2	20	0	0	5	30	65	60	25	25
B29	1	72	15	25	50	75	80	75	75	85
B30	2	91	50	50	55	65	60	65	80	90
B31	1	10	5	0	0	-5	DNT	-5	DNT	10
B32	2	29	90	105	115	115	115	NR	NR	NR
B33	1	77	50	70	80	90	100	95	NR	NR
B34	1	65	55	60	55	55	55	60	60	55
B35	2	95	75	70	65	60	70	70	75	75
B36	1	21	0	5	5	5	DNT	0	DNT	5
B37	2	32	10	5	-5	0	DNT	-5	20	5
B38	1	12	0	10	5	0	5	10	15	DNT
B39	2	7	0	0	5	5	20	15	5	0
B40	1	79	35	55	55	70	80	80	80	NR
B41	1	60	5	10	10	10	15	35	DNT	40
B42	1	61	15	10	20	85	100	105	90	85
B43	1	64	10	10	20	65	70	80	75	75
B44	2	76	15	20	40	60	75	80	100	NR
B45	1	81	30	35	35	40	45	45	DNT	50
B46	2	10	15	10	5	10	DNT	0	DNT	-10
B47	1	78	25	20	20	35	65	70	90	NR
B48	2	11	10	5	5	5	15	20	5	-5
B49	2	22	10	5	5	0	DNT	5	DNT	5
B50	1	88	25	45	40	55	DNT	65	70	90
B51	2	7	10	0	0	5	DNT	0	DNT	0
B52	1	7	15	10	0	5	DNT	-5	DNT	0
B53	1	84	20	25	35	45	DNT	55	DNT	75
B54	2	11	10	0	0	0	DNT	0	DNT	15
C1	1	28	25	25	80	110	DNT	110	NR	NR
C2	2	70	20	45	60	95	DNT	85	DNT	NR
C3	1	79	50	55	50	65	DNT	70	DNT	80
C4	2	78	10	20	15	20	DNT	45	55	80
C5	1	59	15	5	5	10	60	60	90	75
C6	2	20	10	5	0	15	DNT	15	DNT	20
C7	2	23	5	0	0	0	0	20	40	75

Appendix B continued

C8	1	72	25	25	30	45	DNT	60	100	95
C9	1	21	5	5	5	5	DNT	-5	DNT	-5
C10	2	89	DNT	DNT	80	75	DNT	75	100	NR
C11	1	44	5	5	20	30	50	45	30	30
C12	2	91	20	30	45	60	55	65	75	70
C13	1	28	5	10	5	5	10	5	5	10
C14	1	64	20	15	15	15	35	50	DNT	55
C15	1	70	35	30	35	45	65	80	60	75
C16	2	54	15	5	10	10	DNT	15	DNT	14
C17	2	80	60	65	65	60	70	75	80	70
C18	1	67	80	80	80	105	110	105	DNT	NR
C19	2	74	15	20	20	35	40	50	60	60
C20	2	7	5	0	5	5	DNT	0	DNT	-5
C21	2	54	15	20	45	70	65	75	95	90
C22	2	85	30	35	30	35	55	50	55	55
C23	2	58	60	60	60	55	45	35	35	60
C24	2	8	20	15	0	10	DNT	5	DNT	15
C25	2	7	10	10	5	5	DNT	5	DNT	15
C26	1	8	15	5	0	0	DNT	10	5	0
C27	1	11	5	5	5	0	5	10	DNT	5
D1	2	56	5	5	10	20	20	20	20	35
D2	2	75	MHL	MHL	MHL	MHL	MHL	MHL	MHL	MHL
D3	1	45	10	10	10	5	35	60	55	50
D4	1	72	15	15	15	50	DNT	55	65	70
D5	2	22	5	5	0	5	DNT	0	DNT	5
D6	2	57	NR	NR	115	NR	DNT	NR	DNT	NR
D7	2	33	0	0	-5	0	DNT	5	DNT	15
D8	2	73	40	45	65	85	110	110	100	90
D9	2	65	5	5	15	5	10	10	5	20
D10	1	79	45	50	55	60	70	75	105	NR
D11	2	9	5	5	-5	0	DNT	10	DNT	10
D12	1	71	20	15	15	50	65	65	70	85
D13	1	76	15	15	25	50	55	60	60	65
E14	2	86	30	40	50	55	DNT	70	75	95
D15	2	12	5	10	10	0	0	5	DNT	0
E13	2	20	0	5	5	-5	DNT	0	DNT	-5
E1	2	39	0	0	0	0	10	5	DNT	10
E2	1	52	-10	10	15	0	DNT	-5	-10	15
E3	1	21	0	0	0	0	DNT	0	DNT	0
E4	1	80	15	30	45	60	70	70	65	75
E5	1	80	40	55	60	65	75	80	DNT	80

Appendix B continued

E6	2	78	60	60	60	55	DNT	50	50	50
E7	1	76	25	35	60	65	DNT	75	65	60
E8	1	56	5	10	15	30	45	60	70	85
E9	1	64	25	25	20	30	50	70	60	65
E10	2	20	5	5	0	0	0	0	10	0
E12	2	9	15	10	5	5	DNT	0	DNT	0
E13	1	42	5	5	10	5	10	35	40	25
F1	1	86	40	40	40	70	70	75	80	70
F2	2	73	65	65	70	60	70	65	70	70
F3	1	86	40	35	45	40	55	60	75	90
F4	1	49	CHL	CHL	CHL	CHL	CHL	CHL	CHL	CHL
F5	2	20	0	0	0	0	DNT	0	DNT	0
F6	2	83	50	50	50	75	DNT	70	DNT	90
F7	1	52	25	20	15	55	65	75	65	45
F8	2	96	50	50	55	60	65	65	85	100
F9	1	73	40	50	65	75	75	90	90	85
F10	1	12	10	10	5	5	-5	5	10	0
F11	1	12	5	5	5	0	DNT	10	DNT	10
F12	2	26	15	5	5	5	DNT	10	DNT	10
F13	2	83	15	25	25	55	60	50	65	65
F14	1	69	20	15	10	20	60	70	DNT	70
F15	1	44	0	0	0	25	30	35	30	10
F16	2	20	-5	5	5	-5	DNT	-5	DNT	10
F17	1	54	20	15	5	25	DNT	25	DNT	60
F18	2	54	15	10	15	15	DNT	15	DNT	40
F19	2	57	15	15	10	0	DNT	5	20	25
F20	1	39	5	0	0	0	0	0	0	10
G1	2	31	25	20	5	5	5	5	0	5
G2	2	23	5	5	5	0	DNT	0	DNT	10
G3	2	44	15	20	20	15	DNT	10	DNT	10
G4	1	15	0	0	0	0	0	0	10	10
G5	1	76	60	50	60	80	80	90	DNT	95
G6	1	65	20	25	25	55	DNT	60	DNT	60
G7	2	55	15	20	15	5	DNT	5	DNT	10
G8	1	61	10	10	15	60	60	60	60	60
G9	2	82	60	50	60	70	75	80	95	NR
G10	1	94	35	50	55	65	65	65	70	85
G11	1	60	85	85	80	75	DNT	85	DNT	80
G12	2	20	5	10	10	5	DNT	-5	5	10
G13	1	88	80	70	70	70	70	75	90	NR
G14	1	70	10	-10	10	20	80	NR	DNT	90

Appendix B continued

G15	1	8	10	10	0	0	DNT	20	25	30
G16	2	78	25	10	30	40	45	50	75	75
G17	1	11	5	10	5	5	DNT	5	DNT	5
G18	1	9	10	5	0	0	DNT	0	DNT	0
H1	1	65	25	35	50	65	70	75	DNT	65
H2	1	50	15	5	5	20	60	55	60	70
H3	1	55	25	45	55	50	80	80	110	NR
H4	1	81	35	20	35	70	DNT	75	DNT	75
H5	2	12	10	5	0	0	DNT	5	DNT	0
H6	2	24	15	0	0	5	DNT	0	DNT	-10
H7	2	27	5	5	5	0	DNT	0	DNT	15
H8	1	24	10	0	0	0	0	0	15	30
H9	1	48	15	5	10	15	45	45	20	5
H10	1	52	10	5	0	10	DNT	25	DNT	15
H11	2	26	10	15	10	0	10	5	15	20
H12	1	90	45	50	55	60	70	90	85	95
H13	1	89	55	50	55	70	75	85	80	90
H14	1	78	70	75	85	70	DNT	75	80	95
H15	2	11	15	15	10	15	DNT	10	DNT	10
H16	1	65	5	5	5	5	DNT	10	DNT	5
H17	1	61	15	10	30	15	20	35	20	40
H18	2	75	65	70	70	55	40	40	60	60
H19	1	41	15	10	15	25	25	20	30	35
H20	1	72	10	-5	-5	0	30	35	40	40
H21	2	24	5	5	5	-10	DNT	-10	DNT	-10
H22	1	88	20	25	25	45	90	90	85	90
H23	2	87	45	55	55	50	DNT	60	DNT	70
H24	2	86	60	60	65	60	60	65	60	70
H25	2	73	50	50	65	80	80	80	100	100
H26	1	57	5	5	5	5	45	55	DNT	60
H27	1	91	45	55	60	60	85	90	90	80
H28	1	68	25	35	45	75	85	100	DNT	NR
H29	2	86	55	55	55	85	95	100	DNT	NR
H30	1	13	5	5	0	5	0	10	5	5
H31	2	9	-5	-5	-5	0	-5	-5	5	10
H32	2	9	0	0	0	-5	0	-10	5	5
H33	2	9	10	0	0	-10	DNT	-10	DNT	-10
H34	1	11	0	10	0	0	DNT	0	DNT	0
H35	1	10	5	10	5	5	DNT	15	DNT	5
I1	1	79	25	25	35	55	75	85	85	75
J1	1	21	5	0	5	5	5	5	5	0

Appendix B continued

J2	1	66	25	15	15	35	60	60	60	65
J3	2	8	5	5	5	-5	-10	-10	-10	-10
J4	1	59	50	60	65	60	65	70	65	95
K1	2	32	5	0	0	10	DNT	0	DNT	10
K2	2	83	20	20	45	50	DNT	45	DNT	40
K3	1	81	10	15	30	40	75	95	85	105
K4	1	38	5	10	5	10	10	30	20	40
K5	1	76	65	60	60	80	80	75	75	85
K6	1	7	5	10	5	10	DNT	0	DNT	0
K7	1	74	35	35	40	55	70	60	DNT	55
K8	1	28	25	25	20	25	DNT	35	DNT	25
K9	2	81	70	60	55	70	DNT	80	95	100
K10	2	73	20	40	40	40	45	50	45	60
K11	2	71	60	70	95	100	105	110	NR	NR
K12	1	77	45	45	45	60	65	70	70	70
K13	2	14	15	15	10	5	DNT	5	DNT	0
K14	2	31	60	65	65	80	75	70	60	55
K15	1	10	5	0	0	0	DNT	5	DNT	20
L1	1	34	30	30	5	20	95	90	90	75
L2	1	31	20	10	10	15	DNT	20	DNT	15
L3	1	62	10	15	10	20	40	50	50	55
L4	2	75	15	15	40	50	45	60	65	90
L5	1	8	10	15	10	5	DNT	-5	DNT	5
L6	2	10	5	5	10	5	DNT	0	DNT	10
M1	1	72	10	0	15	20	25	55	DNT	65
M2	1	39	5	0	0	5	DNT	0	DNT	0
M3	1	58	0	5	5	0	5	35	35	5
M4	1	59	30	20	5	25	45	60	70	85
M5	1	72	20	20	15	15	60	70	80	70
M6	2	54	10	5	0	0	DNT	10	DNT	5
M7	2	59	50	50	55	55	DNT	50	90	100
M8	1	18	5	5	10	5	5	0	0	5
M9	1	78	30	35	45	85	90	95	NR	NR
M10	1	89	5	5	20	50	65	75	70	75
M11	1	71	25	30	45	65	DNT	70	DNT	75
M12	1	14	10	10	5	5	DNT	10	DNT	5
M13	1	65	10	10	20	75	90	95	95	85
M14	1	75	35	40	45	75	DNT	85	DNT	85
M15	1	88	20	30	45	55	55	70	85	90
M16	2	77	15	10	35	35	35	20	30	45
M17	2	48	5	10	10	0	DNT	10	DNT	15

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M18	1	73	45	55	55	65	DNT	70	DNT	70
M19	1	73	5	15	35	60	80	80	80	90
M20	1	77	30	30	65	65	65	70	DNT	70
M12	1	90	45	35	35	45	85	90	DNT	NR
M13	2	69	75	70	75	NR	NR	NR	NR	NR
M14	1	11	15	10	5	10	0	5	5	-5
M15	2	22	5	0	5	5	DNT	0	DNT	0
M16	1	9	10	5	5	5	DNT	-5	5	5
N1	1	48	10	5	5	5	30	40	40	0
N2	1	20	NR	NR	NR	NR	DNT	NR	DNT	NR
N3	2	55	15	15	25	50	DNT	60	60	60
N4	2	18	15	15	10	15	55	45	0	0
N5	2	10	10	5	0	0	DNT	5	DNT	0
N6	1	50	10	15	15	20	50	55	50	35
N7	1	81	55	65	80	95	DNT	95	DNT	100
N8	2	63	5	5	10	20	40	45	55	50
N9	1	7	10	5	0	-5	DNT	0	DNT	-10
O1	1	75	25	5	25	70	80	90	DNT	100
O2	2	85	35	35	45	40	DNT	55	DNT	70
O3	2	40	5	10	0	10	DNT	15	DNT	30
O4	2	19	15	5	0	5	DNT	10	DNT	20
O5	2	61	5	5	10	5	5	0	25	20
O6	1	9	5	5	0	0	DNT	-5	DNT	10
O7	1	14	5	5	0	5	5	-5	DNT	0
O8	2	94	60	60	50	65	60	65	70	80
O9	1	96	30	35	55	65	90	95	90	95
O10	2	10	5	0	-5	5	DNT	5	DNT	5
P1	1	59	5	5	5	10	45	55	DNT	60
P3	2	7	5	5	0	0	DNT	0	DNT	0
P4	2	20	0	0	0	-10	DNT	0	DNT	0
P5	1	55	0	0	5	5	25	35	20	30
P6	1	17	5	5	5	5	5	5	5	5
P7	1	12	15	15	10	5	5	5	5	15
P8	1	90	45	50	60	75	DNT	85	DNT	85
P9	2	13	0	0	5	5	5	-5	-5	-10
P10	2	75	55	55	70	90	95	105	DNT	105
P11	1	46	10	5	10	15	DNT	15	DNT	15
P12	2	79	10	10	15	35	45	55	95	95
P13	2	20	0	5	10	0	DNT	-5	DNT	-10
P14	1	56	10	5	0	15	45	25	15	10
P15	2	82	90	90	90	90	110	110	DNT	NR

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P16	1	89	65	55	50	55	70	70	65	80
P17	2	74	55	50	45	85	DNT	90	NR	NR
P18	2	46	10	5	15	10	DNT	15	DNT	15
P19	2	14	5	5	0	5	DNT	0	DNT	-5
P20	1	7	30	10	10	5	DNT	0	DNT	0
P21	1	73	15	20	30	55	DNT	60	60	90
P22	2	73	20	15	15	25	65	65	75	85
P23	2	38	50	70	75	70	DNT	65	25	10
R1	1	11	10	10	10	5	0	0	0	0
R2	2	20	10	10	5	5	DNT	5	DNT	0
R3	1	72	50	40	50	75	DNT	100	DNT	NR
R4	1	31	0	0	5	15	5	30	55	10
R5	2	32	15	0	0	-5	DNT	0	DNT	15
R6	2	88	35	35	60	110	115	115	NR	NR
R7	2	81	20	30	55	55	65	60	95	90
R8	1	8	5	5	10	15	DNT	5	DNT	10
R9	1	47	20	15	15	15	DNT	20	DNT	15
R10	1	8	5	5	0	0	DNT	5	20	15
R11	2	8	10	10	5	0	DNT	5	DNT	0
R12	2	10	0	5	0	0	DNT	0	DNT	0
S1	2	21	5	0	0	5	DNT	0	10	30
S2	2	51	5	5	5	0	0	5	10	10
S3	2	20	10	0	0	0	DNT	-10	DNT	-10
S4	1	24	0	5	0	5	0	5	0	20
S5	1	59	0	10	20	10	25	30	35	20
S6	2	67	95	75	85	75	70	70	75	70
S7	1	14	15	15	15	20	15	20	DNT	10
S8	1	45	0	-10	0	10	20	20	30	25
S9	1	43	0	0	5	0	0	0	0	20
S10	1	51	10	10	10	5	5	25	40	40
S11	1	12	15	15	15	10	10	10	0	5
S12	1	72	15	20	25	40	DNT	40	35	55
S13	2	84	20	15	15	35	DNT	50	60	70
S14	1	55	15	15	15	35	DNT	45	45	50
S15	2	66	10	5	0	0	0	20	15	35
S16	1	79	45	40	45	40	DNT	60	80	80
S17	1	30	15	5	5	5	DNT	20	DNT	5
S18	2	20	5	5	0	-5	DNT	-5	DNT	-5
S19	2	28	10	10	10	10	DNT	5	DNT	10
S20	1	70	15	15	20	50	DNT	55	DNT	70
S21	1	53	15	20	10	60	75	70	65	60

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S22	1	70	35	30	45	20	50	60	DNT	70
S23	2	87	35	60	55	55	60	65	75	85
S24	2	16	5	10	5	5	DNT	15	DNT	5
S25	1	91	20	20	30	55	65	70	75	85
S26	2	81	5	5	15	25	45	55	75	85
S27	1	85	20	25	35	70	75	75	60	75
S28	1	80	30	40	40	70	65	70	55	70
S29	2	54	30	35	35	45	45	50	50	70
S30	1	13	0	5	0	30	40	70	65	70
S31	2	93	20	25	35	50	70	75	75	NR
S32	1	16	10	5	5	10	DNT	10	DNT	15
S33	2	16	5	5	0	-5	DNT	-5	5	10
S34	1	80	15	20	30	60	60	80	75	80
S35	1	67	15	20	5	20	65	65	75	75
S36	2	89	45	40	40	50	55	60	80	105
S37	1	8	5	5	0	5	DNT	5	DNT	0
S38	1	73	15	25	30	60	55	50	55	55
S39	2	85	30	35	50	70	DNT	75	65	75
S40	2	8	20	15	10	5	DNT	5	DNT	15
S41	2	12	10	5	0	5	DNT	0	DNT	10
T1	2	77	50	30	25	35	45	45	60	95
T2	2	10	10	5	-10	-10	DNT	-5	-10	5
T3	2	19	15	15	10	10	DNT	20	DNT	10
T4	2	23	35	40	50	60	DNT	55	DNT	70
T5	2	21	15	20	55	90	110	105	100	85
T6	1	8	20	5	5	5	DNT	5	DNT	0
T7	2	85	60	55	60	95	115	NR	DNT	NR
T8	2	19	65	55	80	105	DNT	95	DNT	95
T9	2	86	45	50	50	55	DNT	50	DNT	55
T10	2	9	10	10	15	15	DNT	10	DNT	0
T11	1	84	20	35	45	60	70	70	DNT	75
T12	2	22	10	5	5	5	DNT	5	DNT	5
T13	1	83	65	65	70	80	DNT	80	NR	NR
T14	2	8	0	0	5	0	DNT	0	DNT	0
T15	2	28	5	5	5	10	5	0	10	25
U1	2	26	5	5	-5	5	DNT	15	DNT	5
U2	2	15	10	10	10	15	10	0	0	5
V1	2	33	20	10	20	15	DNT	20	DNT	20
V2	2	21	10	10	5	5	DNT	5	DNT	0
V3	1	12	10	10	5	0	DNT	0	0	5
V4	2	88	60	35	30	55	65	80	80	90

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V5	2	74	15	30	35	40	60	70	75	85
V6	2	85	25	30	45	50	DNT	60	75	75
V7	1	83	45	40	60	90	90	90	100	NR
V8	2	9	5	5	0	-10	-5	0	0	0
W1	2	42	0	-5	-5	5	DNT	5	DNT	-5
W2	1	88	35	30	40	50	70	75	95	100
W3	1	47	5	10	0	0	0	5	30	25
W4	1	72	20	20	35	30	30	70	DNT	80
W5	1	53	5	5	5	50	55	60	55	45
W6	1	96	25	40	50	60	70	70	75	90
W7	1	80	40	40	45	50	60	70	95	90
W8	1	59	15	15	10	50	75	75	65	65
W9	1	93	40	35	50	65	70	70	DNT	75
W10	1	57	25	20	30	60	70	75	75	65
W11	1	10	-5	-5	-5	-5	DNT	5	DNT	0
W12	1	76	50	60	65	80	90	90	100	95
W13	2	92	55	50	60	90	110	95	NR	NR
Y1	1	18	5	5	0	0	DNT	10	DNT	10
Z1	2	76	10	10	10	10	20	55	70	60
Z2	2	78	15	20	35	65	DNT	80	DNT	75
Z3	2	17	15	10	10	5	15	5	10	5
Z4	1	12	0	0	0	0	DNT	-10	DNT	0
Z5	2	11	5	0	0	5	DNT	0	DNT	-5

250L	500L	1000L	2000 L	3000 L	4000L	6000L	8000L	PTA R	PTA L	HFPTA R
80	65	65	90	85	80	100	NR	61.7	73.3	96.7
5	-5	10	0	DNT	10	30	30	3.3	1.7	6.7
0	0	0	0	DNT	15	DNT	5	5	0	CNC
5	10	5	5	25	25	10	25	5	6.7	23.3
10	5	0	0	DNT	5	DNT	10	0	1.7	CNC
10	5	5	15	DNT	10	10	-5	6.7	8.3	1.7
15	15	15	30	50	50	60	70	20	20	CNC
5	0	5	10	DNT	10	DNT	15	0	5	CNC
50	30	40	50	65	70	DNT	75	33.3	40	CNC
20	30	30	55	DNT	75	DNT	80	38.3	38.3	CNC
10	10	0	5	10	10	0	10	10	5	11.7
15	15	25	75	80	80	70	60	41.7	38.3	71.7
25	15	10	5	10	15	10	25	70	10	83.3
30	30	35	50	60	65	60	65	41.7	38.3	68.3
10	10	10	5	5	5	0	0	8.3	8.3	8.3
10	15	15	10	DNT	15	DNT	15	13.3	13.3	11.7
5	15	10	5	DNT	5	DNT	0	10	10	CNC

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40	45	60	55	75	100	NR	NR	48.3	53.3	CNC
10	0	5	0	DNT	0	DNT	0	5	1.7	CNC
15	10	5	0	DNT	5	DNT	0	6.7	5	CNC
30	35	70	85	DNT	105	S	NR	60	63.3	CNC
MHL	MHL	MHL	MHL	MHL	MHL	MHL	MHL	48.3	MHL	66.7
50	60	60	60	55	40	50	60	36.7	60	36.7
20	20	20	55	DNT	65	75	70	56.7	41.7	75
10	10	10	10	10	10	DNT	10	15	10	CNC
5	5	0	5	DNT	10	DNT	10	6.7	3.3	CNC
10	5	5	5	DNT	0	DNT	5	3.3	5	CNC
5	5	5	0	DNT	0	DNT	0	5	3.3	CNC
10	5	5	5	DNT	5	DNT	0	5	5	CNC
30	25	5	30	45	60	60	45	26.7	20	40
5	5	5	10	0	5	25	20	6.7	6.7	15
0	0	0	5	DNT	5	15	15	5	1.7	10
10	5	0	-5	DNT	-10	DNT	10	-1.7	0	CNC
NR	NR	NR	NR	NR	NR	NR	NR	-1.7	CNC	3.3
15	5	-5	0	DNT	0	DNT	0	1.7	0	CNC
15	20	20	5	DNT	5	DNT	5	11.7	15	CNC
10	10	10	15	25	25	20	15	13.3	11.7	11.7
15	10	15	15	DNT	10	DNT	10	11.7	13.3	CNC
5	5	5	10	DNT	15	15	15	6.7	6.7	1.7
10	10	10	10	0	5	0	-5	10	10	3.3
65	55	40	50	50	55	55	95	56.7	48.3	CNC
35	30	50	80	115	115	NR	NR	58.3	53.3	CNC
55	50	55	60	55	60	75	75	56.7	55	60
25	15	15	20	DNT	30	65	75	13.3	16.7	35
0	0	0	5	DNT	-5	DNT	0	3.3	1.7	CNC
15	15	25	15	15	15	DNT	5	8.3	18.3	CNC
15	20	25	25	30	35	35	55	68.3	23.3	73.3
5	5	5	40	55	55	50	30	11.7	16.7	38.3
10	20	50	80	90	85	100	110	50	50	75
50	50	60	55	60	55	75	70	56.7	55	70
5	5	0	0	DNT	-5	DNT	15	-1.7	1.7	CNC
15	15	60	65	100	95	100	NR	111.7	46.7	CNC
65	70	75	80	95	90	95	NR	80	75	CNC
15	20	20	30	40	35	45	35	56.7	23.3	58.3
85	75	70	60	65	65	70	75	65	68.3	68.3
5	10	5	5	DNT	10	DNT	5	5	6.7	CNC
20	5	5	0	DNT	0	0	0	0	3.3	5

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15	10	5	0	10	5	5	DNT	5	5	8.3
0	0	0	5	15	15	10	0	3.3	0	8.3
50	30	60	75	90	90	90	NR	63.3	53.3	76.7
CHL	CHL	CHL	CHL	CHL	CHL	CHL	CHL	10	CHL	CNC
15	10	30	80	100	115	95	95	38.3	40	93.3
5	5	25	65	80	85	80	75	31.7	31.7	73.3
10	20	35	75	65	70	95	95	40	43.3	80
35	45	45	45	65	70	100	NR	36.7	45	CNC
20	20	0	0	DNT	-5	DNT	-5	8.3	6.7	CNC
25	30	40	60	90	105	105	NR	25	43.3	65
10	5	10	20	DNT	30	5	-5	5	11.7	10
10	5	0	0	DNT	0	DNT	10	3.3	1.7	CNC
50	45	45	60	DNT	70	75	85	46.7	50	63.3
0	-5	-10	-5	DNT	10	DNT	15	1.7	-6.7	CNC
10	5	0	-5	DNT	-5	DNT	-10	5	0	CNC
20	35	60	60	DNT	65	DNT	70	35	51.7	CNC
10	0	5	0	DNT	10	DNT	0	0	1.7	CNC
25	15	85	105	DNT	115	NR	NR	71.7	68.3	CNC
25	45	65	105	NR	105	NR	NR	66.7	71.7	CNC
55	55	50	65	DNT	70	DNT	80	56.7	56.7	CNC
20	10	10	10	DNT	25	45	80	18.3	10	40
5	5	5	10	55	75	75	55	6.7	6.7	53.3
5	0	5	20	DNT	20	DNT	5	6.7	8.3	CNC
15	20	10	5	0	25	35	75	0	11.7	20
20	20	35	45	DNT	55	110	95	33.3	33.3	68.3
10	10	5	10	DNT	30	DNT	10	5	8.3	CNC
75	80	80	75	DNT	80	95	NR	CNC	78.3	83.3
10	15	5	30	50	35	30	25	18.3	16.7	41.7
15	30	45	60	60	60	75	70	45	45	66.7
0	10	5	5	15	10	15	10	6.7	6.7	5
20	25	20	20	35	50	DNT	55	15	21.7	CNC
25	30	35	35	55	55	70	80	36.7	33.3	60
10	5	5	5	20	25	DNT	40	8.3	5	CNC
55	65	65	70	75	80	70	65	63.3	66.7	71.7
30	20	20	30	30	40	DNT	55	88.3	23.3	CNC

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15	20	20	40	55	55	65	70	25	26.7	48.3
10	5	5	5	DNT	-5	DNT	-5	3.3	5	CNC
15	15	35	80	115	115	95	95	55	43.3	80
65	60	60	55	60	60	60	55	33.3	58.3	46.7
70	70	65	55	55	45	55	65	58.3	63.3	41.7
5	5	10	5	DNT	0	DNT	0	8.3	6.7	CNC
5	5	0	5	DNT	5	DNT	5	6.7	3.3	CNC
10	5	10	0	DNT	5	10	25	1.7	5	5
5	10	5	5	10	5	DNT	0	3.3	6.7	CNC
10	10	15	10	25	15	25	45	11.7	11.7	20
35	45	50	55	DNT	70	DNT	NR	MHL	50	MHL
20	15	10	0	20	30	45	35	8.3	8.3	40
80	75	80	75	DNT	80	85	95	26.7	76.7	56.7
55	65	70	65	DNT	55	DNT	65	3.3	66.7	CNC
30	5	10	10	DNT	15	DNT	5	CNC	8.3	CNC
CHL	CHL	CHL	CHL	CHL	CHL	CHL	CHL	-1.7	CHL	CNC
10	20	35	60	80	85	100	95	65	38.3	98.3
15	20	20	10	5	10	10	15	8.3	16.7	6.7
45	40	60	65	70	75	85	75	55	55	80
5	5	0	0	DNT	0	DNT	5	0	1.7	CNC
25	15	25	50	70	70	70	90	26.7	30	61.7
15	15	30	45	55	60	60	60	30	30	56.7
25	35	50	45	DNT	60	65	90	48.3	43.3	66.7
5	10	10	0	0	5	DNT	0	6.7	6.7	CNC
-5	5	0	0	DNT	-5	DNT	-10	1.7	1.7	CNC
20	10	10	10	25	10	DNT	15	0	10	CNC
0	0	0	0	DNT	5	-10	25	6.7	0	-5
0	5	0	0	DNT	0	DNT	0	0	1.7	CNC
15	25	40	65	70	80	75	75	45	43.3	65
50	45	60	65	70	75	DNT	75	60	56.7	CNC
65	65	65	60	DNT	55	50	50	58.3	63.3	51.7
20	20	35	40	DNT	55	55	60	53.3	31.7	68.3
10	10	10	15	30	5	55	80	18.3	11.7	53.3
20	20	15	25	55	60	50	60	25	20	53.3
5	5	0	0	0	0	10	0	1.7	1.7	3.3

Appendix B continued

15	10	10	0	DNT	0	DNT	5	6.7	6.7	CNC
5	5	10	5	20	45	40	35	6.7	6.7	26.7
45	45	40	65	75	75	75	75	50	50	75
40	40	40	40	55	45	55	60	65	40	65
40	40	45	50	65	70	100	100	40	45	58.3
5	5	5	10	DNT	15	DNT	35	CHL	6.7	CHL
5	0	-5	0	DNT	-5	DNT	-10	0	-1.7	CNC
40	40	40	70	DNT	70	DNT	60	58.3	50	CNC
30	30	25	60	80	80	75	60	30	38.3	65
50	45	50	55	60	75	75	75	55	50	70
50	60	70	65	70	75	75	80	63.3	65	85
10	10	15	5	5	0	0	5	6.7	10	6.7
5	5	0	0	DNT	0	20	35	3.3	1.7	CNC
5	5	10	0	DNT	10	DNT	5	5	5	CNC
15	25	30	55	60	60	60	65	35	36.7	56.7
30	30	10	20	60	75	DNT	65	15	20	CNC
5	-5	0	20	45	40	DNT	30	8.3	5	30
0	0	0	-5	0	20	DNT	5	1.7	-1.7	CNC
25	20	5	25	DNT	25	DNT	60	15	16.7	CNC
15	10	15	20	DNT	20	DNT	5	13.3	15	CNC
15	10	10	0	DNT	5	20	20	8.3	6.7	8.3
0	0	0	0	10	0	0	10	0	0	0
25	15	5	5	0	5	20	15	10	8.3	3.3
110	110	115	NR	DNT	115	DNT	NR	3.3	CNC	CNC
0	5	10	10	DNT	5	DNT	10	18.3	8.3	CNC
0	0	0	0	0	0	0	5	0	0	3.3
20	15	30	45	80	95	DNT	100	63.3	30	CNC
20	15	30	70	DNT	80	65	55	35	38.3	CNC
15	15	10	10	DNT	10	DNT	-5	13.3	11.7	CNC
10	15	20	40	65	70	80	80	28.3	11.7	60
90	80	65	75	80	90	95	NR	60	71.7	81.7
45	60	65	65	70	75	75	75	56.7	63.3	60
NR	NR	NR	NR	DNT	NR	DNT	NR	80	CNC	CNC
20	20	20	10	DNT	15	20	25	8.3	16.7	1.7
70	70	70	75	80	85	100	NR	70	71.7	78.3

Appendix B continued

70	75	90	NR	NR	NR	DNT	NR	6.7	CNC	CNC
5	5	0	0	DNT	0	-5	5	3.3	1.7	15
20	15	35	35	45	45	70	70	26.7	28.3	55
10	10	10	10	DNT	5	DNT	10	6.7	10	CNC
5	5	0	0	DNT	0	DNT	5	1.7	1.7	CNC
30	30	45	65	75	85	DNT	60	50	46.7	CNC
10	10	10	30	50	50	60	70	10	16.7	45
5	5	5	15	60	55	60	75	50	8.3	81.7
40	20	20	65	DNT	75	DNT	75	41.7	35	CNC
DNT	10	0	0	DNT	5	DNT	10	1.7	3.3	CNC
15	0	-5	5	DNT	10	DNT	-5	1.7	0	CNC
10	10	0	0	DNT	5	DNT	10	3.3	3.3	CNC
20	5	0	0	0	0	25	35	0	1.7	5
5	5	10	45	45	50	25	5	10	20	35
10	5	10	10	40	40	DNT	40	5	8.3	CNC
MHL	MHL	MHL	MHL	MHL	MHL	MHL	MHL	8.3	MHL	6.7
55	55	55	60	75	85	90	95	55	56.7	78.3
45	50	60	65	70	85	85	90	58.3	58.3	78.3
5	0	40	40	DNT	65	DNT	85	76.7	26.7	75
20	15	10	15	DNT	20	DNT	5	13.3	13.3	CNC
10	10	10	10	DNT	10	DNT	10	5	10	CNC
45	45	50	70	85	75	75	60	15	55	23.3
65	60	60	50	45	40	50	65	65	56.7	51.7
0	0	10	30	65	65	50	65	16.7	13.3	25
15	5	0	30	65	55	75	70	-3.3	11.7	25
5	5	5	-10	DNT	-10	DNT	5	0	0	CNC
40	70	75	70	85	85	85	95	31.7	71.7	73.3
60	60	60	55	DNT	60	DNT	80	53.3	58.3	CNC
65	65	60	60	60	65	65	70	61.7	61.7	61.7
55	60	75	80	85	100	NR	NR	65	68.3	86.7
5	0	5	10	25	60	DNT	60	5	5	CNC
50	55	60	65	80	80	85	85	58.3	60	80
25	45	45	75	80	100	DNT	NR	51.7	55	CNC

Appendix B continued

20	25	40	50	50	50	DNT	55	65	41.7	CNC
10	5	5	0	0	5	5	0	3.3	3.3	6.7
5	0	0	0	0	-5	5	10	-3.3	0	0
5	0	5	5	5	5	5	5	-1.7	3.3	-3.3
0	0	0	0	DNT	-10	DNT	-10	-3.3	0	CNC
10	5	0	0	DNT	0	DNT	10	3.3	1.7	CNC
5	5	5	5	DNT	0	DNT	5	6.7	5	CNC
20	25	40	55	80	90	95	90	38.3	40	75
15	10	0	5	0	0	15	5	3.3	5	CNC
45	35	25	40	60	60	70	70	18.3	33.3	51.7
0	5	5	-10	-5	-10	-10	-10	1.7	0	-8.3
50	60	65	65	70	75	80	NR	61.7	63.3	65
10	5	0	0	DNT	-5	DNT	10	3.3	1.7	CNC
25	30	50	55	DNT	55	DNT	55	38.3	45	CNC
30	25	30	60	75	95	110	105	28.3	38.3	73.3
10	10	0	5	15	35	45	45	8.3	5	20
60	60	60	75	90	85	70	90	66.7	65	76.7
15	5	10	10	DNT	0	DNT	0	6.7	8.3	CNC
30	30	35	65	90	95	100	NR	43.3	40	CNC
15	15	15	15	DNT	25	DNT	25	23.3	15	CNC
70	65	70	65	DNT	80	NR	NR	61.7	66.7	81.7
40	50	55	55	60	65	65	65	40	53.3	45
45	45	75	110	NR	NR	NR	NR	88.3	76.7	CNC
50	45	40	60	60	65	70	70	50	48.3	66.7
15	15	10	10	DNT	5	DNT	5	10	11.7	CNC
55	60	65	65	65	60	60	50	70	63.3	70
5	0	0	0	DNT	-5	DNT	10	0	0	CNC
10	5	10	15	70	80	85	75	18.3	10	66.7
MHL	MHL	MHL	MHL	MHL	MHL	MHL	MHL	11.7	MHL	CNC
15	20	15	20	45	50	55	45	15	18.3	40
15	15	35	35	50	50	55	65	35	28.3	58.3
10	10	20	0	DNT	-5	DNT	10	10	8.3	CNC
0	5	5	5	DNT	0	DNT	10	6.7	5	CNC

Appendix B continued

10	10	15	50	65	65	DNT	75	11.7	26.7	CNC
-5	-5	-5	0	DNT	5	DNT	-5	1.7	-3.3	CNC
5	5	5	15	DNT	10	25	35	3.3	8.3	23.3
35	40	5	25	45	65	60	85	16.7	23.3	51.7
20	20	15	50	85	75	65	60	16.7	28.3	55
10	5	-5	0	DNT	10	DNT	10	1.7	0	CNC
50	55	45	50	DNT	45	70	100	53.3	50	65
10	10	5	10	10	10	5	5	6.7	8.3	1.7
30	35	40	80	95	100	110	NR	55	51.7	CNC
60	45	25	45	55	65	65	75	25	38.3	65
25	30	30	75	DNT	75	DNT	85	46.7	45	CNC
10	10	0	5	DNT	10	DNT	5	6.7	5	CNC
10	10	25	80	100	100	DNT	NR	35	38.3	88.3
25	25	30	75	DNT	80	DNT	NR	53.3	43.3	CNC
MHL	MHL	MHL	MHL	MHL	MHL	MHL	MHL	43.3	MHL	70
15	5	5	10	20	20	40	45	26.7	6.7	28.3
15	10	0	5	DNT	10	DNT	-5	6.7	5	CNC
45	55	60	80	DNT	85	DNT	75	58.3	65	CNC
10	10	35	75	80	95	95	NR	36.7	40	73.3
35	30	50	65	70	75	DNT	70	53.3	48.3	CNC
30	25	30	50	80	85	DNT	NR	38.3	35	CNC
0	15	25	20	50	45	35	45	CNC	20	CNC
10	5	5	5	0	5	10	5	8.3	5	6.7
5	-5	-5	0	DNT	-5	DNT	0	3.3	-3.3	CNC
10	10	5	5	DNT	-5	0	5	5	6.7	1.7
5	10	10	5	50	50	35	15	5	8.3	28.3
15	10	10	20	DNT	20	DNT	30	CNT	13.3	CNC
MHL	MHL	MHL	MHL	MHL	MHL	MHL	MHL	30	MHL	56.7
20	10	10	5	25	45	15	5	13.3	8.3	20
20	15	0	0	DNT	5	DNT	0	1.7	5	CNC
5	10	10	20	60	70	65	50	16.7	15	41.7
60	75	80	85	DNT	80	DNT	90	80	80	CNC
5	5	10	35	40	45	55	60	11.7	16.7	40

Appendix B continued

5	10	5	10	DNT	5	DNT	-10	0	8.3	CNC
25	10	10	65	75	95	DNT	90	33.3	28.3	CNC
25	20	30	35	DNT	45	DNT	60	40	28.3	CNC
5	10	10	20	DNT	25	DNT	35	6.7	13.3	CNC
CHL	CHL	CHL	CHL	CHL	CHL	CHL	CHL	3.3	CHL	CNC
5	10	5	10	45	15	35	90	6.7	8.3	3.3
0	5	5	-10	DNT	0	DNT	5	1.7	0	CNC
10	5	0	5	5	5	DNT	0	3.3	3.3	CNC
50	40	40	50	60	60	65	75	58.3	43.3	66.7
30	40	55	65	90	105	100	NR	51.7	53.3	83.3
5	5	-10	0	DNT	-5	DNT	10	0	-1.7	CNC
15	15	10	15	50	60	DNT	70	6.7	13.3	CNC
5	5	0	0	DNT	0	DNT	0	1.7	1.7	CNC
-10	-5	0	-10	DNT	0	DNT	0	-3.3	-5	CNC
5	5	10	5	45	50	40	25	3.3	6.7	20
10	10	15	10	15	10	15	5	5	11.7	5
5	5	5	5	0	0	-5	5	10	5	5
55	50	55	70	DNT	80	DNT	75	61.7	58.3	CNC
0	-5	0	0	5	0	-5	-10	3.3	-1.7	-1.7
45	40	50	70	105	95	DNT	105	71.7	53.3	CNC
5	5	15	20	DNT	20	DNT	20	10	13.3	CNC
20	20	15	50	45	60	85	80	20	28.3	61.7
0	5	5	-10	DNT	-5	DNT	-10	5	0	CNC
10	10	10	10	15	15	10	20	6.7	10	18.3
60	65	70	75	DNT	85	DNT	NR	90	70	CNC
60	60	55	65	65	70	80	80	53.3	60	63.3
CHL	CHL	CHL	CHL	CHL	CHL	CHL	CHL	60	CHL	CNC
20	15	10	10	DNT	5	DNT	20	10	11.7	CNC
10	5	-5	0	DNT	-10	DNT	-10	3.3	0	CNC
25	15	15	0	DNT	-5	DNT	0	8.3	10	CNC
15	15	25	50	S	65	80	90	35	30	58.3
15	10	10	30	65	65	75	80	18.3	16.7	55

Appendix B continued

25	25	15	15	DNT	10	10	10	71.7	18.3	53.3
10	10	10	5	5	0	0	-10	8.3	8.3	1.7
5	5	5	5	DNT	5	DNT	0	6.7	5	CNC
20	20	55	60	DNT	75	DNT	85	55	45	CNC
5	5	5	5	25	40	60	30	6.7	5	33.3
5	0	0	5	DNT	10	DNT	35	-1.7	1.7	CNC
30	35	60	75	70	80	80	90	68.3	56.7	CNC
20	30	35	55	55	55	55	45	46.7	40	70
15	10	10	20	DNT	5	DNT	10	10	13.3	CNC
20	10	15	15	DNT	20	DNT	15	15	13.3	CNC
20	10	10	0	DNT	0	10	10	3.3	6.7	CNC
5	10	10	5	DNT	0	DNT	0	5	8.3	CNC
0	0	-5	0	DNT	-10	DNT	5	1.7	-1.7	CNC
0	0	10	0	DNT	0	DNT	15	1.7	1.7	5
5	0	5	5	0	5	20	20	3.3	3.3	5
10	5	5	0	DNT	-10	DNT	-10	0	3.3	CNC
5	0	0	0	0	15	0	-5	3.3	0	3.3
5	10	10	15	20	30	25	25	13.3	11.7	25
20	25	25	25	25	20	25	40	78.3	25	73.3
5	5	5	0	DNT	5	DNT	5	16.7	3.3	CNC
-5	-10	0	15	30	30	15	30	0	1.7	20
20	20	10	10	10	20	40	35	1.7	13.3	0
20	20	15	15	15	45	45	50	8.3	16.7	23.3
10	15	10	5	5	5	0	-5	13.3	10	6.7
15	15	20	25	DNT	35	40	55	28.3	18.3	38.3
25	15	25	40	50	65	DNT	80	21.7	26.7	48.3
10	10	15	40	DNT	50	50	35	21.7	21.7	41.7
5	5	5	0	0	5	25	35	1.7	3.3	11.7
30	15	20	25	45	60	85	90	41.7	20	60
20	15	0	0	5	20	DNT	15	5	5	CNC
0	0	-5	-5	DNT	-5	DNT	o	0	-3.3	CNC
10	10	0	5	DNT	5	DNT	10	10	5	CNC
25	30	50	55	DNT	70	DNT	90	28.3	45	CNC
20	30	40	75	80	75	70	60	30	48.3	65

Appendix B continued

40	50	40	20	55	65	DNT	75	31.7	36.7	CNC
35	55	60	50	60	65	75	75	56.7	55	65
5	10	5	5	DNT	5	DNT	10	6.7	6.7	CNC
30	30	35	55	60	70	75	90	35	40	66.7
5	5	10	30	55	65	85	85	15	15	51.7
30	35	55	70	80	90	85	NR	43.3	53.3	68.3
25	35	40	70	75	80	80	70	50	48.3	66.7
65	60	60	55	65	65	70	75	38.3	58.3	48.3
0	0	5	20	60	65	45	50	11.7	8.3	55
20	30	50	50	60	70	70	90	36.7	43.3	66.7
15	15	5	10	DNT	10	DNT	5	6.7	10	CNC
0	-5	0	5	DNT	0	5	10	0	0	-1.7
25	20	35	45	DNT	55	65	75	36.7	33.3	71.7
15	20	5	15	55	70	70	80	15	13.3	53.3
45	50	45	65	60	70	85	NR	43.3	53.3	63.3
5	10	5	0	DNT	10	DNT	0	3.3	5	CNC
25	20	30	55	55	60	60	70	38.3	35	55
20	35	50	70	DNT	70	90	95	51.7	51.7	70
20	10	10	10	DNT	10	DNT	15	10	10	CNC
15	10	5	0	DNT	5	DNT	10	3.3	5	CNC
95	85	80	80	70	80	NR	NR	30	81.7	46.7
5	0	-5	5	DNT	5	-10	5	-5	0	-8.3
10	10	10	15	DNT	25	DNT	10	8.3	11.7	CNC
MHL	MHL	MHL	MHL	MHL	MHL	MHL	MHL	50	MHL	CNC
15	20	60	110	100	105	95	80	55	63.3	98.3
15	10	5	-5	DNT	0	DNT	-10	5	3.3	CNC
60	50	55	75	105	110	DNT	NR	70	60	CNC
65	65	85	85	DNT	95	DNT	95	80	78.3	CNC
40	45	45	45	DNT	55	DNT	60	51.7	45	CNC
5	15	5	5	DNT	5	DNT	0	13.3	8.3	CNC
85	85	85	85	75	75	DNT	80	46.7	85	CNC
10	10	5	5	DNT	0	DNT	5	5	6.7	CNC
65	60	65	75	DNT	75	90	NR	71.7	66.7	CNC

Appendix B continued

5	5	5	0	DNT	0	DNT	0	1.7	3.3	CNC
0	0	5	45	40	35	30	0	6.7	16.7	6.7
0	5	-5	0	DNT	10	DNT	0	1.7	0	CNC
5	10	15	5	10	0	-5	0	11.7	10	5
10	10	5	10	DNT	10	DNT	5	15	8.3	CNC
10	0	0	-5	DNT	0	DNT	0	6.7	-1.7	CNC
5	10	10	5	DNT	0	0	0	5	8.3	0
60	40	35	55	75	80	95	NR	40	43.3	71.7
20	20	35	45	55	60	60	75	35	33.3	61.7
10	15	25	45	DNT	50	65	80	41.7	28.3	61.7
25	20	35	40	50	80	DNT	90	63.3	31.7	93.3
0	-5	5	-5	-5	-5	0	0	-1.7	-1.7	-3.3
5	0	-10	0	DNT	-10	DNT	10	-1.7	-3.3	CNC
45	25	35	50	75	75	90	100	40	36.7	73.3
15	10	0	5	0	5	5	10	3.3	5	11.7
25	25	20	25	30	55	80	95	28.3	23.3	CNC
10	5	5	55	65	60	80	65	20	21.7	55
25	35	45	65	80	80	85	85	50	48.3	68.3
20	30	30	60	70	65	65	65	45	40	71.7
15	15	10	70	80	85	75	70	25	31.7	63.3
35	45	60	65	70	70	DNT	75	50	56.7	CNC
20	15	30	55	75	80	80	70	36.7	33.3	70
5	5	5	-5	DNT	-5	DNT	-10	-5	1.7	CNC
45	55	65	80	100	110	NR	NR	58.3	66.7	90
85	80	70	85	85	90	90	NR	66.7	78.3	CNC
5	5	-5	5	DNT	5	DNT	5	1.7	1.7	CNC
10	5	10	5	20	35	55	40	10	6.7	45
60	60	60	55	DNT	70	DNT	85	40	58.3	CNC
5	5	5	0	0	5	5	5	8.3	3.3	6.7
0	5	0	5	DNT	-5	DNT	0	-1.7	3.3	CNC
5	5	5	5	DNT	5	DNT	5	1.7	5	CNC
HFPTAL	**SRTR**	**SRTL**	**WRSR**	**WRSL**	**PLR**	**PLL**	**Words Presented**	**Voice**	**Word List**	**OAE[a]**
90	60	60	29	4	90	90	50	1	2	5

Appendix B continued

13.3	0	5	92	100	40	45	25	1	2	2
CNC	10	5	96	96	50	45	25	1	1	2
13.3	10	10	88	96	45	45	25	2	2	4
CNC	0	0	96	88	40	40	25	2	1	5
11.7	0	5	100	92	35	40	25	1	2	2
46.7	25	25	72	92	75	75	25	1	1	5
CNC	5	5	100	92	45	45	25	1	1	2
CNC	35	40	64	60	65	65	25	2	2	5
CNC	30	30	52	52	70	70	25	1	2	5
5	10	10	90	90	40	40	10	1	1	4
75	25	20	56	52	85	85	25	None	None	5
10	80	15	8	100	100	50	25	1	1	2
58.3	25	35	48	84	70	70	25	None	None	2
3.3	DNT	DNT	90	100	55	55	10	2	1	1
CNC	15	15	88	92	55	55	25	2	2	5
CNC	10	15	100	90	55	55	10	2	1	5
CNC	55	60	28	56	90	90	50	1	1	1
CNC	-5	5	96	96	20	40	25	1	2	5
CNC	10	10	88	96	40	40	25	2	2	4
CNC	25	25	12	12	75	75	25	1	2	5
MHL	50	MHL	44	MHL	85	MHL	25	1	1	5
50	40	40	38	X	75	X	50(R) & 10(L)	1	1	5
66.7	50	65	10	24	100	100	50	1	1	5
CNC	10	5	100	84	45	40	25	1	1	2
CNC	5	0	100	92	45	40	25	1	1	5
CNC	0	0	100	92	40	40	25	None	1	1
CNC	0	0	90	90	35	35	10	1	1	1
CNC	5	5	90	100	40	40	10	None	None	2
50	10	10	76	84	50	50	25	None	None	5
13.3	10	10	80	84	45	45	25	2	2	5
8.3	10	10	92	96	40	40	25	2	2	2
CNC	-5	0	92	92	35	40	25	None	None	5
CNC	0	NR	92	CNT	40	NA	25	None	None	5
CNC	0	0	96	92	40	40	25	1	1	2
CNC	5	10	88	100	45	50	25	1	1	5
20	15	15	96	92	50	50	25	2	2	1
CNC	5	15	88	96	45	55	25	1	None	2
15	5	10	100	92	50	50	25	1	2	5
5	DNT	DNT	100	90	55	55	10	None	1	2
53.3	55	35	0	56	100	75	25	1	2	5

Appendix B continued

CNC	40	45	56	8	90	90	25	2	1	5
65	60	55	0	4	90	90	25	1	3	5
38.3	10	15	88	96	50	55	25	1	2	3
CNC	10	10	90	100	45	45	10	1	1	5
CNC	10	15	92	96	50	50	25	2	2	2
31.7	CNT	25	10	92	90	65	10	2	1	5
48.3	5	15	84	96	45	55	25	2	1	5
88.3	30	25	28	24	80	75	25	1	1	5
61.7	55	65	52	40	85	85	25	1	1	5
CNC	0	0	96	96	55	55	25	2	2	2
86.7	DNT	25	DNT	40	DNT	85	25	2	1	5
88.3	80	75	40	12	100	95	25	2	1	5
36.7	60	15	26	100	95	55	50	1	1	5
65	65	65	30	0	90	90	10	1	1	5
CNC	0	5	92	100	40	45	25	1	1	5
0	5	5	96	100	45	45	25	1	1	5
3.3	5	5	90	90	45	45	10	2	1	4
10	5	5	88	88	45	45	25	2	2	2
85	60	40	60	24	85	85	25	1	1	5
CHL	5	CHL	90	CHL	45	CHL	10	1	1	5
96.7	15	20	36	24	55	60	25	1	1	5
76.7	20	20	40	52	75	75	25	1	1	5
80	30	30	48	52	85	85	25	1	1	5
48.3	40	50	68	40	80	90	25	None	None	5
CNC	0	5	90	96	50	55	50	1	2	5
90	20	35	76	52	60	75	25	1	1	5
CNC	10	10	90	100	60	60	10	None	None	2
CNC	5	0	100	96	45	40	25	2	1	5
68.3	50	75	30	26	80	90	50	1	1	5
CNC	10	15	96	96	50	55	25	1	2	5
CNC	10	5	88	100	50	50	25	2	2	1
CNC	35	50	48	36	75	90	25	None	2	5
CNC	10	15	84	92	45	45	25	1	2	2
CNC	35	35	36	26	80	80	50	1	3	5
CNC	50	60	10	0	90	90	50	2	1	5
CNC	60	60	52	32	100	100	25	2	2	5
26.7	20	15	76	80	60	55	25	1	2	5
53.3	5	10	76	88	50	45	25	None	None	5
CNC	20	10	92	100	45	35	25	1	2	1
21.7	0	5	96	96	40	45	25	1	2	5

Appendix B continued

70	35	35	68	60	80	80	25	1	1	5
CNC	15	15	92	92	45	45	25	1	2	5
83.3	DNT	DNT	0	0	85	85	50	1	None	5
31.7	15	15	92	84	65	65	25	1	1	2
65	50	45	X	40	X	80	10(R) & 50(L)	2	1	2
10	5	5	100	92	45	45	25	1	1	2
CNC	15	25	88	96	50	60	25	2	2	4
53.3	30	35	40	60	90	85	25	1	1	5
CNC	10	5	92	100	50	45	25	2	1	2
73.3	95	70	40	24	90	85	25	None	None	5
CNC	DNT	DNT	0	80	95	60	10	1	3	1
53.3	15	25	84	76	55	65	25	1	1	5
CNC	0	5	88	84	40	45	25	2	2	5
96.7	30	25	56	28	85	85	25	1	1	5
58.3	20	50	76	16	65	90	25	1	1	5
51.7	60	65	36	36	85	80	25	2	1	5
CNC	5	5	88	100	45	45	25	1	None	5
CNC	5	5	96	88	45	45	25	1	3	2
5	5	5	92	88	35	35	25	1	None	2
CNC	5	0	90	90	40	35	10	1	1	2
16.7	10	15	90	100	45	50	10	1	1	5
CNC	MHL	55	MHL	46	MHL	85	25	1	2	5
25	10	15	92	92	75	75	25	None	None	5
80	15	70	88	16	55	90	50	1	2	5
CNC	5	65	100	16	40	70	25	1	1	2
CNC	DNT	10	DNT	92	DNT	45	25	2	2	5
CHL	-5	CHL	96	CHL	30	CHL	25	1	1	5
81.7	55	20	30	84	85	80	50	1	1	5
10	5	20	92	100	45	60	25	2	1	5
75	55	55	28	28	90	90	25	1	1	5
CNC	-5	-5	96	92	55	55	25	2	2	2
63.3	20	25	68	68	80	80	25	1	1	5
55	15	25	88	72	75	85	25	1	1	5
56.7	55	40	44	36	85	80	25	1	1	5
CNC	DNT	DNT	100	90	50	50	10	2	1	2

Appendix B continued

CNC	10	10	92	100	45	45	25	1	2	5
CNC	5	15	92	100	45	55	25	1	1	1
-1.7	5	5	96	96	40	40	25	1	2	5
CNC	0	0	96	96	40	40	25	None	None	5
73.3	30	20	52	44	80	70	25	1	1	5
CNC	55	45	28	20	80	75	25	1	1	5
55	65	70	32	48	90	90	25	1	1	5
50	55	30	60	70	95	70	50	None	None	4
40	15	10	84	96	55	55	25	1	1	3
45	20	20	100	84	60	60	25	1	1	5
3.3	5	0	100	96	45	40	25	1	1	2
CNC	5	5	92	96	65	55	25	2	2	1
30	5	15	96	92	50	50	25	1	1	5
71.7	45	45	58	26	90	90	50	2	1	5
46.7	65	35	0	68	70	60	25	2	1	5
73.3	40	30	52	40	80	95	25	1	1	5
CNC	CHL	5	CHL	92	CHL	35	25	None	None	5
CNC	5	5	96	100	45	45	25	1	1	5
CNC	65	50	48	44	90	90	25	1	1	5
71.7	30	25	56	68	90	90	25	1	1	5
68.3	60	35	8	32	80	80	25	1	1	5
71.7	75	70	12	20	85	85	25	2	1	4
1.7	DNT	DNT	90	100	50	50	10	None	1	2
6.7	10	5	92	92	40	40	25	2	2	2
CNC	5	0	96	92	40	40	25	1	1	5
58.3	30	25	60	48	80	80	25	1	None	5
CNC	20	15	84	76	80	80	25	2	2	5
CNC	10	10	92	96	50	50	25	1	2	2
CNC	5	5	92	96	45	45	25	2	1	5
CNC	20	10	60	60	50	50	25	1	2	5
CNC	25	30	80	100	55	60	25	1	2	5
8.3	10	10	88	96	35	35	25	2	2	5
0	0	0	100	92	40	40	25	1	1	5
10	5	10	100	92	35	40	25	2	1	2
CNC	5	NR	88	DNT	40	DNT	25	1	1	5

Appendix B continued

CNC	15	5	100	92	55	45	25	1	None	5
0	10	5	92	100	50	50	25	2	2	5
CNC	85	30	44	70	95	70	50	2	1	5
71.7	25	25	68	56	75	80	25	1	2	5
CNC	15	10	100	90	50	45	10	1	1	5
63.3	15	15	68	84	55	55	25	None	None	5
86.7	50	75	32	12	90	95	25	1	1	5
71.7	50	60	40	8	85	90	25	1	1	5
CNC	75	NR	8	DNT	100	DNT	25	None	None	5
15	10	20	90	90	50	60	10	2	1	5
86.7	65	75	42	22	95	95	50	1	1	5
CNC	5	95	80	DNT	45	DNT	25	1	1	5
-1.7	5	5	96	92	50	50	25	2	2	2
50	15	20	60	76	70	70	25	2	1	5
CNC	5	0	92	90	40	35	25	1	None	2
CNC	10	10	96	92	50	50	25	1	1	4
CNC	40	40	44	48	65	70	25	1	1	5
46.7	10	5	100	84	45	40	25	1	1	4
43.3	50	15	24	76	85	50	25	1	2	5
CNC	20	30	56	64	85	85	25	1	2	5
CNC	0	5	92	100	40	45	25	1	1	2
CNC	0	0	100	96	40	40	25	1	1	5
CNC	10	10	92	100	45	45	25	1	2	2
8.3	5	10	96	100	50	50	25	2	2	1
40	15	20	88	100	55	65	25	1	1	2
CNC	15	15	92	100	50	50	25	2	2	2
MHL	5	MHL	92	MHL	45	MHL	25	2	1	5
78.3	55	57	36	36	85	85	25	1	2	5
75	65	65	60	32	95	95	50	2	1	5
CNC	70	10	4	80	90	70	25	1	1	5
CNC	10	10	88	88	50	50	25	2	2	1
CNC	10	15	40	48	50	55	25	1	1	5
73.3	10	45	96	22	50	85	25	1	1	5
50	50	60	46	16	95	95	25	1	1	5

Appendix B continued

48.3	15	15	84	88	55	80	25	1	2	5
53.3	5	5	90	66	45	45	50	1	1	5
CNC	0	0	92	100	40	40	25	1	1	5
80	30	70	72	16	70	85	25	1	1	5
CNC	45	50	56	16	85	90	25	2	1	5
63.3	65	65	56	32	85	85	25	1	2	5
CNC	60	65	25	8	80	80	25	1	None	5
CNC	5	5	88	100	70	70	25	2	1	5
76.7	DNT	DNT	32	36	90	95	25	2	1	5
CNC	55	40	32	64	80	80	25	None	1	5
CNC	45	30	0	88	85	70	25	2	1	5
3.3	DNT	DNT	100	90	50	50	10	None	1	2
0	DNT	DNT	90	100	50	50	10	None	1	1
5	DNT	DNT	100	90	50	50	10	None	1	1
CNC	5	0	96	96	45	45	25	1	2	2
CNC	10	5	88	88	45	45	25	2	2	4
CNC	10	0	80	100	40	40	10	1	None	1
80	20	25	52	52	80	80	25	1	1	5
CNC	5	5	100	92	45	45	25	1	1	2
56.7	10	25	76	72	75	75	25	1	1	5
-10	0	0	92	100	40	40	25	1	2	2
73.3	55	70	32	12	95	100	25	2	1	5
CNC	0	0	96	92	40	40	25	1	1	5
CNC	30	40	50	54	70	80	25	1	1	5
88.3	25	25	48	36	65	65	25	2	1	2
28.3	-5	0	92	88	35	40	25	2	1	4
76.7	60	60	28	20	85	85	25	1	1	5
CNC	0	10	90	100	40	45	10	1	3	4
86.7	40	45	100	44	80	80	25	1	1	5
CNC	15	10	100	88	50	45	25	1	None	2
CNC	70	60	16	52	70	85	25	1	1	5
61.7	30	50	36	40	70	80	25	1	1	5
CNC	85	60	32	4	115	105	25	1	1	5
65	50	50	52	48	90	90	25	2	1	5

Appendix B continued

CNC	5	10	88	88	50	50	25	2	2	2
58.3	65	45	0	68	85	85	25	2	1	5
CNC	0	5	96	100	40	45	25	1	None	2
60	15	10	72	90	50	45	50	None	1	2
MHL	15	MHL	88	MHL	55	MHL	25	1	3	5
41.7	10	15	88	92	65	65	25	2	1	5
46.7	25	20	44	68	65	65	25	1	1	5
CNC	5	5	90	90	45	45	10	2	1	5
CNC	10	5	92	92	45	40	25	2	2	4
CNC	10	15	96	72	50	55	25	None	None	5
CNC	0	10	96	92	35	35	25	2	1	5
16.7	10	10	96	92	45	45	25	2	2	5
50	10	15	65	72	50	55	25	1	None	5
63.3	10	10	92	60	45	60	25	1	1	5
CNC	5	0	92	100	50	50	25	1	2	5
55	50	50	40	60	65	65	25	None	None	5
8.3	DNT	DNT	90	90	50	50	10	None	1	2
96.7	40	30	16	40	85	85	25	1	None	5
58.3	30	40	68	44	65	75	25	1	1	5
CNC	35	40	64	20	75	80	25	2	1	5
CNC	10	10	100	90	50	50	10	1	None	5
CNC	15	20	74	60	55	60	50	1	1	5
CNC	40	30	44	16	80	70	25	1	1	5
MHL	40	MHL	48	MHL	85	MHL	25	1	1	5
23.3	25	5	68	88	65	45	25	1	1	5
CNC	10	10	92	100	50	50	25	2	1	2
CNC	55	50	68	28	85	80	50	1	1	5
88.3	20	20	40	40	60	60	50	1	1	5
CNC	55	45	64	44	90	90	25	1	1	5
CNC	30	25	44	44	80	80	25	1	1	5
33.3	85	25	16	84	95	65	25	2	1	1
6.7	DNT	DNT	90	90	50	50	10	None	1	5
CNC	5	0	84	96	45	40	25	2	1	5

Appendix B continued

0	5	5	90	100	55	55	10	None	None	5
30	10	10	88	84	45	45	25	2	2	5
CNC	CNT	15	CNT	88	NA	55	25	1	2	3
MH L	30	MHL	72	MHL	65	MHL	25	1	1	4
21.7	15	10	84	90	50	45	25	1	1	2
CNC	0	10	88	96	45	45	25	2	1	2
53.3	15	10	100	84	55	50	25	None	None	4
CNC	75	75	0	0	95	95	25	1	None	5
45	10	10	88	92	50	50	25	2	1	5
CNC	5	10	96	100	40	50	25	None	Non	5
CNC	15	10	50	66	55	50	50	1	1	5
CNC	60	40	68	50	70	90	50	1	2	5
CNC	15	15	92	92	45	45	25	2	2	1
CHL	0	CHL	92	CHL	40	CHL	25	1	1	5
20	5	10	88	100	45	50	25	2	1	5
CNC	5	10	92	96	45	45	25	2	2	1
CNC	10	10	100	92	50	50	25	2	2	5
58.3	50	45	56	52	90	80	25	1	1	5
90	40	40	40	20	85	85	25	1	1	5
CNC	0	5	84	84	35	40	25	2	2	5
CNC	10	20	88	84	45	55	25	1	1	5
CNC	0	5	80	100	40	45	25	None	None	5
CNC	10	5	96	96	50	50	25	1	1	2
31.7	10	5	92	92	50	45	25	1	2	5
11.7	DNT	DNT	100	90	50	50	10	None	1	2
0	DNT	DNT	100	92	50	50	25	None	1	2
CNC	60	70	50	24	90	90	25	1	2	5
-1.7	DNT	DNT	90	100	50	50	10	None	1	2
CNC	80	52	8	52	85	80	25	1	2	5
CNC	10	15	100	84	55	55	25	1	1	5
65	20	20	84	80	60	60	25	None	None	5
CNC	5	5	100	96	45	45	25	2	1	5

Appendix B continued

11.7	5	5	100	88	40	40	25	1	1	5
CNC	90	85	24	24	100	100	25	1	None	5
71.7	50	60	54	36	90	100	50	1	1	5
CHL	CNT	CHL	2	CHL	80	CHL	50	1	1	5
CNC	5	10	100	90	45	50	10	1	None	5
CNC	0	5	100	96	40	45	25	2	1	1
CNC	5	10	92	100	55	55	25	2	2	4
65	25	25	68	60	75	75	25	1	None	5
56.7	15	15	84	84	90	90	25	1	1	5
11.7	50	5	0	100	75	45	10	1	1	5
1.7	DNT	DNT	90	100	55	55	10	None	1	5
CNC	15	0	100	92	50	35	25	1	2	5
CNC	65	45	8	32	80	80	25	2	2	5
35	5	5	100	92	40	40	25	1	2	2
CNC	5	5	96	96	45	45	25	1	2	5
78.3	40	45	24	44	80	85	25	1	1	5
55	45	35	40	56	85	75	25	1	1	5
CNC	15	15	90	100	55	55	10	1	None	4
CNC	20	15	88	76	60	55	25	1	1	5
CNC	5	15	92	92	45	45	25	1	3	4
CNC	-5	-5	92	88	30	30	25	1	3	4
CNC	10	5	100	96	50	45	25	1	2	2
CNC	0	0	84	100	35	35	25	2	2	4
10	10	5	96	92	45	45	25	2	2	2
CNC	0	0	96	100	40	40	25	1	1	5
5	0	0	100	96	40	40	25	1	2	5
23.3	5	5	88	92	45	45	25	1	1	2
16.7	90	28	0	88	100	50	25	2	1	5
CNC	20	0	96	88	55	35	25	1	None	2
20	0	0	96	100	35	35	25	1	2	5
23.3	10	20	96	88	50	60	25	1	2	4
35	15	25	90	100	55	60	10	2	1	4
3.3	DNT	DNT	100	90	50	50	10	None	1	5
33.3	25	15	72	100	60	50	25	1	None	2

Appendix B continued

CNC	10	20	80	68	70	80	25	1	2	5
46.7	25	25	80	72	60	60	25	1	1	5
10	10	10	92	96	45	45	25	1	2	5
56.7	50	30	52	68	80	70	25	1	2	5
CNC	0	5	92	92	40	45	25	1	1	5
CNC	5	0	96	100	55	45	25	1	1	5
CNC	5	5	92	96	45	45	25	1	1	5
CNC	10	30	68	80	50	80	25	1	1	5
73.3	15	20	60	72	80	60	25	1	None	2
CNC	25	25	68	68	65	65	25	1	1	1
63.3	55	50	24	28	85	85	25	1	2	5
CNC	5	5	90	90	45	45	10	2	1	2
66.7	30	35	64	52	90	90	25	1	1	5
60	15	20	84	56	55	60	25	1	1	2
81.7	30	40	40	0	85	85	25	1	1	5
76.7	40	40	72	20	80	80	50	2	1	5
61.7	40	75	92	12	80	95	25	2	1	5
43.3	10	10	72	80	50	50	50	2	1	2
63.3	35	35	52	60	75	85	25	1	1	5
CNC	0	0	100	90	40	40	10	1	1	5
3.3	0	0	100	96	40	40	25	2	1	2
55	30	20	64	76	85	80	25	1	1	5
51.7	20	15	88	100	65	60	25	1	1	5
73.3	45	50	52	8	85	95	25	1	1	5
CNC	5	10	80	80	55	55	25	2	2	5
58.3	35	35	76	64	75	75	25	1	1	5
76.7	50	40	56	24	90	80	25	1	1	5
CNC	10	10	90	100	45	40	25	1	3	2
CNC	0	10	88	96	35	35	25	2	2	2
CNC	35	CNT	72	CNT	75	NA	25	1	2	5
0	-10	-5	96	100	40	40	25	1	1	4
CNC	10	10	92	100	50	50	25	None	None	5
MHL	55	MHL	40	MHL	80	MHL	25	1	1	5
103.3	35	35	40	56	85	90	25	2	None	5
CNC	DNT	DNT	88	96	50	50	25	2	2	5

Appendix B continued

CNC	60	55	20	70	90	95	25	2	1	5
CNC	85	75	0	0	90	90	25	1	1	5
CNC	50	45	32	72	90	85	25	1	1	5
CNC	5	0	88	96	55	55	25	2	2	5
CNC	35	90	84	0	80	95	50	2	1	5
CNC	5	5	100	76	30	30	25	2	1	5
80	70	65	10	0	105	100	25	2	1	5
CNC	0	5	90	70	40	45	10	1	None	2
36.7	5	10	100	84	40	55	25	1	2	5
CNC	5	5	96	96	45	45	25	2	1	5
0	10	10	96	92	50	50	25	2	2	5
CNC	10	5	100	92	50	45	25	1	2	1
CNC	10	0	96	92	40	35	25	1	1	5
1.7	5	10	92	100	45	50	25	1	1	4
76.7	25	35	32	44	85	85	25	1	1	5
55	30	25	60	68	70	65	25	1	1	5
53.3	30	25	64	56	75	70	25	1	1	5
CNC	60	35	0	80	85	70	25	2	1	5
-3.3	DNT	DNT	90	100	50	50	10	None	1	2
CNC	0	0	100	96	40	40	25	1	2	5
71.7	45	40	68	60	80	75	25	2	2	5
5	5	5	88	92	45	45	25	2	1	5
53.3	25	20	72	84	65	60	50	2	1	5
65	15	5	84	84	55	45	25	1	2	2
76.7	50	45	28	28	90	90	25	1	1	5
63.3	50	40	56	60	85	85	25	1	1	5
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CNC	40	50	36	40	80	85	25	1	1	5
71.7	30	30	60	56	80	80	25	1	1	5
CNC	0	0	96	100	40	40	25	2	1	2

Appendix B continued

CNC	65	65	4	12	90	90	25	1	1	5
88.3	70	90	34	14	105	90	50	2	1	5
CNC	0	0	100	96	40	40	25	1	1	5
31.7	DNT	DNT	100	76	40	40	25	None	None	5
CNC	15	55	52	42	55	85	25	1	1	5
3.3	5	10	84	96	50	50	25	2	1	5
CNC	0	0	100	88	40	40	25	2	2	5
CNC	5	5	84	100	45	45	25	2	2	5

SIN[b]	**Lang/ Learn Disorder[b]**	**Dyslexia[b]**	**ADHD[b]**	**OME[b]**	**Noise Exposure[b]**	**Difficulty Understanding[b]**	**DifficultyInNoise[b]**	**Repeat[b]**	**Stress[b]**	**Fam Hx[b]**
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Appendix B continued

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Appendix B continued

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Appendix B continued

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Appendix B continued

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Appendix B continued

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Appendix B continued

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Appendix B continued

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3	1	3	3	2	2	2	2	3	3	2
3	2	3	3	3	2	3	3	3	2	3
2	3	3	3	3	3	3	3	3	3	2
3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	2	2	1	3	3	3	2
3	3	3	3	3	1	3	1	3	3	2
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2	2	2	2	1	3	2	1	3	2	3
1	3	3	1	1	3	2	1	3	1	3
3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	1	3	1	3	3	3	2
3	3	3	3	3	3	3	3	3	3	3
2	3	3	1	1	3	3	3	3	3	3
3	3	3	3	1	3	2	2	3	3	1
3	3	3	3	3	3	3	1	3	3	1
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1	1	3	3	2	3	2	2	3	3	3
2	3	3	3	1	3	2	1	3	2	1
3	3	3	3	3	2	2	2	3	3	2

Appendix B continued

3	2	3	3	3	3	2	2	3	2	2
3	2	3	3	3	3	3	3	3	3	3
3	3	3	3	3	1	2	2	3	3	3
3	2	3	3	3	1	1	3	1	2	2
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1	3	3	1	1	3	1	1	3	3	1
3	2	3	3	3	1	2	2	3	2	2
3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	1	1	3	3	3	2
2	1	1	1	1	3	3	1	1	3	1
3	3	3	3	3	2	1	3	3	3	1
3	2	3	3	3	3	3	3	3	1	2
3	3	3	3	3	3	1	3	3	3	1
3	3	3	3	3	3	1	1	3	3	3
3	2	3	3	3	1	1	1	3	2	2
3	1	3	3	3	3	1	3	3	1	3
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3	3	3	3	3	1	3	1	3	3	2
3	3	3	3	3	3	1	1	3	3	1
2	3	3	3	1	3	1	1	1	3	1
3	3	3	3	3	2	3	3	3	1	2
3	3	3	3	3	3	1	1	3	3	3
3	3	3	3	1	2	3	3	3	3	2
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3	2	3	3	3	1	1	1	3	2	2
3	3	3	3	2	1	3	1	3	3	2
3	3	3	3	3	3	1	3	3	3	3
1	2	2	1	1	3	1	1	3	2	3
3	3	3	3	3	1	1	3	3	3	2
3	3	3	3	2	2	3	3	3	3	3
2	3	3	3	2	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3

Appendix B continued

3	3	3	3	3	2	3	3	3	3	3
2	1	3	3	2	3	3	1	3	3	2
3	3	3	3	3	2	2	2	3	3	2
3	3	3	3	1	3	3	1	3	3	1
3	3	3	3	3	3	3	1	3	3	1
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3	3	3	3	3	3	1	3	3	3	1
3	3	3	3	3	3	3	3	3	3	1
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1	3	3	1	2	3	1	3	3	3	3
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3	3	3	3	3	1	3	3	3	3	2
2	1	3	1	1	3	2	1	1	2	3
3	3	3	3	3	2	2	2	3	3	3
3	3	3	3	2	1	3	3	3	3	2
2	2	1	1	1	3	2	1	3	1	2
1	3	1	3	1	3	3	1	3	3	1
3	3	3	3	3	3	2	2	3	1	3
1	2	2	2	1	3	3	1	3	3	3
3	3	3	3	3	1	3	3	3	3	2
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3	3	3	3	2	3	3	3	3	3	3
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2	1	3	2	2	3	3	2	2	3	3
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3	3	3	3	3	3	3	3	3	3	2
3	3	3	3	2	1	3	3	3	3	2
3	3	3	3	2	1	3	3	3	3	2
3	3	3	3	3	2	1	1	3	3	2
2	3	3	2	2	2	2	1	3	2	2
3	3	3	3	2	1	3	3	3	3	2
3	3	3	3	3	3	1	3	3	3	3
3	3	3	3	3	3	2	2	2	3	3
3	3	3	3	3	3	1	3	3	3	3

Appendix B continued

3	2	3	3	2	1	1	3	3	2	2
3	3	3	3	1	3	3	3	3	3	2
1	2	2	2	2	3	2	3	3	2	2
2	2	2	2	2	3	2	3	3	2	3

Note. Original data sheet. CNC = could not calculate.
Note[a]. OAE coding as follows: 1 = yes DPOAE notch; 2 = no DPOAE notch; 3 = yes TEOAE notch; 4 = no TEOAE notch; 5 = not reported.
Note[b]. All other coded variables: 1 = yes; 2 = no; 3 = not reported.

Appendix C

		Age	T250R	T500R	T1000R	T2000R	T3000R	T4000R	T6000R	T8000R	T250L	T500L	T1000L	T2000L	T3000L
Age	***Pearson Correlation***	1	.497**	.532**	.563**	.602**	.524**	.594**	.596**	.714**	.544**	.568**	.653**	.609**	.452**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	231	227	227	229	228	161	226	152	197	225	225	225	224	160
T250R	***Pearson Correlation***	.497**	1	.926**	.838**	.647**	.560**	.541**	.499**	.549**	.659**	.638**	.613**	.476**	.285**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	227	227	227	227	227	161	225	151	197	221	221	221	220	160
T500R	***Pearson Correlation***	.532**	.926**	1	.923**	.713**	.589**	.575**	.519**	.562**	.621**	.662**	.679**	.546**	.338**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	227	227	227	227	227	161	225	151	197	221	221	221	220	160
T1000R	***Pearson Correlation***	.563**	.838**	.923**	1	.810**	.660**	.657**	.588**	.633**	.548**	.585**	.692**	.597**	.416**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	229	227	227	229	228	161	226	152	197	223	223	223	222	160
T2000R	***Pearson Correlation***	.602**	.647**	.713**	.810**	1	.864**	.817**	.730**	.745**	.508**	.540**	.696**	.833**	.650**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	228	227	227	228	228	161	226	152	197	222	222	222	221	160

Appendix C continued

T3000R	***Pearson Correlation***	.524**	.560**	.589**	.660**	.864**	1	.863**	.827**	.754**	.397**	.422**	.566**	.723**	.733**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000
	N	161	161	161	161	161	161	160	127	137	159	159	159	158	153
T4000R	***Pearson Correlation***	.594**	.541**	.575**	.657**	.817**	.863**	1	.877**	.840**	.402**	.441**	.581**	.726**	.652**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000
	N	226	225	225	226	226	160	226	152	196	220	220	220	220	159
T6000R	***Pearson Correlation***	.596**	.499**	.519**	.588**	.730**	.827**	.877**	1	.887**	.358**	.379**	.502**	.626**	.644**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000
	N	152	151	151	152	152	127	152	152	140	149	149	149	149	126
T8000R	***Pearson Correlation***	.714**	.549**	.562**	.633**	.745**	.754**	.840**	.887**	1	.499**	.515**	.608**	.696**	.608**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000
	N	197	197	197	197	197	137	196	140	197	192	192	192	191	137
T250L	***Pearson Correlation***	.544**	.659**	.621**	.548**	.508**	.397**	.402**	.358**	.499**	1	.934**	.807**	.609**	.402**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000
	N	225	221	221	223	222	159	220	149	192	225	225	225	224	160
T500L	***Pearson Correlation***	.568**	.638**	.662**	.585**	.540**	.422**	.441**	.379**	.515**	.934**	1	.894**	.675**	.442**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000
	N	225	221	221	223	222	159	220	149	192	225	225	225	224	160

Appendix C continued

T1000L	***Pearson Correlation***	.653**	.613**	.679**	.692**	.696**	.566**	.581**	.502**	.608**	.807**	.894**	1	.817**	.600**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000
	N	225	221	221	223	222	159	220	149	192	225	225	225	224	160
T2000L	***Pearson Correlation***	.609**	.476**	.546**	.597**	.833**	.723**	.726**	.626**	.696**	.609**	.675**	.817**	1	.861**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000
	N	224	220	220	222	221	158	220	149	191	224	224	224	224	160
T3000L	***Pearson Correlation***	.452**	.285**	.338**	.416**	.650**	.733**	.652**	.644**	.608**	.402**	.442**	.600**	.861**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	N	160	160	160	160	160	153	159	126	137	160	160	160	160	160
T4000L	***Pearson Correlation***	.577**	.370**	.403**	.449**	.721**	.748**	.794**	.702**	.741**	.452**	.504**	.644**	.853**	.928**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	223	219	219	221	220	157	219	149	191	223	223	223	223	160
T6000L	***Pearson Correlation***	.564**	.283**	.301**	.381**	.631**	.707**	.735**	.764**	.740**	.427**	.452**	.582**	.776**	.841**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	151	150	150	151	151	128	150	139	134	151	151	151	151	129
T8000L	***Pearson Correlation***	.643**	.373**	.394**	.413**	.658**	.636**	.750**	.728**	.870**	.450**	.481**	.587**	.706**	.714**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	190	188	188	189	188	131	187	132	177	190	190	190	190	135

Appendix C continued

PTAR	***Pearson Correlation***	.615**	.849**	.928**	.970**	.923**	.761**	.738**	.664**	.700**	.597**	.638**	.748**	.736**	.523**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	226	226	226	226	226	161	225	151	197	220	220	220	219	159
PTAL	***Pearson Correlation***	.667**	.631**	.701**	.690**	.765**	.628**	.640**	.551**	.661**	.830**	.909**	.967**	.905**	.697**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	224	220	220	222	221	158	220	149	191	224	224	224	224	160
HFPTAR	***Pearson Correlation***	.601**	.566**	.604**	.691**	.902**	.938**	.960**	.932**	.845**	.403**	.438**	.595**	.751**	.727**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	152	151	151	152	152	127	152	152	140	149	149	149	149	126
HFPTAL	***Pearson Correlation***	.549**	.334**	.371**	.455**	.740**	.790**	.789**	.732**	.707**	.491**	.534**	.681**	.920**	.933**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	151	150	150	151	151	128	150	139	134	151	151	151	151	129
SRTR	***Pearson Correlation***	.552**	.874**	.931**	.922**	.740**	.616**	.610**	.572**	.597**	.571**	.616**	.678**	.580**	.397**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	222	222	222	222	222	157	220	148	194	217	217	217	216	156
SRTL	***Pearson Correlation***	.617**	.649**	.698**	.655**	.636**	.518**	.527**	.450**	.561**	.853**	.913**	.907**	.736**	.514**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	220	217	217	218	217	155	215	145	189	220	220	220	219	156

Appendix C continued

WRSR	***Pearson Correlation***	-.526**	-.796**	-.871**	-.900**	-.860**	-.727**	-.685**	-.641**	-.636**	-.485**	-.546**	-.669**	-.653**	-.460**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	154	154	154	154	154	112	153	106	132	148	148	148	147	112
WRSL	***Pearson Correlation***	-.669**	-.578**	-.682**	-.663**	-.746**	-.585**	-.633**	-.547**	-.642**	-.741**	-.823**	-.896**	-.861**	-.651**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	162	158	158	160	159	114	158	109	137	162	162	162	162	114
PLR	***Pearson Correlation***	.547**	.729**	.804**	.814**	.767**	.703**	.680**	.636**	.630**	.494**	.542**	.611**	.633**	.484**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	154	154	154	154	154	112	153	106	132	148	148	148	147	112
PLL	***Pearson Correlation***	.686**	.647**	.698**	.654**	.701**	.531**	.620**	.533**	.661**	.695**	.757**	.818**	.781**	.550**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	165	161	161	163	162	116	161	112	140	165	165	165	165	116
WordsPresented	***Pearson Correlation***	.244**	.147*	.151*	.177**	.250**	.205**	.275**	.201*	.205**	.188**	.208**	.227**	.313**	.248**
	Sig. (2-tailed)	.000	.027	.022	.007	.000	.009	.000	.013	.004	.005	.002	.001	.000	.002
	N	231	227	227	229	228	161	226	152	197	225	225	225	224	160

Appendix C continued

		T4000L	T6000L	T8000L	PTAR	PTAL	HFPTAR	HFPTAL	SRTR	SRTL	WRSR	WRSL	PLR	PLL	WordsPresented
Age	***Pearson Correlation***	.577**	.564**	.643**	.615**	.667**	.601**	.549**	.552**	.617**	-.526**	-.669**	.547**	.686**	.244**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	223	151	190	226	224	152	151	222	220	154	162	154	165	231
T250R	***Pearson Correlation***	.370**	.283**	.373**	.849**	.631**	.566**	.334**	.874**	.649**	-.796**	-.578**	.729**	.647**	.147*
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.027
	N	219	150	188	226	220	151	150	222	217	154	158	154	161	227
T500R	***Pearson Correlation***	.403**	.301**	.394**	.928**	.701**	.604**	.371**	.931**	.698**	-.871**	-.682**	.804**	.698**	.151*
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.022
	N	219	150	188	226	220	151	150	222	217	154	158	154	161	227
T1000R	***Pearson Correlation***	.449**	.381**	.413**	.970**	.690**	.691**	.455**	.922**	.655**	-.900**	-.663**	.814**	.654**	.177**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.007
	N	221	151	189	226	222	152	151	222	218	154	160	154	163	229

Appendix C continued

T2000R	***Pearson Correlation***	.721**	.631**	.658**	.923**	.765**	.902**	.740**	.740**	.636**	-.860**	-.746**	.767**	.701**	.250**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	220	151	188	226	221	152	151	222	217	154	159	154	162	228
T3000R	***Pearson Correlation***	.748**	.707**	.636**	.761**	.628**	.938**	.790**	.616**	.518**	-.727**	-.585**	.703**	.531**	.205**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.009
	N	157	128	131	161	158	127	128	157	155	112	114	112	116	161
T4000R	***Pearson Correlation***	.794**	.735**	.750**	.738**	.640**	.960**	.789**	.610**	.527**	-.685**	-.633**	.680**	.620**	.275**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	219	150	187	225	220	152	150	220	215	153	158	153	161	226
T6000R	***Pearson Correlation***	.702**	.764**	.728**	.664**	.551**	.932**	.732**	.572**	.450**	-.641**	-.547**	.636**	.533**	.201*
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.013
	N	149	139	132	151	149	152	139	148	145	106	109	106	112	152
T8000R	***Pearson Correlation***	.741**	.740**	.870**	.700**	.661**	.845**	.707**	.597**	.561**	-.636**	-.642**	.630**	.661**	.205**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.004
	N	191	134	177	197	191	140	134	194	189	132	137	132	140	197

Appendix C continued

T250L	***Pearson Correlation***	.452**	.427**	.450**	.597**	.830**	.403**	.491**	.571**	.853**	-.485**	-.741**	.494**	.695**	.188**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.005
	N	223	151	190	220	224	149	151	217	220	148	162	148	165	225
T500L	***Pearson Correlation***	.504**	.452**	.481**	.638**	.909**	.438**	.534**	.616**	.913**	-.546**	-.823**	.542**	.757**	.208**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002
	N	223	151	190	220	224	149	151	217	220	148	162	148	165	225
T1000L	***Pearson Correlation***	.644**	.582**	.587**	.748**	.967**	.595**	.681**	.678**	.907**	-.669**	-.896**	.611**	.818**	.227**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001
	N	223	151	190	220	224	149	151	217	220	148	162	148	165	225
T2000L	***Pearson Correlation***	.853**	.776**	.706**	.736**	.905**	.751**	.920**	.580**	.736**	-.653**	-.861**	.633**	.781**	.313**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	223	151	190	219	224	149	151	216	219	147	162	147	165	224
T3000L	***Pearson Correlation***	.928**	.841**	.714**	.523**	.697**	.727**	.933**	.397**	.514**	-.460**	-.651**	.484**	.550**	.248**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002
	N	160	129	135	159	160	126	129	156	156	112	114	112	116	160

Appendix C continued

T4000L	***Pearson Correlation***	1	.873**	.792**	.595**	.726**	.770**	.952**	.451**	.564**	-.500**	-.685**	.518**	.645**	.287**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	223	151	190	218	223	149	151	215	218	147	161	147	164	223
T6000L	***Pearson Correlation***	.873**	1	.866**	.494**	.657**	.768**	.935**	.338**	.497**	-.377**	-.663**	.456**	.634**	.273**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001
	N	151	151	133	149	151	139	151	147	148	101	113	101	115	151
T8000L	***Pearson Correlation***	.792**	.866**	1	.566**	.645**	.713**	.794**	.435**	.520**	-.448**	-.640**	.482**	.666**	.254**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	190	133	190	187	190	132	133	184	187	126	133	126	136	190
PTAR	***Pearson Correlation***	.595**	.494**	.566**	1	.786**	.797**	.589**	.922**	.719**	-.933**	-.780**	.846**	.763**	.205**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.002
	N	218	149	187	226	219	151	149	221	216	154	157	154	160	226
PTAL	***Pearson Correlation***	.726**	.657**	.645**	.786**	1	.650**	.777**	.692**	.914**	-.707**	-.933**	.686**	.854**	.282**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	223	151	190	219	224	149	151	216	219	147	162	147	165	224

Appendix C continued

HFPTAR	***Pearson Correlation***	.770**	.768**	.713**	.797**	.650**	1	.807**	.664**	.526**	-.765**	-.674**	.758**	.635**	.249**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.002
	N	149	139	132	151	149	152	139	148	145	106	109	106	112	152
HFPTAL	***Pearson Correlation***	.952**	.935**	.794**	.589**	.777**	.807**	1	.402**	.581**	-.482**	-.767**	.536**	.698**	.277**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.001
	N	151	151	133	149	151	139	151	147	148	101	113	101	115	151
SRTR	***Pearson Correlation***	.451**	.338**	.435**	.922**	.692**	.664**	.402**	1	.706**	-.867**	-.671**	.819**	.698**	.233**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000
	N	215	147	184	221	216	148	147	222	216	150	155	149	158	222
SRTL	***Pearson Correlation***	.564**	.497**	.520**	.719**	.914**	.526**	.581**	.706**	1	-.625**	-.839**	.599**	.842**	.251**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000
	N	218	148	187	216	219	145	148	216	220	145	158	144	161	220
WRSR	***Pearson Correlation***	-.500**	-.377**	-.448**	-.933**	-.707**	-.765**	-.482**	-.867**	-.625**	1	.787**	-.781**	-.583**	-.177*
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.028
	N	147	101	126	154	147	106	101	150	145	154	85	153	88	154

Appendix C continued

WRSL	***Pearson Correlation***	-.685**	-.663**	-.640**	-.780**	-.933**	-.674**	-.767**	-.671**	-.839**	.787**	1	-.648**	-.802**	-.274**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000
	N	161	113	133	157	162	109	113	155	158	85	162	86	162	162
PLR	***Pearson Correlation***	.518**	.456**	.482**	.846**	.686**	.758**	.536**	.819**	.599**	-.781**	-.648**	1	.867**	.191*
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.017
	N	147	101	126	154	147	106	101	149	144	153	86	154	88	154
PLL	***Pearson Correlation***	.645**	.634**	.666**	.763**	.854**	.635**	.698**	.698**	.842**	-.583**	-.802**	.867**	1	.233**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.003
	N	164	115	136	160	165	112	115	158	161	88	162	88	165	165
WordsPresented	***Pearson Correlation***	.287**	.273**	.254**	.205**	.282**	.249**	.277**	.233**	.251**	-.177*	-.274**	.191*	.233**	1
	Sig. (2-tailed)	.000	.001	.000	.002	.000	.002	.001	.000	.000	.028	.000	.017	.003	
	N	223	151	190	226	224	152	151	222	220	154	162	154	165	231

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