THE RELATIONSHIP BETWEEN SCAN:3-A AND HEARING-IN-NOISE TEST PERFORMANCES

by

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*For the purposes of this paper, an APD is considered the same as a CAPD.

Abstract

According to the Central Auditory Processing Disorder (CAPD) guidelines by the American Academy of Audiology (AAA; 2010), "specific treatment options (e.g. personal FM systems) may be more appropriately recommended for individuals who present deficits on monaural low-redundancy (MLR) (e.g. speech recognition in noise, filtered or compressed speech) and/or dichotic speech tests." The assumption appears to be that MLR speech tests may be used to adequately evaluate the necessity for an FM system. In other words, the MLR speech tests may be used to determine the presence of a speech recognition in noise deficit.

The purpose of this study was to evaluate the assumption that "low-redundancy" speech tests may be used to identify the need for an FM system by comparing these test results to that of the Hearing-in-Noise Test (HINT; Nilsson et al., 1994; Vermiglio, 2008). Twenty-nine young, native English-speaking with normal pure tone thresholds participated in the study. The subjects were evaluated using the MLR subtests of the SCAN-3:A and the HINT. The SCAN-3:A subtests included: Auditory Figure-Ground (0 dB), Filtered Words, Competing Words-Directed Ear, Competing Sentences, and Time-Compressed Sentences. The standard HINT conditions included; Quiet, Noise Front, Noise Right, and Noise Left. Composite scores were determined for each test battery. Statistically significant relationships were found between most of the SCAN-3:A conditions and HINT conditions. However, while relatively strong relationships between the MLR and HINT test results were found, clinicians should be cautious when inferring the presence of an SRN disorder from the MLR test results.

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Introduction

The literature review in this background was obtained through searches in East Carolina University's Library Database (ecu.edu/lib) or PubMed.gov. The key phrases in these searches included the following: (C)APD, low-redundancy speech tests, speech recognition in noise, HINT, and SCAN-3(: A).

Professional Responsibilities of an Audiologist

Audiologists administer a variety of tests to determine disorders of function and/or sites of lesion. They interpret test results of behavioral and objective measures. Examples of these tests include pure-tone testing (air conduction hearing test), speech testing (speech reception threshold/word recognition), inner ear testing, middle ear testing (tympanometry and acoustic reflex thresholds), and outer hair cell testing (otoacoustic emissions). Audiologists identify, test, diagnose, and manage disorders of human hearing (e.g. acoustic neuroma, congenital deafness, hearing loss, hyperacusis, otosclerosis), balance (B12 deficiency, Mal de Debarquement, Meniere's disease, vertigo), and tinnitus. Most of the aforementioned disorders are fairly clear and easy to understand.

However, there is a disorder in audiology that is highly controversial – Auditory Processing Disorder (APD), also called Central Auditory Processing Disorder (CAPD). (C)APD is typically defined as an inability to interpret sounds heard by ears with normal hearing sensitivity (Jerger and Musiek, 2000). ASHA (2005) states that "CAPD refers to difficulties in the perceptual processing of auditory information in the central nervous system and the neurobiological activity that underlies that processing and gives rise to the electrophysiologic auditory potentials." According to ASHA, this condition may have a profound influence on the individual's ability to listen, learn, and navigate through social

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environments. However, the definition, diagnosis, and treatment of CAPD remain controversial, mainly because of confusion on the ambiguous nature of CAPD, which does not facilitate intervention (Vermiglio, 2014).

Central Auditory Processing Disorder (CAPD)

The American Academy of Audiology (AAA), in its *Clinical Practice Guidelines for the Diagnosis, Treatment, and Management of Children and Adults with Central Auditory Processing Disorder* (AAA, 2010), builds on the previously mentioned ASHA (2005) definition of CAPD. According to AAA (2010), "If certain test patterns have been demonstrated to have good sensitivity and specificity in adults with confirmed Central Auditory Nervous System (CANS) lesions, then one may presume a high degree of likelihood that the same pattern of test results, when observed in a child or an older adult undergoing testing for central auditory dysfunction, confirms a CAPD in that child or older adult." Thus, the test battery used in diagnosis and assessment of CAPD should include tests known to identify lesions of the CANS (AAA, 2010). However, this represents a "target displacement," where the diagnostic accuracy of an index test for the detection of a lesion of the CANS is attributed to the same index test when it is used for the diagnosis of a CAPD (Vermiglio, 2016).

According to AAA (2010), the criterion for the diagnosis of CAPD is a score at least two standard deviations below the mean for at least two different tests from the CAPD test battery. There is a wide range of characteristics for patients with CAPD, including trouble with understanding speech in background noise, difficulty following rapid speech and directions, attention deficits, and poor singing/musical ability (AAA, 2010; Chermak, 2002). Often, children with CAPD exhibit academic difficulties related to the use of language (e.g.

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reading, spelling, other “auditory-reliant” topics) (Bellis, 2008). An assumption has been made that poor performance on the CAPD test battery would necessitate intervention for a speech recognition in noise (SRN) disorder (Vermiglio, 2014).

Legitimacy of CAPD

ASHA (2005) describes CAPD as an auditory deficit that may be diagnosed only by audiologists, thus affirming the diagnostic entity of CAPD. A ‘true’ clinical disorder, also known as a clinical entity, is a disorder that is diagnosed and treated (Vermiglio, 2014). However, Aetna (2016) states that auditory processing disorder (APD*) is not, in fact, a distinct clinical entity. The legitimacy of CAPD, then, would depend on the criteria used to determine if the disorder is a clinical entity. There are two sets of criteria presented in the literature: Kamhi (2011) and Vermiglio (2014). Kamhi (2011) justifies CAPD as a clinical entity using the following criteria: 1) the disorder is associated with a distinct professional and practitioner; 2) that professional is the only qualified person to test for and diagnose the disorder; and 3) the label for the disorder is not stigmatizing and is easy to understand, remember, and communicate to others such as a “meme.” Therefore, Kamhi argues, CAPD could be considered a clinical entity if these criteria are used (even though he is not a proponent of CAPD).

Kamhi questions the validity of CAPD because it has an ambiguous definition, lacks clear criteria for diagnosis, and also does not help or hinder language or academic performance. Thus, it may be better to view auditory deficits as a resulting consequence of other more common developmental disorders. DeBonis & Moncrieff (2008) also question the diagnosis of APD because the central nervous system is responsible for sensory

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processing that is intertwined and supported by other language and cognitive processing, making it difficult to separate APD from other learning disabilities.

On the contrary, Vermiglio (2014) refutes (C)APD as a clinical entity using the Sydenham-Guttentag criteria, which states that a clinical entity must: 1) possess an unambiguous definition; 2) represent a homogeneous patient group; 3) represent a perceived limitation; and 4) facilitate diagnosis and intervention. First, the definition of (C)APD is ambiguous, as exhibited by various definitions. For example, Aetna (2012) states, "auditory processing disorder…supposedly interferes with both the input and integration of verbal information, and results in a potentially permanent cognitive dysfunction during the developmental period of acquisition of language." ASHA (2005) states, "(C)APD is a deficit of neural processing of auditory stimuli that is not due to higher order language, cognitive, or related factors." Jerger and Musiek (2000) state, "An APD may be broadly defined as a deficit in the processing of information that is specific to the auditory modality." Second, (C)APD does not represent a homogeneous patient group. Vermiglio (2014) lists 22 different behavioral central auditory tests, and the criterion for the diagnosis of (C)APD is a score of 2 standard deviations or more below the mean for at least one ear on at least two of those tests. Thus, when looking at the options for diagnosis, there are a total of 462 distinct subcategories of (C)APD, this clearly represents a heterogeneous patient group. Third, each subcategory of (C)APD may or may not represent a limitation for the patient. A patient "failing" one test in his/her right ear and another test in his/her left ear may result in different limitations, but this is questionable. Dillon et al (2012) state that a patient "failing" a test may not actually represent a limitation for him/her. Hence, the first three parts of the criteria (unambiguous definition, homogeneous patient group, and

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perceived limitation) are not being met. Lastly, if a subcategory does not represent a limitation, then diagnosis and intervention are unnecessary, thus refuting the fourth part of the criteria.

While (C)APD is not a legitimate disorder as per the Sydenham-Guttentag criteria, a SRN disorder is a valid clinical entity as per the same. A SRN disorder has an unambiguous definition ("difficulty recognizing speech in the presence of a competing signal"), represents a homogeneous patient group (all have some degree of the same deficit), represents a perceived limitation, facilitates diagnosis with commercially available speech recognition in noise tests, and facilitates intervention. For example, an FM system or a mild-gain hearing aid with a directional microphone may provide benefit for a speech recognition in noise disorder (Vermiglio, 2014).

Goal of Study

To summarize, CAPD is a highly controversial area of audiology. The presence of a CAPD affects the central nervous system's ability to effectively use auditory stimuli (ASHA, 2005) and therefore could have a profound influence on the individual's ability to listen, learn, and navigate through social environments. However, the definition, diagnosis, and treatment of CAPD remains controversial, mainly because of confusion on the ambiguous nature of the disorder, which does not facilitate intervention.

A speech recognition in noise (SRN) difficulty has been considered a major characteristic of CAPD (Vermiglio, 2014; AAA, 2010; Bellis and Anzalone, 2008; LaGace et al., 2010), so someone with CAPD may have a SRN problem. However, someone could be diagnosed with CAPD by failing two non-SRN tests, so a CAPD is not equivalent to an SRN disorder (Vermiglio, 2014). AAA (2010) states that "specific treatment options (e.g.

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personal FM systems) may be more appropriately recommended for individuals who present deficits on monaural low-redundancy (MLR) (e.g. speech recognition in noise, filtered or compressed speech) and/or dichotic speech tests." According to AAA (2010), a relationship is assumed between performance on MLR speech tests and a SRN disorder. The assumption is that there is a relationship between SRN performance and monaural performance on behavior tests and/or dichotic listening tests. In other words, the MLR speech tests may be used to determine the presence of a SRN deficit.

In this study, the presence of a SRN disorder was determined using the Hearing in Noise Test (HINT; Nilsson et al., 1994, Vermiglio, 2008). The standard HINT conditions included Quiet, Noise Front, Noise Right, and Noise Left. Performances on MLR speech tests was obtained using subtests from the SCAN-3:A (Keith, 2009). These tests included 5 subtest; Auditory Figure-Ground (0 dB SNR) (AFG 0), Filtered Words (FW), Competing Words-Directed Ear (CW-DE), Competing Sentences (CS), and Time-Compressed Sentences (TCS).

Purpose of study.

The purpose of this study was to evaluate the assumption that the MLR speech tests of the SCAN-3:A (Keith, 2009) may be used to identify the need for an FM system by comparing the subtest results to those of the HINT. The implications of the study results for the assessment of and the intervention for patients with speech recognition in noise deficits will be discussed.

Research question.

What is the relationship between performances for the HINT vs. the MLR subtests of the SCAN-3:A?

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Hypothesis.

As the SCAN-3:A and HINT measure different aspects of auditory function, there will be no strong correlations between the test results of the SCAN-3:A subtests and the test results of the HINT. The subtests of the SCAN-3:A that make up the MLR test composite score (i.e. FW, CW-DE, CS, TCS) assess various forms of audition that are distinctly different from the HINT. The FW subtest measures the perception of muffled (low-pass filtered) speech (Keith, 2009). This test is sensitive to the presence of temporal lobe tumors (Bocca et al, 1954). The CW-DE and CS subtests are dichotic listening tasks (Keith, 2009), which may be used to detect brainstem lesions (Musiek, 1983). Lastly, the TCS subtest measures the ability to perceive time compressed speech. It has been shown to be sensitive to the presence of diffuse cortical lesions (Kurdziel et al., 1976). These four subtests will be compared to the HINT, which measures the ability to perceive speech in the presence of speech-shaped noise (Nilsson, et al., 1994; Vermiglio, 2008).

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Methods

Twenty-nine subjects were participated in this study. Subjects were college-aged students who were offered extra credit in a course for participation. The average age was 20.23 years (SD = 0.64). The subjects were all native English speakers. The inclusion criteria included normal pure tone thresholds (≤ 25 dB HL for 500-8000 Hz) for both ears and clear ear canals. Testing procedures began with an otoscopic evaluation to ensure no major issues such as excessive cerumen or the possibility of a collapsed ear canal.

The HINT was used to measure the ability to recognize speech in quiet and in noise. The HINT was administered using custom software provided by the House Ear Institute in Los Angeles, CA. The speech and noise stimuli were delivered under headphones using Knowles Electronic Mannequin for Auditory Research (KEMAR) head-related transfer-functions in order to simulate a sound field where the speech and noise are spatially separated for the Noise Side conditions. Telephonics TDH-50P headphones were used to deliver the stimuli. Short, simple American English sentences were presented binaurally. The "speech-shaped" noise was presented at a fixed level of 65 dBA. There were a total of 250 American English sentences used for 20 sentence lists. Testing for each HINT condition was conducted using a single list. The sentence lists and HINT conditions were randomized. The sentences were always presented at 0°. The noise was presented at 0°, 90°, and 270° for the Noise Front, Noise Right, and Noise Left conditions, respectively (Figure 1). By using an adaptive protocol, the level of the sentences varied based on the subjects' response. A correct repetition resulted in a decrease of the signal-to-noise ratio (SNR). An incorrect or incomplete repetition resulted in an increase of the SNR. A 4 dB step-size was used for the first 4 sentences and a 2 dB step-size was used for sentences 5 through 20. The HINT

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threshold is the SNR where a participant recognizes 50% of the sentences. The HINT composite score is the average of the thresholds for the Noise Front, Noise Right, and Noise Left conditions where the threshold for the Noise Front condition is weighted twice.

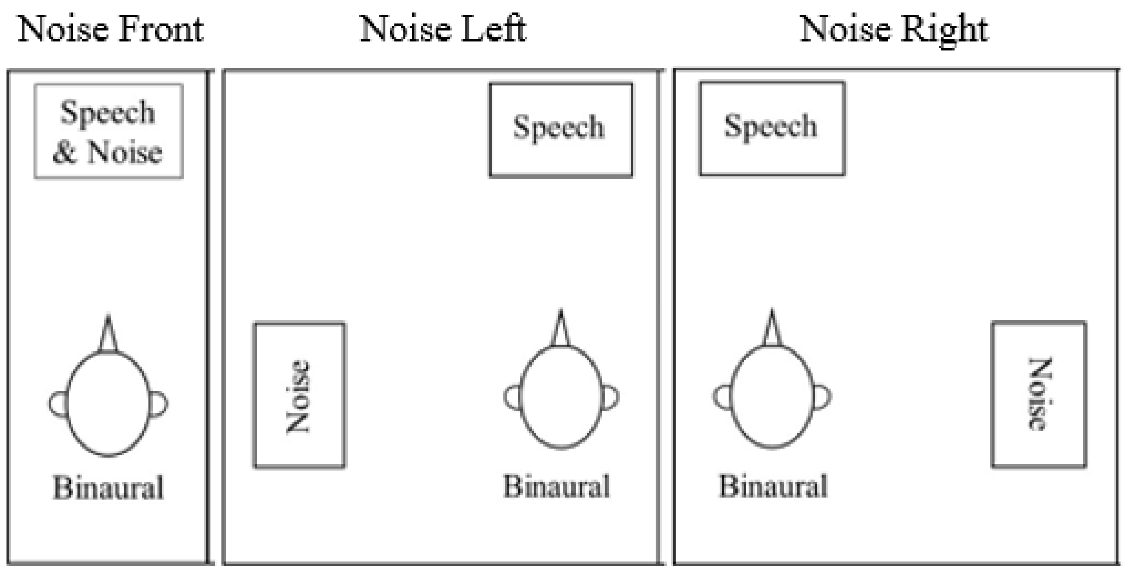

Figure 1. Simulated sound field HINT Noise conditions.

According to Keith (2009), the SCAN-3:A, a test of central auditory processing for adults and adolescents, “has been used to study auditory processing, language, and learning problems.” There are five subtests of the SCAN-3:A: FW, AFG, CW-DE, CS, and TCS (Keith, 2009). The SCAN-3:A manual specifies that the materials should be presented at the patient’s most comfortable listening level. However, for this study, the materials were presented from the audio files for the SCAN-3:A CD and routed from a PC to the audiometer for bilateral delivery through the TDH-50P headphones at 50 dB HL (dial setting). All test conditions were randomized.

In the FW subtest, 40 monosyllabic words were presented to either the left or the right ear, with higher frequencies of sound removed, giving the sound of the words a muffled quality. The subject was asked to repeat the word or to guess if he or she is unsure.

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This test assesses the ability to process distorted speech by presenting the words low-pass filtered at 750 Hz. Bocca et al. (1955) used a filtered speech recognition test in order to determine the absence or presence of temporal lobe tumors. These tumors were verified by using "…clinical investigations as well as radiograms, ventriculography, arteriography and pneumography…" as the reference standard. Results indicated poorer performance for the ear contralateral than the ear ipsilateral to the lesion.

In the present study, for the AFG 0 subtest of the SCAN-3:A, each subject was asked to repeat each of 40 words that were presented to either the right or left ear against a background of noise. The words had been recorded at a level equal to the background noise in order to minimize the occurrence of the ceiling effect (where the test performances reach the maximum level of 100%). Sinha (1959) used a SRN index test in order to determine the absence or presence of temporal lobe lesions. These lesions were verified in surgery. Results indicated "the inferiority of the contralateral ears to the normal hearing ears and also to the ipsilateral ears of the same subjects."

Both of the dichotic listening subtests involve listening to competing speech signals. The subjects listened to competing words or sentences presented to both ears at the same time. In the CW-DE subtest, 30 pairs of words were presented dichotically, and the subject was required to repeat the word presented to either the left or right ear first, followed by a repetition of the word presented to the other ear. No credit was given for words repeated in the incorrect order. In the CS subtest, 20 pairs of short sentences are presented dichotically, with the subject instructed to repeat only the sentences from either the right or left ear (depending on the item). The client was given a point score for each item, based on the number of key words in each target sentence that the client repeated. No credit was

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given for words repeated from the sentence presented to the incorrect ear. Musiek (1983) determined the sensitivity of a dichotic listening task to the absence or presence of cortical and brain stem lesions, using "negative history for ontological or neurological disease or trauma" to confirm the absence of lesions and "neurologically and/or neurosurgically/radiologically confirmed" CNS lesions to confirm the presence of lesions. Results showed the dichotic listening index test to have 78.6% sensitivity to the presence of cortical and brain stem lesions.

For the TCS subtest, 20 short sentences were either presented to the right or left ear. Each sentence was presented at a rapid rate. The subject was asked to repeat the entire sentence, and each item was scored according to the number of key words that the subject repeated correctly. Kurdziel et al. (1976) observed diffuse and discrete cortical lesions in surgery and found that for patients with diffuse lesions, a greater difference was found between contralateral (poorer) and ipsilateral ears than for patients with discrete lesions.

All SCAN-3:A raw scores were converted into scaled scores, according to the author's guidelines. Scaled scores are normative scores used specifically to compare an individual's performance to the performances of others of the same age. These scores are derived from the test raw scores that are converted to a score metric with a mean of 10, a standard deviation of 3, and a range of 1 to 19. A scaled score of 10 corresponds to the average performance within a given age group. Scores of 7 and 13 are 1 standard deviation below and above the mean, respectively. For the test norms, approximately two-thirds of individuals in a given age group had scaled scores between 7 and 13, which is considered the range of normal performance (Keith, 2009).

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In the present study, the monaural, low-redundancy (MLR) speech test composite score represented the sum of all the SCAN-3:A subtests, with the exception of AFG 0. Statistical analyses were conducted using the JMP Pro (V. 12) software. Pearson correlation coefficients were determined for all relationships: HINT composite score vs. MLR speech test composite score and HINT composite score vs. each of the individual MLR speech tests.

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Results

The collected data and results from the study are presented in Tables 1-3, and Figures 2-9. Table 1 shows that for the HINT Noise Front condition, the average threshold was -1.70 dB SNR. This indicates that on average the subjects recognized half of the sentences when the speech was presented 1.70 dB below the level of the noise. For the Noise Right condition, the average threshold was -8.53 dB SNR. This indicates that on average the subjects recognized half of the sentences when the speech was presented 8.53 dB below the level of the noise. For the Noise Left condition, the average threshold was -8.24 dB SNR. This indicates that on average the subjects recognized half of the sentences when the speech was presented 8.24 dB below the level of the noise. Lastly, for the HINT Noise Composite score, derived from the average of all three HINT conditions (with Noise Front weighted twice), the threshold was -5.05 dB SNR, above normal limits (5th percentile around -4 dB SNR). This indicates that across HINT conditions, the subjects on average recognized half of the sentences when the speech was presented 5.05 dB below the level of the noise.

Table 2 displays the average scaled scores for each of the individual subtests of the SCAN-3:A, as well as the monaural, low-redundancy (MLR) speech test composite score. In this study, the MLR speech test composite score was the sum of all the subtests, with the exception of Auditory Figure-Ground (0 dB SNR). As per the SCAN-3:A manual, the average scaled scores within normal limits are represented in the range of 7-19. The maximum-scaled score varies across subtests. Additionally, because the MLR speech test composite score did not include all of the subtests as specified in the SCAN-3:A manual, the cutoffs (Normal, Borderline, and Disordered) could not be designated.

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	HINT Quiet (dBA)	**HINT Noise Front (dB SNR)**	**HINT Noise Right (dB SNR)**	**HINT Noise Left (dB SNR)**	**HINT Composite Score (dB SNR)**
Mean	26.79	-1.70	-8.53	-8.24	-5.05
SD	4.43	0.97	1.50	1.62	1.03
n	29	29	29	29	29

Table 1. Descriptive statistics for all HINT thresholds and the composite score.

	Auditory Figure-Ground 0 dB SNR: Scaled Score	**Filtered Words: Scaled Score**	**Competing Words-Directed Ear: Scaled Score**	**Competing Sentences: Scaled Score**	**Time-Compressed Sentences: Scaled Score**	**Monaural, Low-Redundancy Speech Test Composite Score**
Mean	8.59	11.10	10.24	10.97	9.24	41.55
SD	1.64	2.40	2.46	1.57	2.68	6.56
n	29	29	29	29	29	29

Table 2. Descriptive statistics for all scaled scores for the SCAN-3:A subtests.

	HINT Quiet Threshold (dBA)	HINT Noise Front Threshold (dB SNR)	HINT Noise Right Threshold (dB SNR)	HINT Noise Left Threshold (dB SNR)	HINT Composite Score (dB SNR)
Auditory Figure-Ground 0: Scaled Score	-0.1941 (0.3130)	-0.3556 (0.0583)	-0.2583 (0.1761)	-0.3602 (0.0550)	-0.4014 **(0.0309)**
Filtered Words: Scaled Score	-0.5752 **(0.0011)**	-0.1882 (0.3283)	-0.3557 (0.0583)	-0.5510 **(0.0019)**	-0.4334 **(0.0189)**
Competing Words-Directed Ear: Scaled Score	-0.1922 (0.3180)	-0.3140 (0.0972)	-0.4494 **(0.0144)**	-0.4491 **(0.0145)**	-0.4863 **(0.0075)**
Competing Sentences: Scaled Score	-0.0725 (0.7087)	-0.1344 (0.4870)	-0.2153 (0.2620)	-0.3350 (0.0756)	-0.2725 (0.1527)
Time Compressed Sentences: Scaled Score	-0.2063 (0.2830)	-0.3955 **(0.0337)**	-0.4750 **(0.0092)**	-0.3691 **(0.0488)**	-0.5024 **(0.0055)**
MLR Speech Test Composite Score	-0.3837 **(0.0399)**	-0.3802 **(0.0419)**	-0.5440 **(0.0023)**	-0.6006 **(0.0006)**	-0.6111 **(0.0004)**

Table 3. Pearson correlation coefficients between HINT and SCAN-3:A subtests results (*p*-values in parentheses).

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	Auditory Figure-Ground 0: Scaled Score	Filtered Words: Scaled Score	Competing Words-Directed Ear: Scaled Score	Competing Sentences: Scaled Score	Time Compressed Sentences: Scaled Score
Auditory Figure-Ground 0: Scaled Score	1.0000 (<0.0001)	0.1922 (0.3810)	0.2572 (0.1779)	0.5142 (0.0043)	0.3617 (0.0539)
Filtered Words: Scaled Score	0.1922 (0.3180)	1.0000 (<0.0001)	0.2727 (0.1523)	0.2699 (0.1568)	0.3716 (0.0472)
Competing Words-Directed Ear: Scaled Score	0.2572 (0.1779)	0.2727 (0.1523)	1.0000 (<0.0001)	0.0513 (0.7915)	0.2855 (0.1333)
Competing Sentences: Scaled Score	0.5142 **(0.0043)**	0.2699 (0.1568)	0.0513 (0.7915)	1.0000 (<0.0001)	0.5501 (0.0020)
Time Compressed Sentences: Scaled Score	0.3617 (0.0539)	0.3716 **(0.0472)**	0.2855 (0.1333)	0.5501 **(0.0020)**	1.0000 (<0.0001)

Table 4. Correlation coefficients amongst SCAN-3:A subtests (*p*-values in parentheses).

Table 3 displays the relationship between the SCAN-3:A subtests and the HINT conditions, with the *p*-value denoted in parentheses. A statistically significant negative correlation was found between the MLR speech test and HINT composite scores ($r = -0.6111$, $p \leq 0.01$). Similarly, there was a statistically significant negative correlation ($p \leq 0.05$) between the MLR speech tests composite score and each of the HINT conditions. As for the individual MLR speech tests, statistically significant relationships were found between the HINT composite score and each of the subtests ($p \leq 0.05$), with the exception

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of CS. Other statistically significant relationships were found between the FW subtest vs. the HINT quiet (Figure 8) and between FW vs. HINT noise left thresholds ($p \leq 0.01$). The CW-DE subtest vs. HINT noise right and left thresholds ($p \leq 0.05$) revealed a statistically significant relationship, as did the TCS subtest vs. the HINT noise front, right, and left thresholds ($p \leq 0.05$).

Table 4 displays the relationship amongst the subtests of the SCAN-3:A, with the *p*-value denoted in parentheses. Statistically significant positive correlations were found between the CS and AFG 0 subtests ($p \leq 0.01$), CS and TCS subtests ($p \leq 0.01$), and TCS and FW subtests ($p \leq 0.05$).

Scatterplots were configured to display the relationship between the HINT composite score and the MLR speech test composite score (Figure 7), between the HINT composite score and each of the SCAN-3:A subtests (Figures 2-6), between the HINT quiet threshold and the filtered words subtest (Figure 8), and between the HINT quiet threshold and the MLR speech test composite score (Figure 9). The horizontal axis shows the HINT composite score from -2 to -8 dB SNR (Figures 2-7) or the HINT quiet threshold from 0 to 40 dBA (Figures 8-9). The vertical axis shows the subtest scaled score from 0 to 18 (Figures 2-6, 8) or the MLR speech test composite score from 0 to 50 (Figures 7, 9). Graph features include the line of best fit, 5th percentile cut-off points for the HINT composite score (Figures 2-7) and HINT quiet threshold (Figures 8-9), and SCAN-3:A subtest scaled score classifications of Normal/Borderline/Disordered (Figures 2-6, 8).

Figures 2 through 6 demonstrate that it was possible to pass the individual subtests of the SCAN-3:A but fail the HINT. In Figure 2, three subjects (10%) performed below normal limits for the HINT but scored within normal limits for the AFG 0 subtest. There

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were also two subjects (7%) who performed above normal limits for the HINT but within borderline limits for AFG 0. In Figure 3, two subjects (7%) performed below normal limits for the HINT but scored within normal limits for the FW subtest, and one subject (3%) performed below normal limits for the HINT and within borderline limits for FW. In Figure 4, three subjects (10%) performed below normal limits for the HINT but scored within normal limits for the CW-DE subtest, and there were also two subjects (7%) who performed above normal limits for the HINT but within borderline limits for CW-DE. In Figure 5, two subjects (7%) performed below normal limits for the HINT but scored within normal limits for the CS subtest, and one subject (3%) performed below normal limits for the HINT and within borderline limits for CS. In Figure 6, one subject (3%) performed below normal limits for the HINT but scored within normal limits for the TCS subtest, and there were also two subjects (7%) who performed above normal limits for the HINT and within borderline limits for TCS. Additionally, there were two subjects (7%) who performed below normal limits for the HINT and within borderline limits for TCS.

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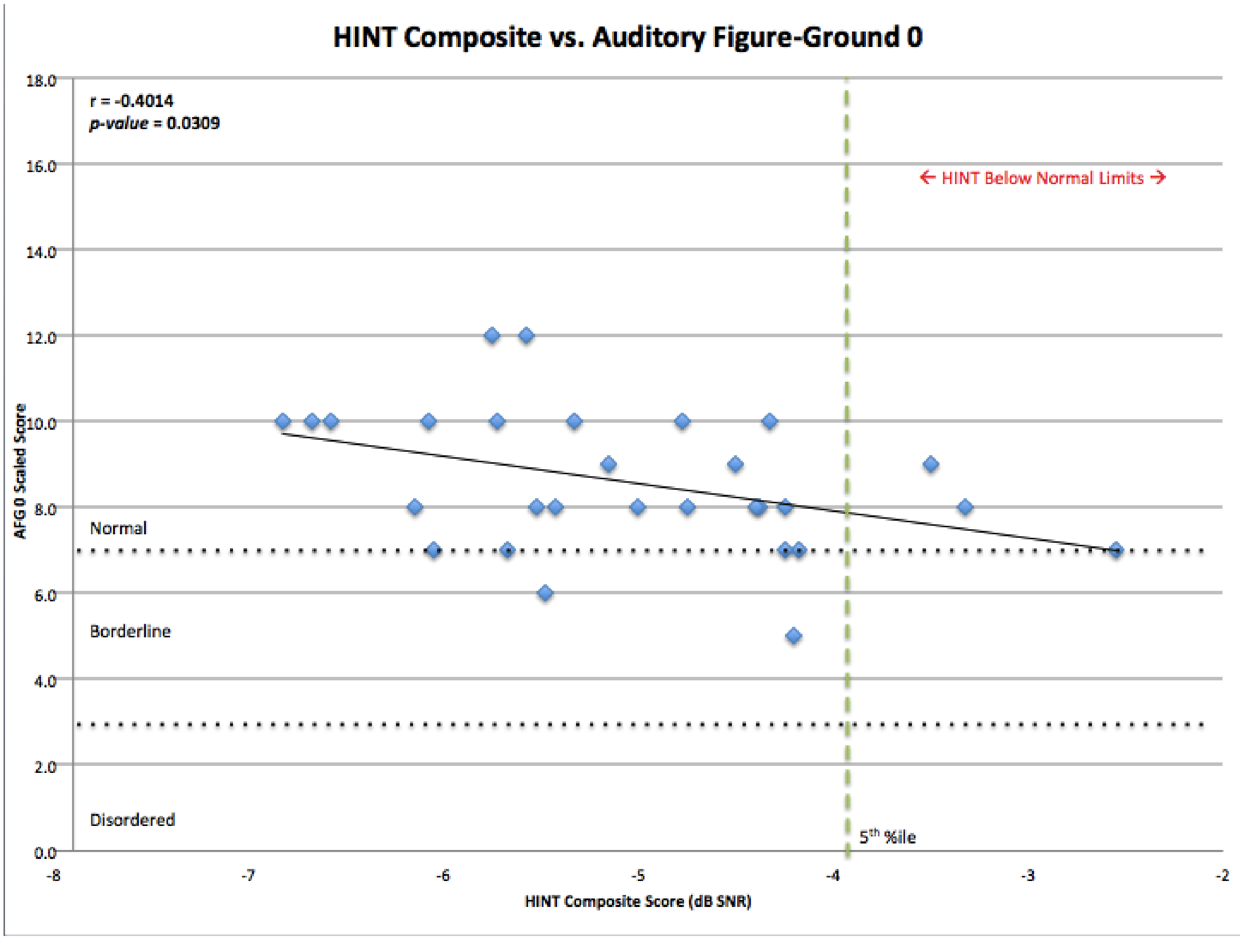

Figure 2. Scatterplot of Auditory Figure-Ground vs. HINT Noise Composite scores. The correlation coefficient (r) and *p*-values are shown.

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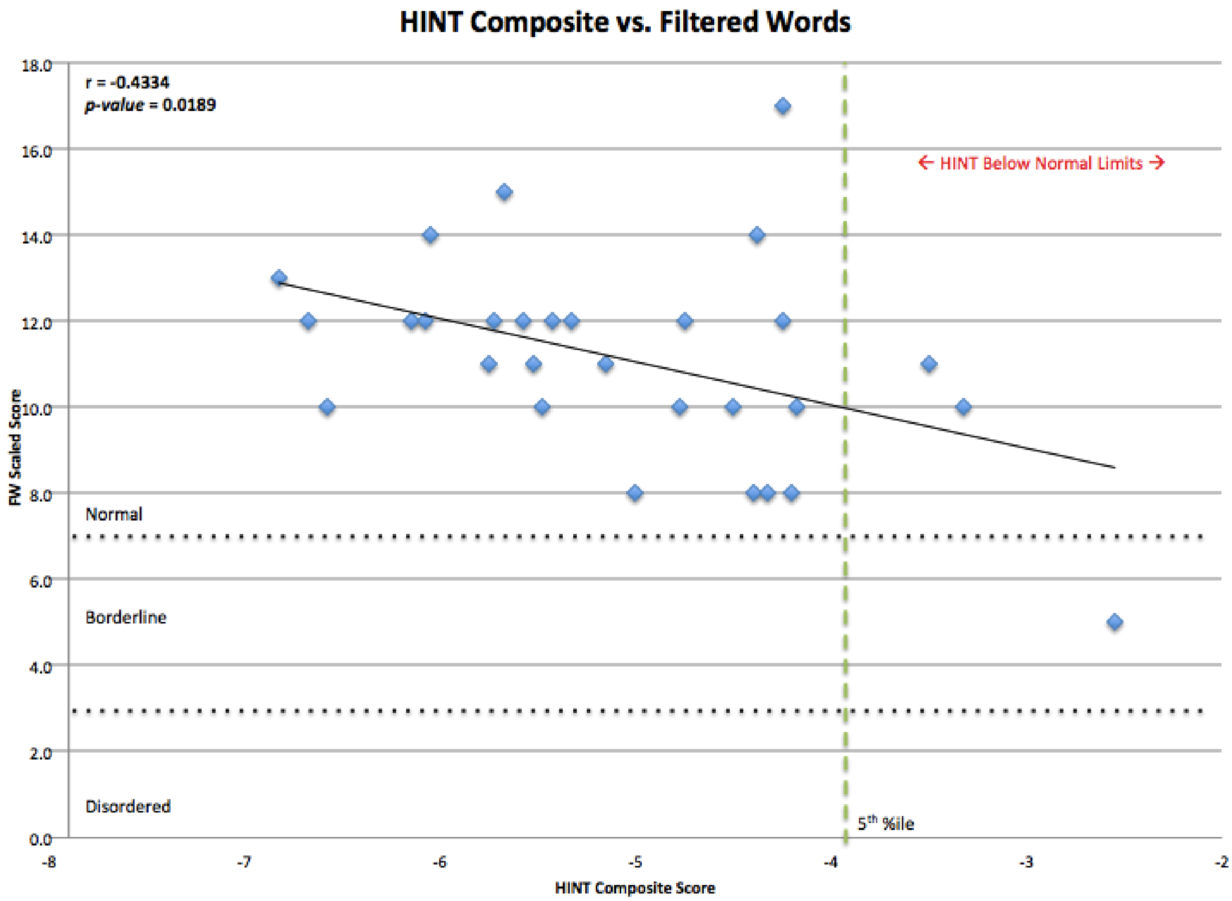

Figure 3. Scatterplot of Filtered Words vs. HINT Noise Composite scores. The correlation coefficient (r) and *p*-values are shown.

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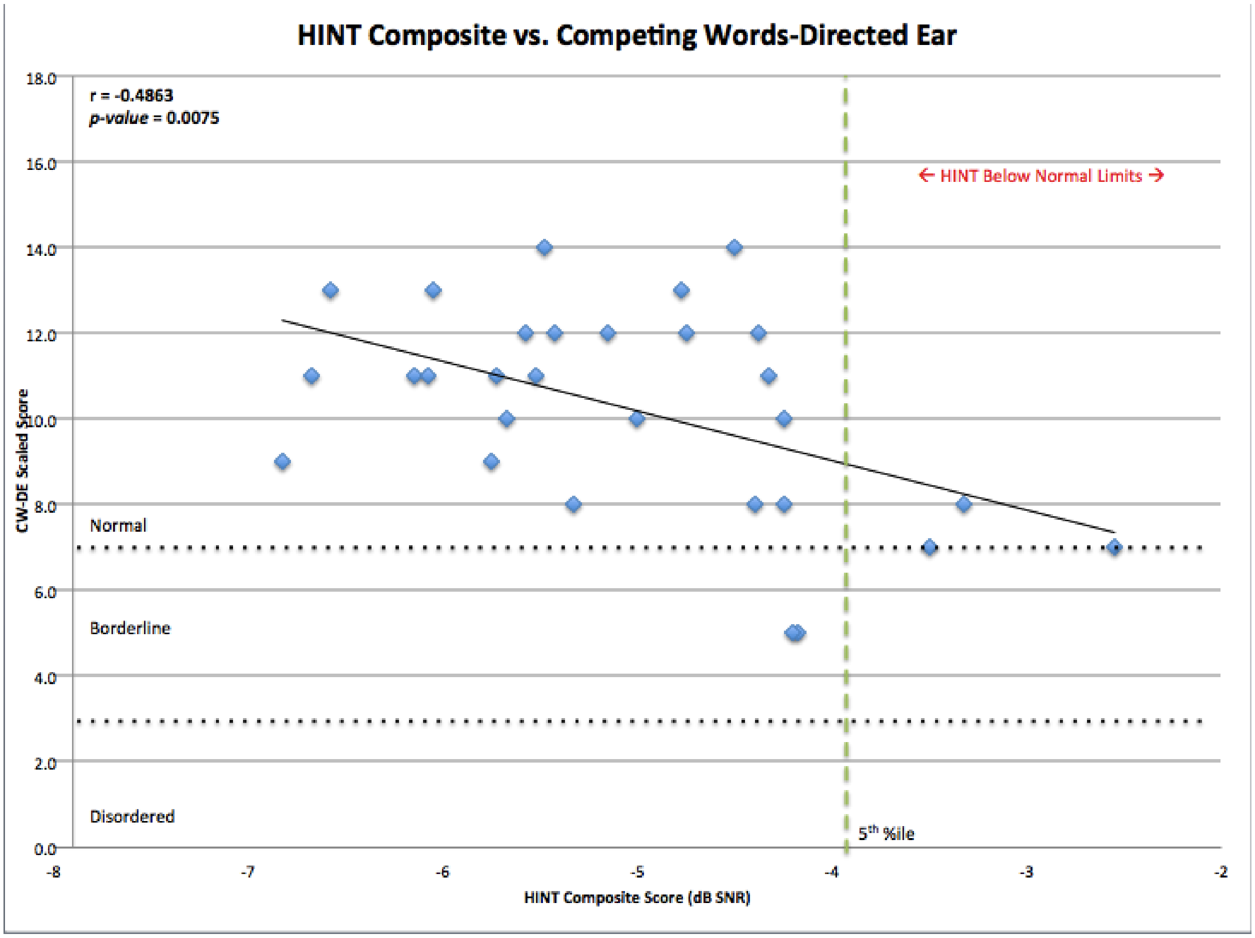

Figure 4. Scatterplot of Competing Words-Directed Ear vs. HINT Noise Composite scores. The correlation coefficient (r) and *p*-values are shown.

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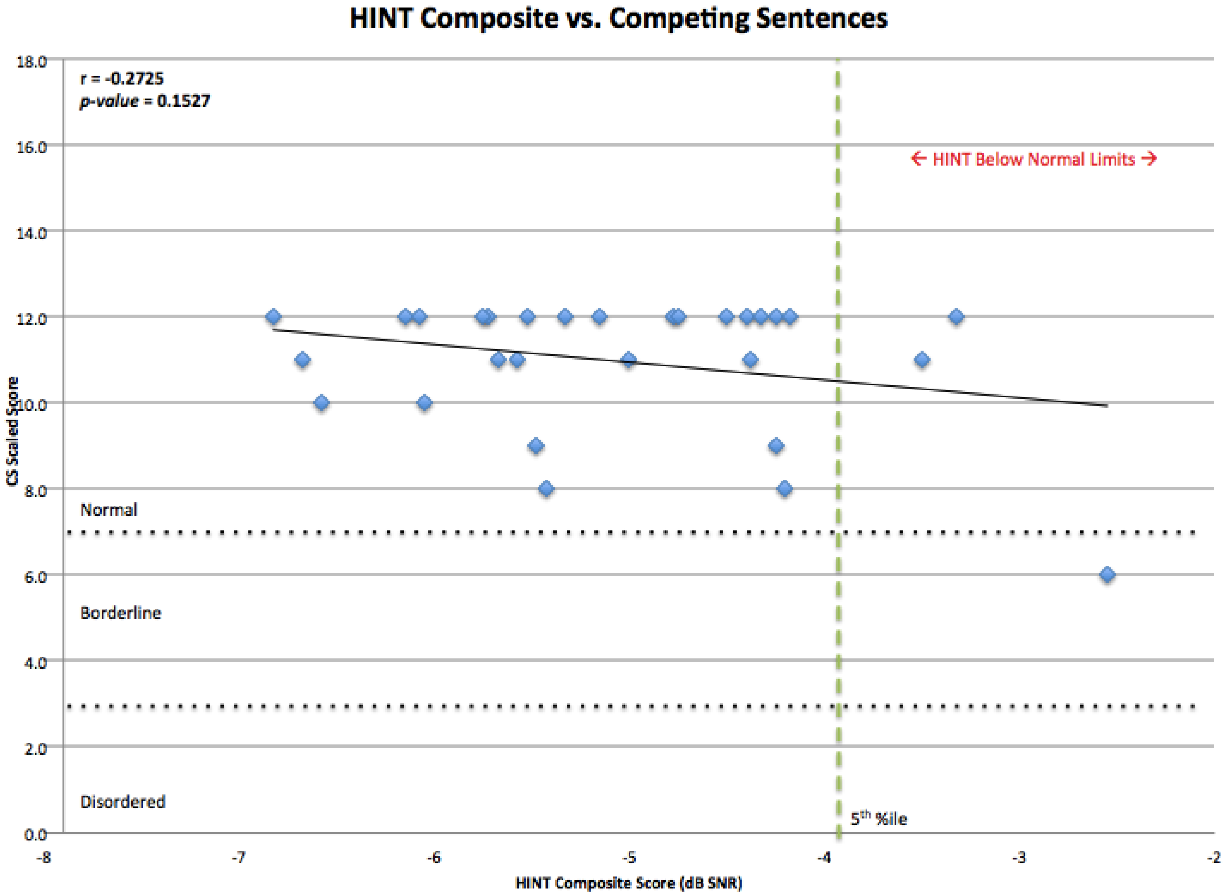

Figure 5. Scatterplot of Competing Sentences vs. HINT Noise Composite scores. The correlation coefficient (r) and *p*-values are shown.

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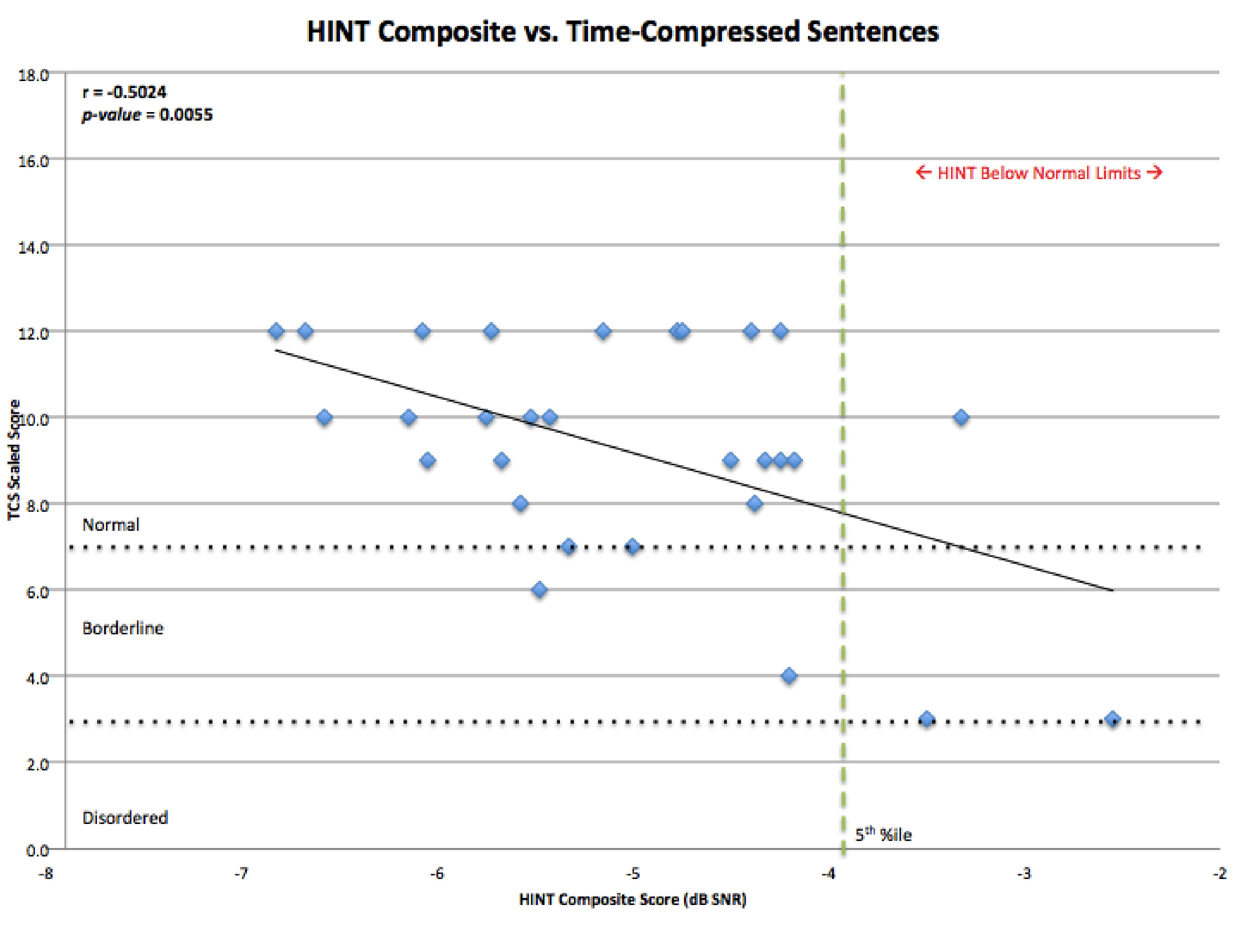

Figure 6. Scatterplot of Time-Compressed Sentences vs. HINT Noise Composite scores. The correlation coefficient (r) and *p*-values are shown.

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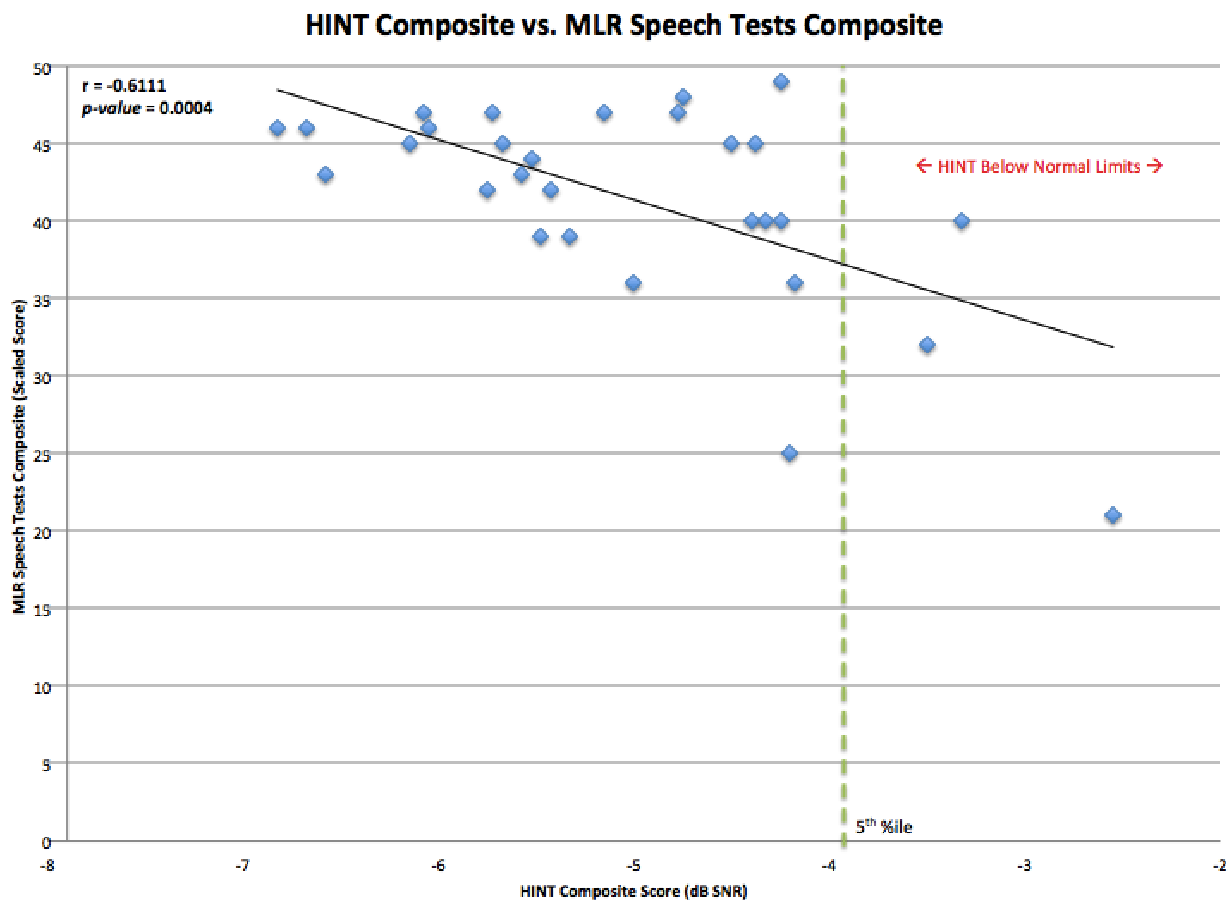

Figure 7. Scatterplot of MLR Speech Test vs. HINT composite scores. The correlation coefficient (r) and *p*-values are shown.

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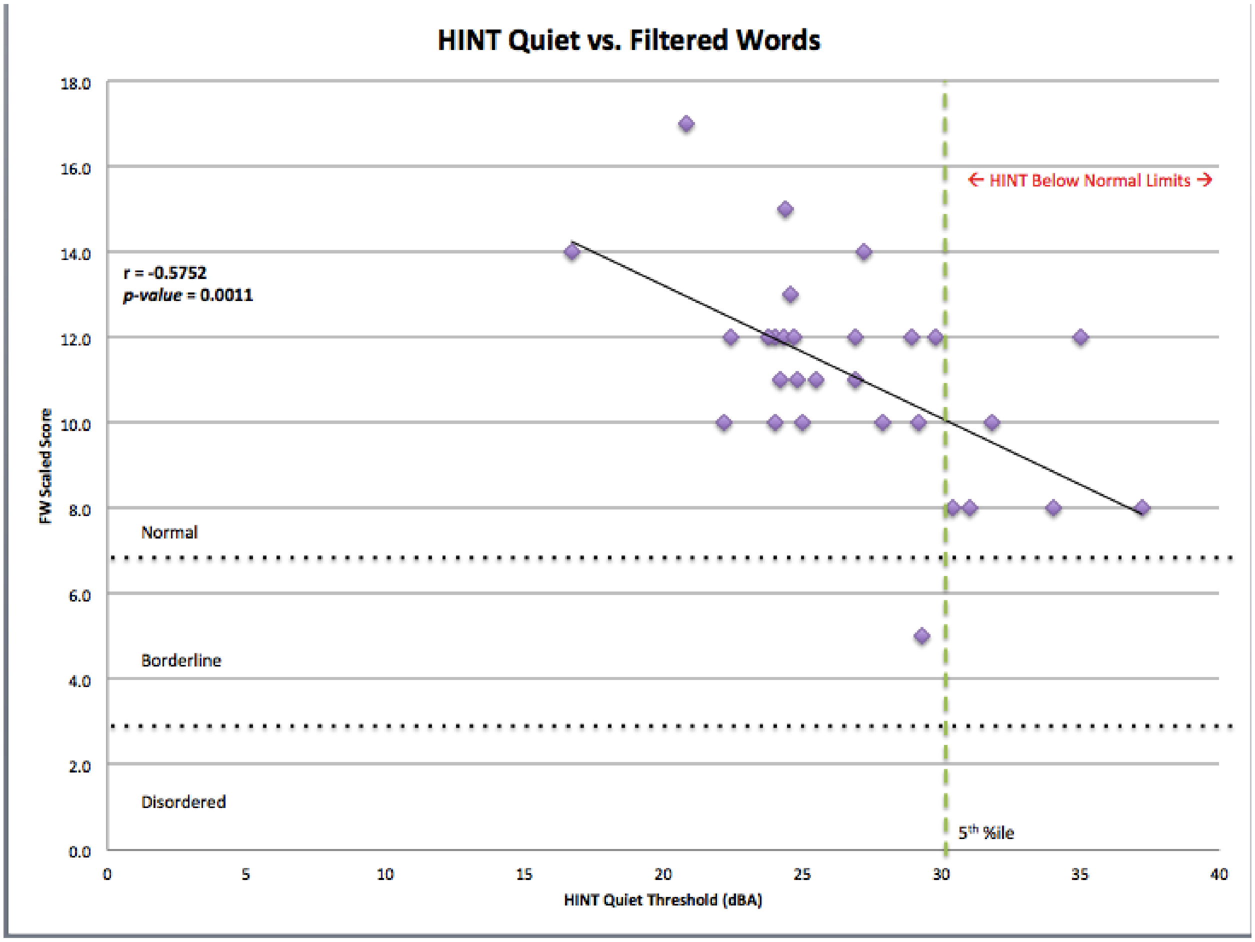

Figure 8. Scatterplot of scores for the Filtered Words test vs. HINT Quiet Thresholds. The correlation coefficient (r) and *p*-values are shown.

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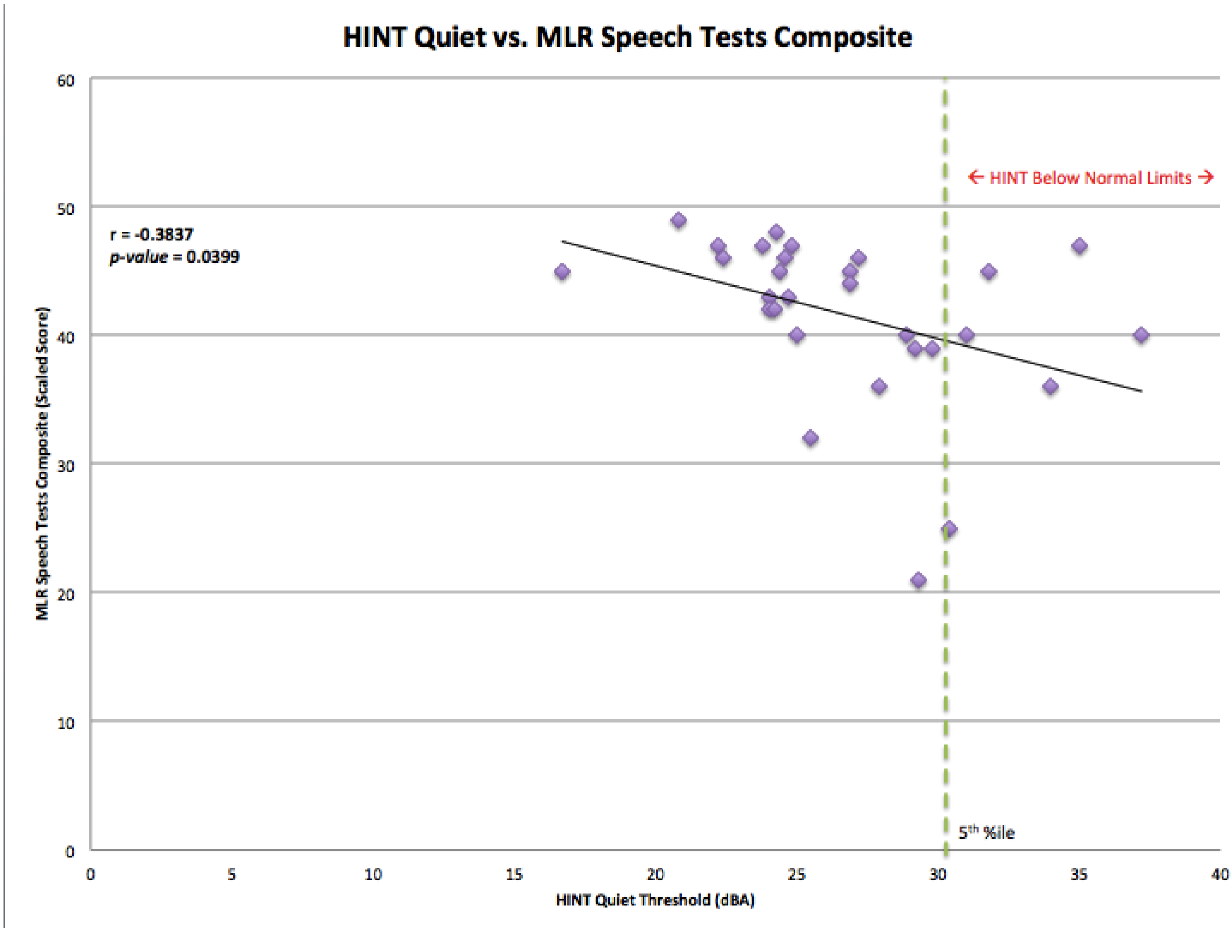

Figure 9. Scatterplot of MLR Speech Test Composite scores vs. HINT Quiet Thresholds. The correlation coefficient (r) and *p*-values are shown.

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Discussion

The goal of this study was to determine the relationship between performances on the MLR speech test battery (as part of the SCAN-3:A) and performances on the HINT. It has been suggested by AAA (2010) and Bellis & Anzalone (2008) that poor performances on MLR speech tests, such as filtered words, dichotic speech, and compressed speech, would necessitate intervention for an SRN disorder. This implies that the MLR tests are sensitive to the presence of an SRN disorder. Recall that the HINT was used to determine the presence of an SRN disorder in the present study.

The hypothesis stated that there would be no significant relationships between the two test batteries because they measure different types of auditory functions. However, the test results do not support this hypothesis, as statistically significant relationships were found between performances on the MLR speech tests and the HINT. Even so, the results demonstrate that it is possible to score below normal limits for the HINT and yet score within the normal range for the MLR subtests of the SCAN-3:A. Thus, a recommendation of intervention for a SRN disorder based solely on MLR test results may be inappropriate.

Two subjects (7%) scored within the borderline range for the AFG 0, CW-DE, and TCS subtests of the SCAN:3-A, thus possibly detecting an SRN disorder, but performed above normal limits on the HINT. Likewise, all of the subtests of the SCAN-3:A did not detect an abnormal performance (borderline or disordered) for a few subjects (1-3, depending on the subtest) who scored below normal limits for the HINT. However, because these SCAN-3:A subtests (AFG 0, CW-DE, TCS) showed borderline performances when the HINT scores were normal, this implies that the SCAN-3:A provides information about auditory function not available from the HINT.

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A ceiling effect was found for two of the subtests: CS and TCS. A ceiling effect occurs when test performances reach the maximum level of 100%. For the competing sentences and time-compressed sentence subtests, although their maximum raw score values vary, they share a maximum scaled score of 12. 16 subjects scored the maximum score in the CS subtest, whereas 9 subjects scored the maximum score in the TCS subtest. This ceiling effect results in poor sensitivity to variation in test performance.

The results of this study are not in agreement with the current literature on relationships amongst APD tests. This study found statistically significant correlations between the following subtests: CW-DE vs. AFG 0 (dichotic words/speech in noise), TCS vs. FW (time-compressed speech/filtered speech), and TCS vs. CS (time-compressed speech/dichotic listening). Versfeld & Dreschler (2002) found a significant relationship between speech in fluctuating noise (AFG 0) vs. time-compressed speech (TCS), which does not match the results of this study. Similarly, Keith et al. (1989) found a significant correlation between dichotic words (CW) vs. dichotic sentences (CS), but did not find a significant correlation between filtered speech (FW) vs. dichotic sentences (CS) or speech in noise (AFG) vs. dichotic sentences (CS). This study also found neither significant relationships between the FW vs. CS/AFG vs. CS nor a significant relationship between CW vs. CS, the latter of which is in contrast to Keith et al. (1989).

Performance on the MLR subtests of the SCAN:3-A should not be used to determine SRN ability, as characterized by the HINT. This is in contrast to the AAA (2010) recommendation to determine the need for an FM system from the MLR tests. Keith (2009) stated that while the SCAN-3:A continues to be used for APD screening purposes, it cannot

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be recommended for diagnostic determinations. Therefore, using the MLR speech tests in order to determine the need for intervention for a SRN disorder may not be appropriate.

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Conclusion and Future Direction

Overall, our hypothesis was refuted based upon the statistically significant correlation between the MLR and HINT composite scores. Even so, the results demonstrated poor sensitivity to a speech recognition in noise disorder as determined by the HINT. While a statistically significant relationship between the MLR and HINT batteries was found, clinicians should be cautious when inferring the presence of an SRN disorder from the MLR test results. Future research will formally investigate the diagnostic accuracy of the MLR speech test battery for an SRN disorder using the HINT as the reference standard.

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