TOWARD EVIDENCE-BASED PRACTICE IN THE SPEECH AUDIOMETRIC ASSESSMENT OF LINGUISTIC MINORITIES[1]

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0.0 ABSTRACT

One of the audiologist's main objectives is to maximize a person's hearing such that he or she can understand speech and maintain communication with others. In the audiological setting, the ability to understand speech is thus most frequently conceived of in relation to one's capacity to hear. While speech understanding may in essence begin with one's ears, the journey beyond perception to comprehension is ultimately dependent on one's knowledge of a language, namely that of the speaker. The factor of language often goes unrealized, however, as the majority of audiologists and their patients are speakers of the same language, English. Moreover, most speech audiometry exams are administered with English test materials that have been standardized on monolingual, English-speaking populations. This predominance of English commonly leaves linguistic minorities underserved. Even though these individuals are liable to have a limited knowledge of English, it is common for the audiologist to nonetheless test their ability to understand speech using English. The question that arises here is whether speech audiometry remains a measure of intelligibility vs. audibility, or whether there are additional language-related influences at play. We argue that linguistic variables are indeed active, can invalidate testing and affect the overall quality of audiological service. The problems borne from language discrepancies are defined in terms of their potential prevalence on populational level. Following that is a review of recent research on speech perception in bilingual[2], non-native[3] English speakers to show how linguistic variables, on multiple levels of processing, can influence a bilingual listener's English word recognition. The implications the research holds for improving speech audiometry in clinical practice is lastly discussed.

1.0 INTRODUCTION

A common hindrance to establishing satisfying relationships with healthcare

professionals and to receiving quality medical treatment is poor communication between the

patient and provider (Leonard, Graham and Bonacum, 2004; Anderson, Barbara and Feldman,

2007). Communication difficulties can arise along linguistic, physiological and cultural lines. In

a predominantly English-speaking country such as the United States, patients who do not speak

English or who have limited proficiency in the language may lack access to medical interpreters

and encounter language barriers in dealing with a monolingual, English-speaking healthcare

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[2] This thesis uses the term *bilingual* to refer to individuals who are capable of communicating in two languages, but who may not have equal proficiency in each. Generally, unless otherwise noted, we use bilingual to imply individuals whose first learned language is not English.
[3] The term *native* is used to refer to a speaker who is a primary learner of the language in focus.

provider. Even if an interpreter is available, the interpreter may mistranslate or omit information with such errors potentially leading to misunderstandings and misdiagnoses (Flores, 2005; Isaac, 2001). Hearing-impaired patients often face communicative issues in that they are unable to clearly hear and/or understand their doctor's words. They may not know how to respond appropriately or be certain of what they are to do with the doctor's prescribed treatment (Iezonni, O'Day, Killeen and Harker, 2004). Cultural beliefs may lead patients and their providers to disagree on the source of the patients' problems, whether they perceive these problems as disabilities and or handicaps, how they should be treated or whether they should even receive treatment at all (Kayser, 1998).

What, then, is the status of medical care for a hearing impaired person with limited proficiency in English? It is noteworthy to ask this question in the context of clinical audiology, for despite holding the maintenance, facilitation and maximization of communication as prime objectives, even this field of health care is susceptible to communicative challenges. As paradoxical as this may sound, the reality is that although the United States is continuously growing into a more culturally and linguistically diverse nation, (1) over eighty percent of this country's audiologists are monolingual English-speakers and (2) most audiological evaluations of speech perception, referred to as speech audiometry, are administered with English test materials that have been standardized on predominantly monolingual, English-speaking populations (Ballachanda, 2001; Ramkissoon 2001). By no direct fault of their own, patients from culturally and linguistically diverse backgrounds are liable to receive inadequate audiological care.

While the physiological functioning of a person's auditory system is undoubtedly a major

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Non-native characterizes individuals who are secondary learners of the language.

determinant of his or her hearing status, linguistic and cultural differences between the audiologist and patient should not be disregarded as they can affect every stage of audiological assessment (Ballachanda, 2001). Strained communication may make it difficult for the audiologist to interview a patient and collect adequate information and thus build a sufficient case history. This can ultimately affect the overall quality of care. A case history is a crucial foundation for subsequent decisions assessment and treatment, as it provides the audiologist with a more subjective understanding of a patient's problems. Discrepancies in language and culture can also hinder a patient's understanding of and compliance with assessment procedures, treatment plans and counseling.

Language differences can become especially problematic during speech audiometric evaluations, which are a key part of standard audiological assessments. Speech audiometry involves tests of word recognition, in which patients must typically listen to spoken words and respond by raising their hand or repeating them back to the audiologist. These tests serve to identify the lowest level at which a person finds speech intelligible at least half of time (Speech Reception Threshold) and to determine his or her ability to recognize words when they are played at suprathreshold levels, in a comfortably audible range (Gelfand, 2001).

Issues with speech audiometry extend beyond language barriers in personal interactions during test instruction and any post-test discussion. Speech audiometric tests are arguably problematic in and of themselves. Clinical observations show that while the speech reception threshold of a monolingual, English speaker typically fall within 5-6 dB of his or her pure-tone average (PTA; lowest intensity at which individual perceives tonal stimuli at 500, 1000 and 2000 Hz), the speech reception thresholds of patients from diverse linguistic backgrounds are not reliably predicted by this norm (Ramkissoon and Khan, 2003). Even when claiming to have

moderate to advanced ability in English, bilingual speakers whose first language is not English are found to score lower on tests of English word recognition than native speakers of the language (Takayanagi, Dirks and Moshfegh, 2002). Notably, this differential performance between native and non-native language users has been demonstrated by both hearing-impaired and fully hearing individuals. The non-native listeners' inability to recognize words therefore cannot be not attributed to their auditory abilities alone, but likely to lesser familiarity with the English words used in testing and/or the influence of their primary language. Language-related test biases are thus a real risk in using English to test the word recognition abilities of a speaker whose first language is not English and who may lack complete fluency in the language. Such biases threaten the accuracy of test results and could lead the audiologist to misinterpret low performances as the effects of hearing loss.

Alternative measures are available to soothe language discrepancies and best serve individuals from diverse linguistic backgrounds. An English-speaking audiologist may recruit the assistance of an interpreter to interview a patient and build the patient's case history. Interpreters can also facilitate patients' understanding of test procedures, what the audiologist is testing of them and suggested treatment plans. Audiologists who have the ability to speak another language may also be sought for these purposes (ASHA, 1985). In an attempt to reduce test biases due to limited familiarity with English, audiologists are known to reduce the number of test stimuli to include the English words that are most familiar to the patient (Ramkissoon, 2001). The seemingly most rational solution to preventing test bias in speech audiometry is to assess a patient client in the language he or she is most fluent (Gelfand, 2001). Test materials recorded in non-English languages are available for such use.

Nonetheless, these alternative options do not fully resolve the challenges in handling

multicultural and multilingual populations. Interpreters are liable to be ineffective unless they are trained in and informed of the purposes and procedures of audiological assessment (Ramkissoon and Khan, 2003), and less than 1 percent of audiologists identify as bilingual (Kayser, 2007). Subjective modifications to the number of test items do not resolve the problem of test inaccuracy, but risk the loss of test standardization and render the test unreliable still (Kayser, 2007). In using non-English test materials, the English-speaking audiologist may have limited ability to accurately score patients' verbal responses if he or she has no knowledge of the other language (Gelfand, 2001). The validity and reliability of non-English tests are made further tenuous as they currently lack normative data (Thibodeau, 2000). This leaves the audiologist without a baseline on which to accurately judge the impact of a patient's hearing status on his or her ability to recognize words, which could ultimately have consequences for diagnosis and treatment.

The fundamental problems constraining the success of any proposed alternative are that there are just too many languages to accommodate for and that the alternative measures are not always available and/or willingly employed. The American Speech-Language-Hearing Association found that one-half of their member audiologists claimed that they were unlikely or unwilling to seek out alternatives in the face of language differences (ASHA, 2002). Regarding speech audiometry, it is a common occurrence that an audiologist considers a person to be testable in English as long as he or she has at least some proficiency in the language (Elliot, 1994). This practice ought to be more prudent not only for the linguistic reasons previously discussed, but for legal ones as well. Federal mandates (PL 94-142 and Title VII of PL95-561), legal decisions (e.g., Dianna v. Board of Education, Lau v. Nichols and Larry P v. Riles) and state education regulations oblige the use of a limited-English-proficient client's primary

language in assessment procedures (ASHA, 1985). The intent of pointing out the pitfalls of the alternatives is not to warrant their disposal, but rather to encourage their development in hope that they become more standardized, reliable and widely-used.

The current protocols in the audiological assessment of culturally and linguistically diverse (CLD) populations deserve considerable scrutiny. Clinical procedures pertaining evaluating the speech perception abilities of this group are of prominent concern. The ability of a person to process speech can disclose more information than whether a person has a hearing impairment or not. It can additionally help discern the type of hearing loss a person may have (Thibodeau, 2000). Speech audiometric measures also have implications for hearing aid selection and fitting (Gelfand, 2001). Hearing aids are valuable devices, as they can be used to moderate hearing loss in about 90 of cases where hearing loss cannot be medically or surgically treated (Mainline Audiology Consultants). On a more personal note, speech comprises some of the most important sound waves to pass through one's ears each day. It is the prime pathway for the passing-on of information, the glue that keeps people connected, a way to set the tone or mood in a social situation. Concerns therefore extend beyond the practices of the audiologist. In all, the quality of service delivery has implications for a person's quality of life.

Most audiologists are aware that linguistic differences can influence audiological assessment. However, it is unclear whether this awareness is due to clinical and personal experience or to a research-based understanding of how language-related factors can influence audiological assessment. The apparent lack of audiologists who seek out alternatives in serving multicultural and multilingual populations is a cause for concern, especially when it comes to speech audiometry. Although topics pertaining to the speech perception abilities of bilingual listeners are well-entrenched in the literature, there appears to either be poor interest, limited

awareness, weak understanding and/or lacking application of the relevant research in the clinical setting.

This thesis is a step toward increasing the application of the research literature to clinical practice, so that decisions and judgments made during the clinical assessment of culturally and linguistically diverse populations are well-informed--what is known as evidence-based practice (Bentler, Eiler, Hornsby, Moodie, Laurel and Valente, 2007). The issues are first approached by defining the potential magnitude of language-related problems through a look at the current demographic profiles of linguistic and ethnic minorities, audiologists and practice trends in the clinical setting. The work then delves into the research literature as it inquires into the impact that linguistic variables have on speech perception at multiple levels of speech processing, particularly in bilingual listeners whose first language is not English. The implications that the research has for the audiological assessment, diagnosis and treatment of non-native speakers of English with limited English proficiency are discussed. Following the review of the literature, the implications that the research holds for speech audiometry are to be discussed.

2.0 DEMOGRAPHICS
2.1 THE EVER-GROWING MINORITY POPULATION: ETHNICITY, RACE AND LANGUAGE

The United States is in essence "united" as one nation, but let not the title and notion of oneness go any further to suggest that the people of this country are a homogeneous group. Take one look around and see people from a multitude of racial and ethnic backgrounds. Listen and English is dampened by the sounds of many other languages. The current number of minorities in this country is approximately one third of the entire population and steadily increasing. By the year 2050, minorities are expected to become the majority, composing 54 percent of the total United States' population (Bernstein and Edwards, 2008).

Much of this racial, ethnic and linguistic diversity is the result of immigration. According to the most recent Census report on the foreign-born population in the United States, approximately 33.5 million people, or 11.7 percent of the total population, were not born in this country. Looking to the numbers of years past, a growing trend in immigration since the year 1970 is evident. In that year, foreign-born individuals constituted a significantly smaller 4.8 percent of the population (U.S. Census Bureau, 2003). Indeed, the past half-century has witnessed an increasing number of immigrants entering the United States, bringing with them a multiplicity of appearances, cultural beliefs/practices and languages.

The trends in immigration, race and ethnicity do not necessarily dictate direct changes in linguistic diversity, but the growing number of non-English speakers does reflect the former to some degree. The 2000 U.S. Census report on language use claims that approximately 47 million people, or 18 percent of the country's population, speak a non-English language at home. Similar to the escalating trend in immigration, non-English language use is increasing. Census data indicates that non-English speakers made up 11 percent of the total population in 1980 and 14 percent in 1990 (U.S. Census Bureau, 2003). Recalling the projections for minority population growth, it is arguable that this nation could witness a significant increase in non-English language use as well.

Although many immigrants likely come to the United States speaking a language other than language, acquiring knowledge of English is useful if one hopes to integrate into mainstream American society. Many do learn the language, resulting in growing numbers of non-standard speakers of English. Such speakers may include those who talk with an accent and who interchange sounds, words and even whole sentences between each language when speaking (ASHA, 2004). And as learning a second language becomes increasingly difficult with age,

many of these English-learners do not become entirely proficient in the language. In asking those people who use a non-English language at home to rate their ability to also speak English as either *very well*, *well*, *not well* or *not at all*, Census reports remark that a little over half (55 percent) claimed to speak English *very well* (U.S. Census Bureau, 2003). The distinction between *very well* and *well* seems rather subjective, so it may be of worth to point out that about 16.2 percent of speakers of a non-English language classified themselves as not speaking English well and 7.2 percent did not speak English at all. The number of people with clearly limited or entirely lacking proficiency in English by no means constitute the majority. The size of this group is considerable nonetheless.

As for the prevalence of hearing loss within this group, an estimated 10 percent of the United States' population has a communication disorder and a similar rate is also applicable to just the minority population (Kayser, 2007). In view of the projected minority growth, an increase in the number of minorities with hearing disorders can be expected as well. Moreover, older adults are particularly prone to hearing loss. By the year 2030, the number of individuals aged 65 years and older is expected to constitute 20 percent of the total population (Bernstein and Edwards, 2008) and minorities alone are expected to make up 25 percent of this elderly group (Weinstein, 2000). It is clear that the number of linguistic minorities that could find themselves seeking help in the audiologist's office is likely to grow in the upcoming years.

2.2 THE UNIFORMITY OF THE AUDIOLOGIST'S UNIFORM

The racial, ethnic and linguistic profile of audiologists in this country paints a seemingly similar, but ultimately different picture. Akin to the entire American population, the current majority of audiologists comprises individuals of the white racial majority, however, to a much greater extent. Of the near 13000 audiologists in this country, a mere 7.8 percent identify with a

racial minority or multiracial background (ASHA, 2007). The 85 percent of audiologists who claim to be monolingual speakers of English (Ramkissoon, 2001) is almost analogous to 82 percent of the country's population that falls within this linguistic group (U.S. Census Bureau, 2003).

The difference in demographics is that the proportional sizes of the racial and ethnic minorities and non-English speakers in the audiologist workforce are not projected to climb like those of the whole country (Deal-Williams, 2002). Moreover, despite the similarities in proportional figures, the actual numbers are more important to consider. There is a mighty discrepancy between the number of linguistic minorities in the general population vs. those who in audiology. It is thus inevitable and perhaps common that an English-speaking audiologist be responsible for the assessment of a person with a limited understanding of the language.

2.3 AUDIOLOGICAL PRACTICE TRENDS

Although striking, the numbers and probability alone cannot bring the issues wrought by linguistic differences between the audiologist and patient/client to light. Relying on just the numbers, it is rash to conclude that simply because an audiologist speaks only English, he or she cannot properly assess and manage patients from linguistically diverse backgrounds. Self-assessment reports and investigations of practice trends in audiology are more informative with regard to this matter. The current practices and attitudes concerning cultural and linguistic diversity in the clinical environment show that language differences do indeed have a negative impact on the delivery of audiological care.

Although minorities make up a significant portion of an audiologist's monthly caseload, a substantial number of audiologists do not modify standard assessment procedures or seek assistance even in the face of language differences (Beverly-Drucker, 2003). In asking those

audiologists who do employ alternative measures to rate their competency in serving

multicultural clients and patients, the distribution of responses further suggest that the linguistic

minorities are vulnerable to inadequate audiological services. Respondents were to characterize

themselves on a 5-point scale, with *1* representing *Not at all qualified* and *5* representing *Very*

qualified. Only 9 percent of audiologists felt fully confident in their abilities, or *very qualified*, to

offer sufficient service to multicultural clients. Combined with those who rated themselves as a

4, approximately a third of audiologists are more certain than not that they are able to offer

appropriate services. Another third classifies their abilities as a *3* and the final third as *1* or *2*

(ASHA, 2006). The mark of *3*, although not explicitly stated, likely corresponds to *qualified*.

However, there seems to be a touch of uncertainty in this intermediate rating or else the

audiologist would have better chosen the likes of *4* or *5* as a self-descriptor. Therefore,

combining the self-ratings of *1*, *2* and *3*, the majority of audiologists are not wholly sure of their

ability to serve multicultural populations.

The grounds on which audiologists were to make these self-judgments were not

specified, but a recent survey on the usage of alternative methods to assess individuals from

culturally and linguistically diverse backgrounds suggests that feelings of incompetence are

largely due to differences in language. Audiologists claim to use alternative methods in the

following ways (ASHA, 2004):

Method	Audiologists Taking this Approach
Use of interpreter/translator	63%
Alternate methods of speech audiometry assessment	38%
Translated written materials (eg, test instructions)	28%
Reliance on electrophysiologic measures	24%
Referral to bilingual colleagues	14%
Use of pre-recorded materials in other languages	11%
Specific marketing/outreach campaigns.	3%

Given the previously mentioned demographics on minorities and language use, these methods are presumably implemented as alternatives to English. One's brow should furrow in looking at the distribution of responses. The use of an interpreter or translator would suggest that the patient does not have enough proficiency in English to communicate with the audiologist without difficulty. If a patient has trouble understanding English speech in conversation, they would likely have difficulty with English speech stimuli during testing as well. However, the percentage of audiologists who use alternate methods of speech audiometry is considerably lower.

The survey results imply that individuals with limited proficiency in English may nonetheless be tested with English test materials. Many audiologists do in fact administer speech audiometric tests in English as long as the patient is thought to have some understanding of the language (Elliot, 1994). This practice may be a result of the audiologist and/or the patient overestimating the patient's ability in English. In either case, such misjudgments could have negative effects on the accuracy and worth of testing. Speech audiometry is intended to be a measure speech understanding as a function of the person's hearing levels and not of his or her knowledge in the test language. Limitations in linguistic competency could present a skewed picture of the patient's hearing, potentially rendering it more degraded than it is.

Having identified language differences as a main source of problems in providing audiological services to multilingual and multicultural populations on a macro-scale, what follows now is a zooming-in of the lens. An understanding of how linguistic variables might influence speech audiometric evaluations are to be gained through a review of the literature on speech perception in bilingual speakers of English and another language. In order to best realize the implications that the research holds for current audiological practices, an overview of the

procedures in a typical audiological assessment, and in particular speech audiometry, is first presented.

3.0 AUDIOLOGICAL ASSESSMENT

A full diagnostic hearing assessment typically involves a patient case history, an evaluation of auditory function through a series of hearing tests, a diagnosis, treatment prescriptions and counseling. The audiologist's main diagnostic objectives are to determine (1) the degree of the person's hearing (ie, normal hearing, mild hearing loss, profound hearing loss), (2) what part(s) of the auditory system may be the source of identified hearing deficits and (3) how pervasive the loss is (ie, Does it affect both sides of the auditory system? Is it limited to auditory stimuli of a particular frequency? Did it come on suddenly or is it progressive? Is it temporary or persistent over time?) Hearing tests are frequently the keystones of these diagnostic procedures. The most routine forms of testing are pure tone audiometry and speech audiometry. While pure tone audiometry tests can determine whether a person has a hearing impairment, speech audiometric measures provide further insight to the actual nature of a person's hearing loss and how much it might affect their day-to-day life in interacting with other people (Thibodeau, 2000).

In a pure tone test, the patient's task is to detect the presence of tonal stimuli played at varying frequencies (Hz) and intensities (dB). This test establishes the patient's pure tone threshold, which is the lowest decibel level at which he or she can detect the tonal signals fifty percent of the time. These levels are plotted on an audiogram, which is a graph of intensity as a function of frequency (Kutz, 2008).

Speech audiometric examinations measure a person's sensitivity to speech by testing at what levels a person can detect a speech signal and at what levels a person can actually

understand it. A person's Speech Detection Threshold (SDT) is the lowest level at which speech is audible fifty percent of the time, while a Speech Reception Threshold (SRT) describes the lowest level at which speech is understandable fifty percent of the time (Thibodeau, 2000).

The speech detection threshold is established in much the same way as a pure-tone threshold, except the stimuli are speech samples such as words. In determining speech recognition thresholds, on the other hand, patients must listen to speech stimuli and indicate their understanding by repeating them back to the audiologist. The speech stimuli that are typically used in establishing SRTs are duosyllabic spondees, such as *blackboard, earthquake, mousetrap, toothbrush,* which are spoken with equal emphasis on each syllable (Gelfand, 2001). It should be noted, that in reality, spondees are unnatural in American English. If these words are spoken with equal emphasis on each word, this is not typical. If these words are spoken with true English prosody, primary stress being on the first syllable, then they are just misnamed in the audiological terminology (Personal communication, Donna Jo Napoli). In either case, these words are typically played from widely used recorded materials, such that these so-called spondees are essentially standardized. It is found that even small changes in the intensity at which these spondees are presented can yield large effects on their intelligibility, helping to more accurately pinpoint SRTs at different frequencies. Although the nature of duosyllabic words makes them a closed-set class and enables some degree of guessing on the basis one of the two syllables, patients are familiarized with the words prior to testing so as to ensure the test is a measure of one's hearing and not vocabulary. It has been found that the average SRT is 4-5 dB lower without a familiarization period (Gelfand, 2001). Ultimately, the SRT typically stands 10-12 decibels higher than the SDT. Deviations in this could be suggestive of hearing loss (Thibodeau, 2001).

After a speech reception threshold is determined, tests of word recognition at suprathreshold levels typically follow. As in SRT testing, patients listen to monosyllabic words one-at-a-time and indicate their understanding by repeating them aloud. Performance on these tests are scored on a percentage correct basis. Generally, scores below 80 % are suggestive of an auditory processing disorder beyond the ear itself, since this test should in essence be within the patient's auditory range (Thibodeau, 2001). Performance on suprathreshold tests can also be indicative of how much the patient's understanding of speech in conversation may benefit from the use of a hearing aid, which would essentially bring their hearing levels to suprathreshold levels as in the test (Thibodeau, 2000). In fact, after being fitted for a hearing aid, patients are often retested with hearing aids to ensure the devices are helpful and retune them if they are not (Smoski, 2008). From all of this, it is clear that speech audiometry is a foremost tool in the audiologist's workbox.

4.0 A THEORETICAL APPROACH TO SPEECH PERCEPTION

The Speech Detection Threshold and Speech Recognition Threshold highlight an important aspect of speech perception. As suggested by the SDT, the speech signal must first be audible enough to be heard. But as implied by the SRT, speech does not enter the ear as language per se. Rather it greets the ear as a continuous stream of sound, which must then be discriminated as phonemes, recognized as words and perhaps interpreted as sentences. These events require more than just a physiological pathway. Understanding and finding meaning in speech further involves higher-level mental processes, such as memory retrieval, inference-making and understanding intention and affect, to name a few. At the end of the day, the ability to comprehend speech requires knowledge of a language, namely that of the speaker.

The processes underlying speech perception are a hot topic in the research literature.

These studies have given rise to a number of theoretical models of spoken word recognition. Recent models tend to agree that spoken word recognition is a multi-step process that involves a highly dynamic integration of both bottom- and top-level sources of information, from the acoustic features of the speech input and lexical knowledge. Activation-competition models of spoken word recognition are commonly addressed with respect to this notion of interactive processing (Luce, Goldinger, Auer and Vitevitch, 2000). These models posit that word recognition is not a mere matter of matching words from the listener's lexical memory to the incoming speech input in a neat, one-set-of-sounds to one-word fashion.

Instead, as proposed by the Neighborhood Activation Model, after the speech signal activates acoustic-phonetic patterns that are stored in the a listener's memory, these then feed upward and trigger not only the spoken target word, but also all close phonemic matches (Goldinger, Luce and Pisoni, 1989). These groups of similar sounding words are termed *neighborhoods*. At this point, higher level lexical knowledge feeds downward to increase the likelihood that the spoken target word will be selected amidst its competitors. The efficiency of this process is dependent on relative word frequencies and the number of words within a given neighborhood (density). Word recognition is biased towards those words that occur more frequently, and the speed with which inter-word competition is resolved on the basis of how many contenders there are to knock out. It is important to point out that bottom-up processes remain ongoing in the midst of this higher level activity. The nature of the speech is a signal is such that increasing amounts of acoustic information become available over time. Thus, all sources of information are constantly monitored and integrated such that, in the end, one word wins out as the best match to the spoken stimulus.

As illustrated by this model, the lexical processes involved in spoken word recognition

are complex. However, the sublexical operations involved in phonemic discrimination and speech segmentation are no less so. Bottom-level processes are complicated by the fact that the sublexical features of speech can vary significantly along a number of lines, such as in speaking rate, loudness, pitch, tone and overall character of sound via the accent and dialect with which it's produced (Takayanagi et al., 2002). Speakers must continually adjust for variations in the speech signal between talkers or even within the extended speech of just one person. Adapting the speech signal to some standardized form serves to uphold the integrity of the acoustic-phonetic representations of vowels and consonants which ultimately enable speech to be understood. The hypothetical mechanism that operates in this process of perceptual normalization shall not be further addressed here. The main point is that the processes are manifold.

5.0 LITERATURE REVIEW

Despite the apparent challenges to be overcome in moving from speech audibility to intelligibility, the complexity of the task typically goes unrealized in listeners who have normal hearing levels and full competence in the language of the speaker. Oftentimes it is only when a person's hearing degrades or when one of the aforementioned sublexical features of speech is outstanding that the listener realizes the true phenomenon that speech perception is. Listeners who are bound by both of these circumstances, say due to hearing loss and a limited knowledge of the speaker's language, understandably have quite a burden facing them when it comes to understanding speech.

The majority of people who are likely to be faced with such circumstances are actually the minority--individuals who are not fully proficient, monolingual speakers of English. This group entails speakers, mainly bilingual, whose proficiency in English may be lacking, who may

have greater proficiency in another language and/or whose predominantly used language may be one other than English. The question that arises is whether their difficulty with understanding speech, more specifically English, is solely product of poor hearing or whether language is additionally factor. This is a question that an audiologist is likely to be faced with in assessing this population. Unfortunately, as has been made evident thus far, it is not one that they are primed to answer. The answer is certainly not simple, which may be part of the problem. Despite how time-consuming and tricky it may be, an answer should be sought.

We argue that theoretical conceptions of speech understanding have implications for the current work's concern with the use of English test materials to assess speech understanding in this special population. Thus, we now turn to the research literature addressing English speech perception in non-native speakers of English. Research directly pertaining to such speakers who are additionally hearing-impaired is lacking, so, with one exception, we mainly refer to the literature on normal-hearing groups. Such work is equally insightful and furthermore abundant. Therefore, it should not be discounted. As word recognition tests are the most routinely used in speech audiometry, the main focus is on non-native English speakers' word recognition ability. Another note is that much of the research presented here operates under the previously mentioned activation-completion models of speech perception as a means of parsing out how specific linguistic variables operate. The primary finds of each study shall be noted throughout, but the main discussion of the implications the research holds for speech audiometry shall be reserved until all the literature has been reviewed.

5.1 LANGUAGE FAMILIARITY AND SPEECH AUDIBILITY: TWO ACTORS, ONE ACT

Takayanagi, Dirks & Moshfegh (2002) investigated the effects that lexical difficulty and inter-talker speech variability have on word recognition in both normal-hearing and hearing

impaired, native and non-native speakers of English. The intent of using these four groups was to examine language status and hearing impairment's impact on speech understanding separately and in concert. The non-native, English speakers who participated in the study came from a wide range of language backgrounds. Most rated their English comprehension abilities as moderate to proficient, but several participants claimed to have beginner-level skills.

Participants were given tests of word recognition in the format of a standard speech audiometric exam, lending this study to be particularly relevant to clinical practice. In place of the word lists that are traditionally used by clinicians, the researchers developed their own. The test stimuli consisted of monosyllabic words of Consonant-Vowel-Consonant phonemic structures, which were classified as either *lexically easy* or *lexically hard* words. The difficulty of these words were determined under the assumptions of the Neighborhood Activation Model. As the model would predict, difficult words are those which occur with low frequency, have many similar-sounding neighbors (high neighborhood density) and whose neighbors occur with high frequency. Given a high density neighborhood, the speech input would activate the target word along with a large number of phonetically similar competitors. If these competitors occurred with overall greater frequency than the target word, word selection would be biased towards them until there was enough acoustic information to rule them out. Recognition of the target word would therefore be a slower, more "difficult" process and perhaps prone to greater inaccuracy. On the other hand, easy words occur with high frequency, have low neighborhood densities and have neighbors which occur with low frequency. They are therefore activated in contention with few competitors, who are readily dropped as their lower frequency levels give them less charge. In this case, target words should be identified more quickly and usually with little mistake. In order to ensure the fairness of the words chosen for the experiment, all

participants were asked to rate the familiarity of the test words. These ratings were high across all groups.

In addition to manipulating the lexical difficulty of the test words, researchers additionally incorporated single- and multi-talker test conditions in order to address the potential difficulty speaker variability poses to the listener. In the single-talker condition, participants listened to word lists which had been recorded by the same speaker throughout. In the multi-talker condition, however, participants listened to stimuli that were recorded by a collection of speakers. The listener would presumably have to adapt to differences in vocal characteristics between speakers.

As was expected, the factors of lexical difficulty and talker variability had significant effects on word recognition performance across all four groups of subjects. Better performance was seen in the single-talker condition that in the multi-talker condition, lending support to the complexity involved in the perceptual normalization of speech. Easy words were more accurately recognized than hard words, giving credence to the presumptions of the Neighborhood Activation Model. On the whole, normal hearing listeners showed more accurate word recognition than those with hearing impairment, and native listeners performed better than the non-native groups.

The most notable find, however, was that amidst the two hearing-impaired groups of subjects, the non-native English speakers performed worse than the native speakers. This implies that in processing a non-native language, audibility is not the only determinant affecting word recognition. In fact, analytical models based on the study's data (for more details see, Takayanagi et al., 2002) were devised in order assess audibility and language familiarity as separate influences on word recognition. Although audibility appeared to be the more dominant

factor, linguistic familiarity had significant bearings nonetheless.

5.2 THE EYE-CAN-TELL: PARALLEL LANGUAGE ACTIVATION IN BILINGUAL SPEAKERS

While Takayanagi et al. (2002) show that language-related factors on the whole are capable of influencing speech comprehension, studies that employ eye-tracking paradigms allow for deeper insight into how these factors might actually take their effect. In a typical eye-tracking study, speech stimuli correspond to a visual component. For instance, listeners may be presented with a spoken command that instructs them to look at one of several objects on a computer display. Listeners' eye movements and fixations can be recorded throughout and matched up with the time course of speech stimulus. By monitoring the latency and accuracy of subjects' gaze in response to different points in the speech stimulus, the comprehension of speech can be observed in real time (Tanenhaus and Spivey-Knowlton, 1996). Eye-tracking therefore affords more than just end results from which to draw conclusions. The following studies use eye-tracking paradigms to investigate online speech processing in bilingual speakers. It is commonly found that when bilingual speakers are listening to their non-native language, both known languages can be simultaneously activated (Blumenfeld and Marian, 2007; Marian, Blumenfeld and Boukrina, 2007; as cited by Marian et al., 2007: Blumenfeld and Marian, 2005; Marian and Spivey 2003a,b; Weber and Cutler 2004; Weber and Paris 2004; Spivey and Marian 1999).

5.2.1 THE INFLUENCE OF LANGUAGE PROFICIENCY AND COGNATE STATUS ON LANGUAGE COACTIVATION IN BILINGUAL LISTENERS

Blumenfeld and Marian (2007) used an eye-tracking paradigm to study English speech perception in bilingual speakers of German and English, who were either German-native, late

learners[4] of English or English-native, late learners of German. All subjects were presented with computer displays of four objects, each distributed in one quadrant of the screen. In each trial, an auditory command was given in English instructing the subject to click on an item (target) in the display. There were two test conditions: (1) English labels of the target items were cognates of German words, such that both the target word and the German translation shared nearly identical phonology (ie, *pills* and *Pillen*), or (2) Target names were English-specific words who did not share any similarities in sound with their German translation (ie, *bike* and *Fahrrad*). The display also included a competitor/control item and two irrelevant filler items. Competitors were items whose German translations were phonetically similar to the German translations of the English targets (and in the cognate condition, the English target word itself). On the other hand, the German translations of control items had no sound overlaps with the targets' translations.

As indicated by significant looking time to the competitor and greater looks to competitor items than to control items, German was coactivated in both groups of bilinguals when the English target was a German cognate. However, when the English target was not a cognate, German was only coactivated in the German-native bilinguals. A control group of monolingual English speakers did not show any effects of language coactivation, confirmed that observed effects were associated with bilingual status. The time course of recorded eye-movements and fixations revealed that the German-native bilinguals coactivated German competitors the most readily out of all the groups.

From these results, Blumenfeld and Marian concluded that the extent to which bilingual listeners coactivated German while listening to English was related to their level of German

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4 Subjects on average did not begin learning English until 10.7 years of age.

proficiency. This could explain the English-native listeners' differential performance between the cognate and English-specific conditions. With lesser proficiency, English-natives' lexical knowledge of German was probably reduced in comparison to that of the German-native group. Therefore, they were not inclined to activate a target's German translation and, as a consequence, the German competitor. The English-natives' coactivation of German in the cognate condition suggests that this coactivation may mostly be a function of bottom-level acoustic information from the speech signal feeding upward.

The main concern, however is the German-native bilinguals' coactivation of German which appeared to be more influenced by top-down processes. First, the equivalent levels of German coactivation across conditions suggests that phonological similarity was not primarily responsible for their coactivation of German. Given the visual component of the task, it is unclear whether translation equivalents were generated on the basis of the spoken target word alone or from the visual stimulus. In either case, the lack of a direct phonological prompt in the non-cognate condition suggests that German was just inherently more active in these highly proficient users.

In all, the data here reveal that a non-native English listener is prone to coactivate his or her native language even without a direct feed from the acoustic input. Furthermore, as revealed by the eye-tracker, coactivation effects occur so automatically that it may occur well beyond a listener's intention, awareness or control. The degree to which language coactivation impedes speech comprehension was not directly addressed by the study , but it should be mentioned that the non-native listeners fixated the English target later than the native listeners did. Therefore, the potential for cross-linguistic influences to affect speech understanding in a bilingual, non-native listener of English is real. It should be noted that the effects of coactivation observed in

this study would have likely gone undetected without the use of some indicator such as an eye-tracker. With regard speech audiometry, concealed effects of parallel language processing on speech comprehension are liable to be misinterpreted as effects of hearing loss.

5.2.2 THE EFFECTS OF PHONOLOGICAL SIMILARITY WITHIN AND ACROSS LANGUAGES ON BILINGUAL SPEECH COMPREHENSION

Similar results were reported by Marian, Blumenfeld and Burkina (2007), who essentially implemented the same experimental task as the previous work. In this study, however, cognate status was not a factor. The main focus was instead on the relative neighborhood densities of the German competitors, meaning the number of similar sounding German words. German-native bilinguals were found to give significantly greater looks to German competitors who belonged to both high and low density neighborhoods than did the English-German bilinguals. Moreover, they responded to manipulations of the German competitors' neighborhood densities as would be predicted from the Neighborhood Activation Model. Competitors with higher neighborhood densities were coactivated for overall less time than those with low density neighborhoods, presumably because they were loaded with competition from other words and therefore were more difficult to recognize.

The results replicate those of Blumenfeld and Marian (2007), wherein translation equivalents of English targets lead to coactivation of phonetically-related German competitors. This again shows that non-native listeners of English are prone to activate their native language even when exposed to an English stimulus and moreover, even when the acoustic features of the English input do not bear an obvious relation to native language's phonology. The current study further indicates that when listening to English, non-native bilinguals are not liable to activate just one word in their native language, but a whole neighborhood of similar-sounding words.

Parallel language processing is clearly robust.

5.3 A PRECURSOR TO PHONOLOGICAL SIMILARITY: PHONEMIC DISCRIMINATION

The studies discussed so far have highlighted the effects that cross-linguistic and within-language phonological similarities have on bilingual speech processing mainly at a lexical level. Presumably, however, the realization of phonological similarity must first follow from lower-level perception and phonemic discrimination. Accurate discrimination of particular language sounds is one of the primary challenges in learning a second language (Iverson, Kuhl, Akahane-Yamada, Diesch, Tohkura, Kettermann and Siebert, 2001). Phonemes in the second language may be absent in the speaker's first language and thus not perceptually salient to the listener. The following studies address the difficulties a non-native English speaker may have at the perceptual level when he or she listening to English.

Spanish and English offer one such example of languages with different phonetic inventories, as Spanish has five (/i, e, a, o, u/) and English has 11 (/i, ɪ, e, ɛ, æ, ʌ, ɑ, ɔ, o, ʊ, u/) (Bradlow, 1995). Levey (2005) investigated whether the status of phonemic categories in Spanish-English bilinguals and native English speakers would result in differential abilities to discriminate vowel contrasts. Vowels were chosen as the main focus instead of consonants as they are subject to greater variability across speakers and are usually more informative of the intonational, rhythmic and stress patterns of speech.   Furthermore, as neither Spanish or English use vowel rounding, length or nasalization to indicate meaning (Bradlow, 1995), the discrimination of phonemic contrasts would be related to bottom-level processes of perception and would not be significantly influenced by higher levels of knowledge.

Test trials followed an *ABX* format, in which listeners heard a word *A*, followed by another word *B* and lastly a repetition of either *A* or *B*. Subjects were to judge whether the last word was the same as the first or second word. The study found that native English speakers discriminated vowel contrasts more accurately than the did the Spanish-English bilingual speakers. This could have been a result of the English-speakers greater awareness of all the phonemes used in the test stimuli. This is supported by the vowel contrasts that gave the bilingual group the most, /ɪ/-/i/, /u/-/ʊ/, /ɔ/-/ɑ/ and /æ/-/e/. Herein, it is evident that the Spanish-English bilinguals had particular difficulty in discriminating vowels that were not part of the Spanish phonetic inventory (/ɪ/, /ʊ/, /ɔ/, /ɑ/ and /æ/). Furthermore, given the contrast pairs, it appears that Spanish speakers may assimilate these absent vowels to the closest known neighbor in articulatory space. This suggests that cross-linguistic influences are active even at the sub-lexical level.

Poor phonemic discrimination has not only been found to be associated with differences in phonetic inventory, but also to inter-language differences in the phonotactics. Cutler, Weber, Smits and Cooper (2004) found results similar to Levey (2005) in Dutch-English bilinguals. Again, these non-native English listeners showed (1) less accurate performance on a discrimination task than native English listeners, (2) particular difficulty discriminating English phonemes that were absent from their native Dutch phonetic inventory and (3) better performance when speech stimuli contained more Dutch phonemes (ie, fewer English phonemes). More significantly, this study also investigated discrimination of consonants and found that in discriminating stimuli with a Vowel-Consonant form, the Dutch listeners showed the most inaccurate discrimination for clusters ending in /b, d, or g/. It was suspected that this

was a result of the Dutch phonotactic rule that does not allow voicing contrasts to be in a word-final position. The evidence here strengthens the argument that the bottom-levels of speech perception are dependent on the listener's language-specific knowledge.

The discrimination tasks used by Levey (2005) and Cutler et al. (2004), although insightful, are essentially indicative of discriminatory abilities alone. Marian et al. (2007) argue that the ability, or lack thereof, to discriminate between phonemes can have consequences for recognition. They demonstrated this with a group of Russian-native bilinguals, who listened to a speech stimulus and subsequently were to judge whether it was a real English word or nonsense. Actual nonsense words were included as controls.

For each word tested, the experimenters varied the degree to which the words' phonemes (CVC structure) were unique to English or were also part of the Russian phonetic inventory. Vowels were characterized on the bases of lip rounding, vertical and horizontal tongue position. Consonants were distinguished with respect to voicing, place and manner of articulation. A phoneme was considered unique to English, unless a Russian phoneme matched it in all three domains.

It was found that as the phonemic overlap of the English words increased, the Russian-native bilinguals' judgments of English words were quicker and more accurate. Seeing that the Russian-natives' word recognition was worse when the test word was increasingly "English-sounding", it appears that difficultly with identifying the sounds of English could limit a non-native listener's ability to recognize English words.

Marian et al. (2007) suggest that this difficulty is not necessarily due to poor perception, but to differences in the phonological representations of sounds that non-native English speakers have encoded in memory. Iverson et al. (2001) argue for an alternative explanation, that poor

discrimination could in fact be associated with low-level perception. It may be the case that primary experience with one language reduces a listener's perceptual sensitivity to all other phonemic distinctions made outside of their native language. Alternatively, it may be that non-native listeners' perceptual attention is directed to features in the speech signal which, while indicative of phonemic contrasts in their native language, are irrelevant to the sound categorizations in another. In either case, both indicate that even the initial processes are tied to specific language experience.

In all the discussion of these sub-lexical processes, it should be noted that they do not only affect speech perception in bottom-up manner, as might seem most intuitive. As mentioned earlier, phonological similarity is also highly influential at the lexical level in language coactivation via translation equivalencies and within-language word competition. Once again returning to the notion of phonologically-related neighborhoods, weakly defined phonemic categories could, in theory, affect the neighborhood size as these are ultimately dependent on phonological similarities and differences (Marian et al., 2007).

6.0 IMPLICATIONS AND SUGGESTIONS

The research reviewed here has revealed a number of cautionary points to be considered against current audiological practices pertaining to speech audiometry and multilingual populations. The most significant finds are the following:

(1) Language is a separate factor from audibility.
(2) Bilingual-language processing is not always obvious to the naked eye:
    Bilinguals can coactivate their native language through translation equivalents of English words, even those which do not bear any obvious relation, such as with cognates or similar sounding words
(3) Non-native listeners have particular trouble with those phonemes which do not also exist in their language. This could inhibit word recognition.
(4) In the same vein, English word recognition increases with phonemic overlaps between the word and the listener's native phonology

Some aspects of these claims may seem intuitive. However, the research implicates that these stated effects occur within a highly dynamic and interactive system, much beyond what one can perceive from the surface. In the review of the literature, phonological similarity has come to light as a particularly influential factor in speech perception, and has been shown to relate to more than just the acoustic features of spoken speech itself. Manipulations to phonological similarity at both lower- and higher- levels, both within and across languages, all yielded effects on the processes of comprehension. Recognition of even just one word is thus not as straightforward as it may seem. Speech perception in the bilingual listener is not a subject that should be treated lightly, especially when it comes to understanding one's non-native language and especially when it is involved as a diagnostic measure of hearing status.

In further support of this argument, it should be acknowledged that the bilingual participants in the studies of Takayanagi et al. (2002), Blumenfeld and Marian (2007) and Marian et al. (2007), recognized English words with less speed and often less accuracy than monolingual, English control groups even when claiming to have moderate to advanced proficiency in English. Many of the subjects furthermore claimed to have greater exposure time in English at the time of the study than their in native language, and near equal numbers showed a preference for using their native language versus English. In view of the finds summarized above, these self-ratings should speak to the issues with speech audiometry and linguistically diverse patients. When a bilingual English speaker claims to have sufficient fluency in the language, they should certainly be given the opportunity to test in English. However, the audiologist should exercise careful judgment. It is one thing to test the person in English and another to then evaluate his or her performance with disregard to the potential influences of his

or her linguistic background. Rating a non-native speaker's performance on a test that has been standardized on a monolingual, English speaking population may not provide a fully accurate assessment of one's hearing status.

Ultimately, the development and standardization of speech audiometry test materials in other languages should continue and there should be a campaign for increased recruitment of bilingual audiologists. This is not to say that testing non-native English speakers in English should end, unless of course they have clearly lacking proficiency, nor is it a practice that will likely ever end. Test materials in other languages would at least provide an alternative for those individuals with very little English ability. And in the case of more proficient English users, it could serve as either an alternative option and/or a comparative measure to a test in English. Bilingual audiologists would enable these tests to actually to be used and interpreted in the most equivalent manner as in the more typical case of the English-speaking audiologist and patient. In reality however, the development and standardization of new test materials and recruitment of new professionals take considerable time. Furthermore, the case of the monolingual, English-speaking audiologist and linguistic minority-patient is not going to be phased out any time soon.

We suggest another viable option is to conduct a deep investigation of the English word lists that are in current use today through a direct application of what is found in the research. For instance, words could be classified words as *easy* or *hard* as defined by the Neighborhood Activation Model and as shown by Takayanagi et al. (2002). Perhaps bilingual listeners will shown an *easy-hard* difference, which could be compared to that of monolingual, English patients in an attempt to identify whether language-related factors limited bilingual performance. Or as shown by Marian et al. (2007), words could be rated by how uniquely "English-sounding" they are or how many phonemes they share with the patient's native language. Likewise, in

looking back to Cutler et al., words could also be scrutinized for whether or not they adhered to the phonotactics of the patient's native language. In evaluating results, the audiologist could compare performance between words with varying degrees of phonemic overlap and between words that violate the sound rules in the patient's language and those that are viable. Again, these supplemental observations could discern the hidden influence of language, apart from hearing status, on a bilingual's ability to recognize the test words. There will undoubtedly be individual differences amongst test takers, but some standardized norms may come to light if these methods were to be significantly employed.

These current proposals are not claimed to be entirely workable solutions, as sorting out the exact logistics are much beyond the scope of this work[5]. What we are promoting is greater interest in the current problems facing linguistic minorities in the audiological setting, in learning from the research and being innovative in its applications to help resolve the issues. In all, this work has merely scratched the surface and still remains illuminating. While the focus here has been on word recognition tests, since they are the most routine exams in speech audiometry, and consequently theoretical models of word recognition, there still remains a plethora of research to draw from and many other forms of speech audiometry tests to address.

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[5] However, work on *easy-hard* word classification for the NU-6 is ongoing and will hopefully continue into next term.

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