Interlist Equivalency of the Northwestern University Auditory Test No. 6 in Quiet and Noise with Adult Hearing-Impaired Individuals

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Abstract

The purpose of the study was to determine the influence of sensorineural hearing loss and broadband noise on the interlist equivalency of the Northwestern University Auditory Test No. 6 (NU-6). There were two groups of participants: the first group consisted of 14 adults with mild-to-moderate hearing loss (mean age = 56 years; SD = 4.83); the second group consisted of 11 age-matched, normal-hearing individuals (mean age = 55 years; SD = 4.69). Each group heard the four lists of the NU-6 in quiet and in broadband noise at four signal-to-noise ratios (−10 dB, −5 dB, 0 dB, and +5 dB). The NU-6 stimuli were presented at 35-dB sensation level relative to each listener's speech reception threshold. Results indicated that, for both groups, there was a significant main effect for NU-6 list. Post hoc single degree of freedom contrasts revealed that this main effect was due to significant differences between some of the lists when presented in background noise. There were no differences between the lists in quiet. Because of the findings of differences between some of the lists in noise, the authors suggested that clinicians or researchers use caution when comparing scores obtained from two different NU-6 lists over time. That is, if scores from two lists are different, it is important for the clinician to determine whether this disparity is due to a change in word recognition ability or simply due to a difference between the lists.

Key Words: Broadband noise, list equivalency, normal hearing, Northwestern University Auditory Test No. 6, sensorineural hearing loss, word recognition

Abbreviations: NU-6 = Northwestern University Auditory Test No. 6, SNR = signal-to-noise ratio, SRT = speech reception threshold

Numerous word recognition measures are available for use by audiologists as a part of the basic audiometric battery of tests. One set of materials, the Northwestern University Auditory Test No. 6 (NU-6), has been used increasingly over the past 2 decades (Martin and Sides, 1985; Martin and Morris, 1989; Martin and Champlin, 1998). In a recent survey, Martin et al (1998) reported that 44 percent of audiologists surveyed use the NU-6 test materials.

Tillman and Carhart developed the current NU-6 materials, which were an expansion of an earlier test reported by Tillman et al (1963). The NU-6 stimuli are monosyllables having a consonant-nucleus-consonant construction taken from lists originally developed by Lehiste and Peterson (1962). The current version of the NU-6 is comprised of four lists with 50 words per list.

An important aspect of the reliability of multiple-list word recognition tests involves list equivalency. Several researchers investigated the relative equivalence of the NU-6 lists in quiet and found the stimuli to be equivalent for both hearing-impaired and normal samples (Tillman and Carhart, 1966; Rintelmann et al, 1974; Wilson et al, 1976, 1990; Stuart et al, 1994).

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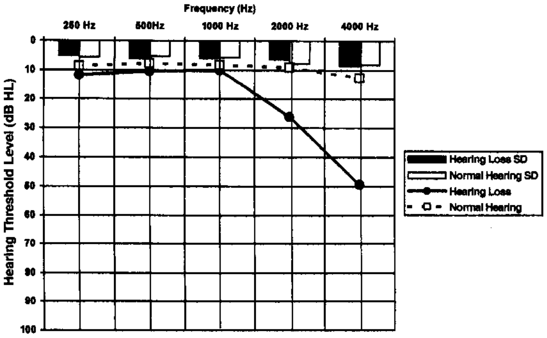

Figure 1 Mean hearing threshold levels from 250 Hz to 4000 Hz with standard deviation bars for normal-hearing and hearing-impaired individuals.

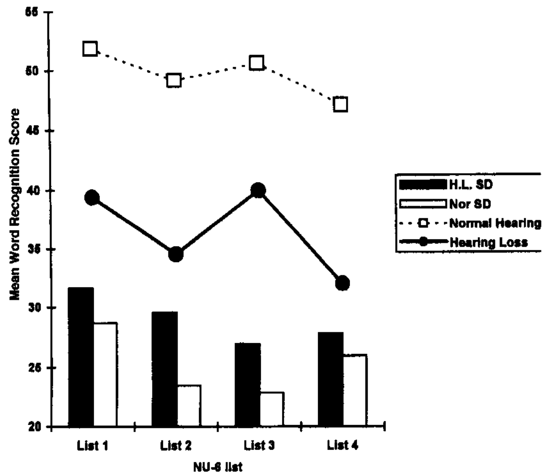

Figure 2 The main effect for NU-6 list in the noise condition with standard deviation bars for the normal-hearing and hearing loss groups.

Other researchers have investigated the relative equivalence of the word lists in the presence of background noise and found that background noise may alter list equivalency (Schubert and Stenhjem, 1978; Gengel et al, 1981; Loven and Hawkins, 1983; Ripply et al, 1983; Chermack et al, 1984, 1988). These studies showed that when noise is added to word recognition materials, the noise interacts with individual words to produce an effect greater than one would predict based on the presence of noise alone. Since the items in each word list are different, noise has differential effects on each list, resulting in a decrease in list equivalency. In contrast to the above findings, Stuart et al (1994) found that noise had a minimal effect on NU-6 list equivalency. These authors investigated the performance of young normal-hearing persons on the NU-6 lists in noise and found small differences between the lists that were clinically irrelevant.

The above studies used normal-hearing individuals when examining the effects of noise on list equivalency. It was of interest to investigate the effect of background noise on NU-6 list equivalency using hearing-impaired individuals. It is well known that background noise has a pronounced effect on word recognition in individuals with cochlear hearing impairments (Cooper and Cutts, 1971; Keith and Talis, 1972; Cohen and Keith, 1975; Findlay, 1976; Quist-Hanssen, 1979; Beattie, 1989). Factors identified as being responsible for increased impairment in background noise for hearing-impaired individuals include reduced auditory sensitivity (Crandall, 1991; Stuart, 1995), frequency selectivity and temporal processing (Crandall, 1991; Moore, 1991; Stuart, 1995), and loudness recruitment (Moore, 1991).

Cochlear hearing impairment presents a complex of symptoms that may have an influence on word recognition performance in noise. Although studies have shown that word recognition lists are equivalent when administered to people with hearing loss in quiet settings, it cannot be assumed that these lists are necessarily equal when administered in the presence of background noise. An extensive review of literature revealed no information involving list equivalency of the NU-6 in background noise using hearing-impaired persons as participants. Therefore, the purpose of the study was to investigate the combined effects of sensorineural hearing loss and broadband noise on the list equivalency of the NU-6.

METHOD

Participants

Twenty-five individuals participated in the experiment. The hearing loss group consisted of 14 individuals (11 males and 3 females; mean = 56 years, SD = 4.64, range = 48–65 years); the normal-hearing group consisted of 11 individuals (seven males and four females; mean = 55 years, SD = 4.55, range = 49–62 years). An unpaired t-test revealed that the two groups did not differ with regard to mean age ($t[23] = .490$; $p = .6245$). One ear was tested from each individual. To be included in the study, participants met one of the two sets of criteria described below.

Table 1 Significant List Differences at Each Signal-to-Noise Ratio as a Function of Hearing Status

	Signal-to-Noise Ratio				
	−10	*−5*	*0*	*+5*	*Quiet*
Hearing loss group	2 < 3** 4 < 3*	No significant difference	4 < 1** 4 < 2* 4 < 3***	2 < 1* 4 < 1**	No significant difference
Normal-hearing group	3 < 1*	4 < 1** 4 < 2** 4 < 3**	No significant difference	2 < 1** 3 < 1*	No significant difference

"4 < 1" means that performance on list 4 was significantly poorer than performance on list 1, and so on.
*$p < .05$, **$p < .01$, ***$p = .0001$.

Participants in the hearing loss group had pure-tone air-conduction thresholds of 60 dB HL or better at 4000 Hz, 40 dB HL or better at 2000 Hz, and 25 dB HL or better from 250 Hz to 1000 Hz. Bone-conduction thresholds agreed with air-conduction thresholds. That is, air–bone gaps were less than 10 dB. Mean hearing threshold levels for the hearing loss group are illustrated in Figure 1.

Participants in the normal-hearing group had pure-tone air-conduction thresholds better than 25 dB HL from 250 to 4000 Hz in at least one ear. There were no significant air–bone gaps for the test ear. Mean hearing threshold levels for the group with normal hearing are also illustrated in Figure 1.

All participants had normal middle ear status in the test ear as determined from the following criteria: (a) normal tympanometry and absolute immittance and (b) ipsilateral acoustic reflex thresholds better than 100 dB HL at 1000 Hz and 2000 Hz.

Stimuli

Test stimuli consisted of custom two-channel compact disc recordings (Stuart, 1998) of the Department of Veterans Affairs (VA) (1989) female talker version of the NU-6. Channel one contained the original VA NU-6 recordings that were edited to remove the carrier phrase and to reduce the interstimulus interval from 4.2 to 3.0 seconds. Channel two contained a computer-generated continuous broadband noise. The spectrum of the continuous broadband noise was confirmed to be flat within 2 dB from 100 to 8000 Hz. The speech and noise stimuli were normalized to have equal power. For more detail and description regarding the construction of the test materials, see Stuart et al (1994).

Apparatus

The test was conducted in a sound-treated audiometric suite (Industrial Acoustics Corporation) that met American National Standards Institute specifications for permissible ambient noise (ANSI, 1977). The recorded NU-6 stimuli were routed from a stereo compact disc player (Sony Model 608ESD) to a clinical audiometer (Grason Stadler GSI 61 Model 1761) and presented to participants through TDH-50P supra-aural earphones with Telephonics Corp P/N cushions. The output of the stimuli was monitored via the audiometer's VU meter.

Procedure

First, each participant's pure-tone air-conduction thresholds, speech reception thresholds (SRTs), and middle ear status were determined. Next, each participant performed the Mini Mental State (Folstein et al, 1975), which is a quick measure of cognitive state (i.e., memory, orientation, attention, sentence writing ability, ability to name items, and ability to copy complex objects). Upon passing the Mini Mental State (i.e., a score greater than 24), one of the participant's ears was presented the four lists of the NU-6 in a quiet condition and in the presence of ipsilateral, continuous, broadband noise at each of the following signal-to-noise ratios (SNRs): −10, −5, 0, and +5 dB. All speech stimuli were presented at 35-dB sensation level (SL) relative to the test ear's SRT. The participant's task was to repeat each word as it was presented to him/her. The percentage of words correctly identified by each participant at each

SNR and in the quiet condition was the dependent variable. The order of presentation of the four word lists and the SNR (including the quiet condition) was determined randomly. A 10-minute break was given to the participants halfway through the testing session.

RESULTS

Responses were scored as total whole word percent correct for each word list. The proportional scores were transformed into rationalized arcsine units (i.e., a simple linear arcsine transformation) (Studebaker, 1985) prior to inferential statistical analyses.

Because the purpose of the study was to investigate list equivalency of the NU-6 in the quiet and in noise conditions for both normal-hearing and hearing-impaired participants, separate one-way, within-subjects analysis of variance procedures were performed for each group of participants in each condition. The within-subjects factors in these analyses were NU-6 list and SNR. Only statistics relevant to the study of list equivalency are reported below.

Results showed that the lists were similar in quiet for both groups of listeners. That is, there were no significant main effects for NU-6 list for either the normal-hearing ($F [3, 30] = 1.507$; $p = .233$) or the hearing-impaired group ($F [3, 39] = .385$; $p = .764$). Conversely, the results revealed differences between the lists in the noise condition for both groups of listeners. That is, there were significant main effects for NU-6 list for both the normal-hearing ($F [3, 30] = 3.983$; $p < .05$ and hearing-impaired ($F [3, 39] = 7.817$; $p < .01$ groups.

The four NU-6 lists were found to be equivalent in the quiet condition for both groups of participants. These differences, which are illustrated in Figure 2, showed that, regardless of hearing status, scores for lists one and three were similar to each other and higher than scores for lists two and four.

To further examine potential list differences for each SNR and in quiet, post hoc single degree of freedom contrasts were performed for both the normal-hearing and hearing-impaired listeners (Table 1). As mentioned before, there were no list differences in quiet regardless of hearing status. However, there were differences at some of the SNRs. For example, at 0-dB SNR, the hearing loss group scored significantly lower on list four in comparison to lists one, two, and three. Apparently, hearing-impaired listeners found list four to be the most difficult when it was mixed with a 0-dB SNR broadband noise.

DISCUSSION

In the present study, the four lists of the NU-6 were presented to older people with hearing loss and to an age-matched group of normal-hearing individuals. Each participant heard the lists in quiet and in the presence of broadband noise at several SNRs (i.e., –10, –5, 0, and +5 dB). The purpose of the study was to investigate the interlist equivalency of the NU-6 in quiet and in noise for both the normal-hearing and hearing-impaired listeners. It was hypothesized that (a) list equivalency would be maintained in the quiet listening situation for both groups of listeners, (b) list equivalency would be reduced in the noise setting for individuals with sensorineural hearing loss, and (c) list equivalency would be maintained in the noise condition for normal-hearing individuals. With this pattern of findings, it could be reasoned that sensorineural hearing loss affected the interlist equivalency of the NU-6.

Results confirmed the first hypothesis. That is, the lists were equivalent in the quiet condition for both the normal-hearing and hearing loss groups. This finding is consistent with previous research (Tillman and Carhart, 1966; Rintelmann et al, 1974; Wilson et al, 1976, 1990; Stuart et al, 1994). Results also confirmed the second hypothesis. That is, there were differences between the NU-6 lists in noise for the hearing loss group. Results failed to confirm the third hypothesis. That is, there were unexpected differences between the lists when presented to the older normal-hearing listeners in the presence of background noise. This is consistent with the findings of Loven and Hawkins (1983), who found differences between the lists of the CID W-22 in multitalker noise, but is contrary to that of Stuart et al (1994), who found that the NU-6 lists were clinically equivalent when presented to young listeners with normal hearing in noise. Two methodological differences between Stuart et al (1994) and the present study might explain the discrepant results. The first difference was that Stuart et al used young normal-hearing listeners as participants; the present study used older normal-hearing listeners. The second difference was that Stuart et al used a male talker version of the NU-6; the present study used a female talker version of the NU-6.

Two possibilities might explain why the lists were similar in quiet but different when presented in noise. First, subtle list differences might have existed that were evident only when the lists were presented in noise. Second, noise might have interacted with sensorineural hearing loss/aging effects to change the relative difficulty of the lists. These two possibilities are explained in more detail below.

Concerning the first possibility, recording or talker differences (Sherbecoe et al, 1993) between the lists could have made some lists more difficult than others. For example, the overall rms sound pressure level of one list could have been slightly below that of the other lists because of recording/talker factors. It is possible that these differences were not revealed in the quiet condition because of the abundance of acoustic information that was available to the listener. It is also possible that, in the noise condition, noise masked important acoustic information in the lists with lower overall sound pressure levels, which would make them more difficult. A long-term spectral analysis of each list would need to be performed to pick up any subtle list differences that might exist as a result of recording/talker differences.

Concerning the second possibility, it has been shown that deficits related to temporal processing, frequency selectivity, loudness recruitment (Crandall, 1991; Moore, 1991; Stuart, 1995), and/or aging effects (Moore, 1991; Stach et al, 1991) may impair speech perception in noise. The list differences found in the present study could be explained as follows. Certain articulatory features of the word stimuli in the lists may have been adversely affected by the synergistic effect of broadband noise (Loven and Hawkins, 1983) and hearing loss/aging. If one list contained more of these articulatory features, then, conceivably, it would be more difficult than other lists with fewer of these articulatory features. To confirm this speculation, errors would have to be analyzed at the word level to determine if certain words were more difficult for hearing-impaired/older individuals when presented in the presence of background noise.

It is tempting to suggest, from the combined results of the present study and the Stuart et al (1994) study, that age affects the list equivalency of the NU-6 in noise. Before such a conclusion could be made, young normal-hearing listeners would have to be tested using the identical materials and methods of the present study. These results could then be compared to the results from older normal-hearing listeners to determine if such effects of age exist.

The list differences found in the present study, regardless of their cause, were clinically relevant. This interpretation is based on three lines of evidence. First, the magnitude of the main effect for NU-6 list in noise was large, accounting for 28 percent of total data variance. Second, mean list differences exceeded 10 percent at some SNRs, which was judged to be large. Third, there was consistency in the list differences. That is, regardless of hearing status, lists one and three in noise were similar to each other and easier than lists two and four (see Fig. 2).

The results of the present study have certain clinical/research implications. Most importantly, if an audiologist plans on using two different NU-6 word lists to test word recognition ability in noise over time, then the lists chosen should be similar. Table 1 may be a good reference to determine which lists are significantly different at each SNR. As an example, if testing a hearing-impaired individual in broadband noise at 0-dB SNR, one should not compare lists that are different (e.g., lists one and four). Similar lists should be used (i.e., lists one and three).

The list differences found in this study apply only to the materials and noise stimuli used in this study. Sherbecoe et al (1993) showed that the spectra of the NU-6 stimuli differ considerably, depending on the speaker and the recording procedure. Sperry et al (1997) showed that different types of noise have different effects on the NU-6 articulation functions. Thus, when using different recordings or NU-6 stimuli, caution is recommended when interpreting differences between lists.

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