ORIGINAL ARTICLE

# Speech Audiometry: The Development of Modern Greek Word Lists for Suprathreshold Word Recognition Testing

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*Submitted:* 10 February, 2006
*Revised:* 12 May, 2006
*Accepted:* 28 June, 2006

Mediterr J Otol 2006; 3: 117-126



The existing suprathreshold word recognition tests in Greece are of limited value in audiometric speech evaluation that is performed in audiology clinics. One reason for this is that none of the lists approximates phonemic balance. Another reason for the limited value of the existing tests is related to word familiarity. In this study, a valid speech test for determining the word recognition score in Modern Greek-speaking populations has been developed. The test material consists of 4 lists, each of which contains 50 open-set bisyllabic words. Monosyllabic words were not included because few exist in the Modern Greek language. The lists are phonemically balanced and are of approximately equal difficulty. Preliminary results of the test in 10 native Greek-speaking subjects whose hearing was within the normal range suggest that the lists are generally equivalent for clinical purposes. This study can be used as a guideline for the development of word recognition score testing materials in other languages.

A primary purpose of human auditory function is to enable speech. As a result, speech can be used to assess auditory function. Speech audiometry that is properly conducted with calibrated equipment and standardized recorded speech material can be a useful tool for audiologic testing. A typical speech audiometric evaluation usually includes 2 measures. The first, which is a threshold for the identification of speech material, is called the speech recognition threshold (SRT). The second is the maximum word recognition score (WRS, PBmax), which is determined at suprathreshold intensities under optimum conditions. Various speech materials are used to obtain each of these measurements with maximum accuracy. The testing materials differ among languages because of differences in phonetic, syntactic, and semantic rules[1].

Suprathreshold word recognition testing has traditionally been performed for several reasons: to assess the degree of social handicap, to aid in the diagnosis of an auditory impairment by providing useful site-of-lesion information, to monitor rehabilitation, and to compare hearing aid performance[2].

Lists for WRS testing in Greece were first developed several decades ago. Kogias (1961) developed 6 lists of 40 words each[3]. Manolidis (1964) constructed 5 lists of 30 words each[4]. Kastelis developed 10 lists of 10 words each "These findings have been verified (G. Kastelis, MD, unpublished data). Iliades and colleagues developed 24 lists, each of which consists of 10 words (some of which are common) that are based primarily on the words used by Manolidis[5]. Words from the above 45 lists are used for both SRT and WRS testing.

An analysis of phonemic balance and familiarity of words in all of the above lists revealed the following findings: Phonemic balance does not approximate everyday speech in all of the lists, familiarity (ie, ratings from 50 male and 50 female judges [average age, 40.65 years; SD, 12.87] on a 3-point scale of familiarity) was adequate (> 90%) in 28 of the 45 lists, and most lists consist of an inadequate number of items, which increases the variability of test scores.

These factors may have a negative effect on the accuracy of the existing measuring tools used to determine speech intelligibility (eg, tools used to differentiate the effectiveness of hearing aids or to determine the degree of communication impairment). Therefore, the existing speech corpora are of limited value for assessing auditory function in populations who speak Modern Greek. In our collective opinion, the current practices used for the clinical assessment of word recognition are in need of improvement.

Given this rationale regarding the existing tests in Greece for use in assessing speech intelligibility in the audiology clinic, the goal of this work was to develop a test typical of the circumstances of actual use. The specific aims of this study were as follows: to establish the frequency of occurrence of phonemes in Modern spoken Greek, to determine the word familiarity of list items, to construct word lists for suprathreshold word recognition testing, and to perform a preliminary investigation of list equivalence.

## MATERIALS AND METHODS

An analysis of English and Greek speech test literature led to the adaptation of the following criteria that were necessary for generating the word lists:

### Phonemic Balance (PB)

Phonemic balance is also referred to as "phonetic balance." There is a difference between phonemic and phonetic elements. Language works by associating meanings with sounds. Each language has a finite set of sounds from which the forms of utterances in that language are constructed. Phonemic elements (phonemes) are abstract concepts related to semantics. Phonetic elements (allophones) are the articulatory manifestations of phonemes. Thus, different allophones correspond to a particular phoneme. The difference between 2 sounds is said to be phonemic (or contrastive) if it can be used to distinguish one meaning from another[6]. Two allophones belong to 2 different phonemes if, in any word of a language, the substitution of one allophone for the other results in a change of the semantic content of the word. Differences in allophones, such those found in different dialects of a language, do not necessarily impede communication. Therefore, it is the phonemic rather than the phonetic balance that is relevant to speech perception [7].

The number of phonemes in any language depends on the method of determining phoneme versus allophone. The simplest way to demonstrate that the difference between 2 sounds is contrastive (ie, that the 2 sounds belong to separate phonemes) in a particular language is to find minimal pairs. A minimal pair consists of 2 words, phrases, or sentences with distinct meanings whose forms differ by only 1 sound. A study that used minimal pairs to evaluate the most frequent sounds in Modern Greek revealed that 30 sounds were contrastive[8]. Tables 1 and 2 show the phonemic inventory alphabet found suitable for use in our study.

**Table 1. Consonantal phonemes of Modern Greek**

**Place of Articulation**

| Manner of Articulation | Bilabial | Labiodental | Dental | Alveolar | Palatal | Velar |
|---|---|---|---|---|---|---|
| Plosive | p b<br>(π) (μπ) | | | t d<br>(τ) (ντ) | c<br>(κι) | k g<br>(κ) (γκ) |
| Nasal | m<br>(μ) | | | n<br>(ν) | ɲ<br>(νια) | |
| Trill | | | | r<br>(ρ) | | |
| Fricative | | f v<br>(φ) (β) | θ ð<br>(θ) (δ) | s z<br>(σ) (ζ) | ç j<br>(χι) (γι) | χ γ<br>(χ) (γ) |
| Affricate | | | | ts dz<br>(τσ) (τζ) | | |
| Lateral approximate | | | | l<br>(λ) | ʎ<br>(λια) | |

Moving from left to right correlates with how much toward the front or the back of the oral cavity the sounds are produced. The first symbol within a cell denotes an unvoiced sound (eg, "t"), and the second symbol denotes the corresponding voiced sound (eg, "d"). Each row of the table represents a sound quality (International Phonetic Association, 1999). Examples of Greek symbols are included in parentheses.

**Table 2. Vowel phonemes of Modern Greek**

**Tongue position in the Oral Cavity**

| Oral Cavity | Front | Center | Back |
|---|---|---|---|
| **Closed** | i (ι) | | u (ου) |
| **Partially closed** | | | **o** (ο) |
| **Partially open** | ε (ε) | | |
| **Open** | | **a** (α) | |

From left to right, the tongue moves from the front of the oral cavity (near the teeth) to the back of the oral cavity. In the top rows, the mouth is relatively closed, but in the bottom rows, the mouth is more open (International Phonetic Association, 1999). Examples of Greek symbols are included in parentheses.

To establish phonemic balance of the test lists, a large pool of data for everyday speech was created. It was important that the material to be selected was spoken rather than written, because the differences between spoken and written language can be great. This everyday distribution was represented by a phonemic analysis of 102,934 words obtained from 100 television and radio shows from the national Hellenic broadcasting station. All shows belonged to one of the following general categories: medical or health, psychology or human relations, culture, politics, theater or movies, music, education, economics, books, or athletics. Ten shows for each category were selected and were recorded. Each show consisted of about 1000 words. An analysis of the recordings revealed the frequency of occurrence of the 30 phonemes (Table 3).

Different phonemes should appear in the test material with the same relative frequency as that in

**Table 3. Frequency of occurrence of phonemes in Modern Greek and frequency of lists 1 through 4**

| | Phonemes IPA Symbol | Frequency of the Modern Greek | List 1 Frequency (%) | List 2 Frequency (%) | List 3 Frequency (%) | List 4 Frequency (%) |
|---|---|---|---|---|---|---|
| 1 | **a** | 12.3 | 12.32 | 12.21 | 12.21 | 12.21 |
| 2 | **e** | 10.4 | 9.48 | 9.39 | 9.39 | 9.39 |
| 3 | **i** | 14.2 | 14.22 | 14.08 | 14.08 | 14.08 |
| 4 | **o** | 9.49 | 9.00 | 8.92 | 8.92 | 8.92 |
| 5 | **u** | 2.50 | 2.37 | 2.35 | 2.35 | 2.35 |
| 6 | **r** | 4.18 | 4.27 | 4.69 | 4.23 | 4.23 |
| 7 | **θ** | 1.11 | 0.95 | 0.94 | 0.94 | 0.94 |
| 8 | **ð** | 2.04 | 1.90 | 1.88 | 1.88 | 1.88 |
| 9 | **b** | 0.26 | 0.47 | 0.47 | 0.47 | 0.47 |
| 10 | **d** | 0.54 | 0.47 | 0.47 | 0.47 | 0.47 |
| 11 | **ts** | 0.11 | 0.47 | 0.47 | 0.47 | 0.47 |
| 12 | **dz** | 0.02 | 0.47 | 0.47 | 0.47 | 0.47 |
| 13 | **p** | 4.36 | 4.27 | 4.23 | 4.23 | 4.23 |
| 14 | **m** | 3.69 | 3.79 | 3.29 | 3.29 | 3.29 |
| 15 | **f** | 1.28 | 1.42 | 1.88 | 1.88 | 1.41 |
| 16 | **v** | 0.88 | 0.95 | 0.47 | 0.94 | 0.94 |
| 17 | **t** | 7.54 | 7.11 | 7.04 | 7.04 | 7.04 |
| 18 | **z** | 0.54 | 0.95 | 0.94 | 0.94 | 0.94 |
| 19 | **s** | 7.68 | 7.58 | 7.51 | 7.51 | 7.51 |
| 20 | **n** | 6.17 | 6.16 | 6.10 | 6.10 | 6.10 |
| 21 | **g** | 0.12 | 0.47 | 0.47 | 0.47 | 0.47 |
| 22 | **l** | 2.77 | 2.84 | 2.82 | 2.82 | 2.82 |
| 23 | **k** | 2.62 | 2.37 | 2.35 | 2.35 | 2.82 |
| 24 | **χ** | 0.60 | 0.95 | 0.94 | 0.94 | 0.94 |
| 25 | **γ** | 0.74 | 0.95 | 0.94 | 0.94 | 0.94 |
| 26 | **c** | 1.79 | 1.42 | 1.88 | 1.88 | 1.88 |
| 27 | **ç** | 0.88 | 0.95 | 0.94 | 0.94 | 0.94 |
| 28 | **j** | 0.98 | 0.47 | 0.94 | 0.94 | 0.94 |
| 29 | **ʎ** | 0.11 | 0.47 | 0.47 | 0.47 | 0.47 |
| 30 | **ɲ** | 0.10 | 0.47 | 0.47 | 0.47 | 0.47 |
| | Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

IPA, International phonetic alphabet[9].

everyday speech. According to that rationale, if the listener is totally unable to perceive a particular phoneme that occurs infrequently in normal everyday speech, the handicap that he or she experiences is not as severe as it would have been had the phoneme been a more common one[7]. Test lists are regarded as interchangeable if each has the same phonemic balance. Exact phonemic balance is not possible to achieve because each phoneme changes the phonemic balance by about 0.47% (see Table 3).

### Bisyllabic words

Tests for the measurement of maximum speech identification performance must consist of items with low redundancy, or the multiplicity of clues available to the listener can obscure some of the inability to differentiate speech sounds by their acoustic properties[7]. Therefore, monosyllabic word lists are widely used. Egan (1948) showed a relationship between the number of sounds in a word and the ability to recognize that word[10]. The more phonemes and the more acoustic redundancy that characterize a word, the more easily it is recognized. In our study, fulfillment of the criteria necessitated the use of bisyllables for the selection of list items, because an inadequate number of monosyllables exists in the Modern Greek language. However, all bisyllables selected were low in redundancy because we selected words with the minimum possible number of phonemes, thus keeping the number of phonemes as low as possible in each list. List 1 contains 211 phonemes, and lists 2 through 4 contain 213 phonemes each.

### Familiarity of material

To control familiarity, the 10,000 most frequent Greek lemmas were selected from the Hellenic National Corpus (HNC), which is the largest body of written Greek texts available over the Internet. The HNC, which is based on the general language corpus developed by the Greek Institute of Language and Speech Processing, currently contains about 32,000,000 words of written texts from several media (books, periodicals, newspapers, etc), from various genres (articles, essays, literary works, reports, biographies, etc), and on various topics (economy, medicine, leisure, art, human sciences, etc)[11]. Initially, for the construction of the test lists, 900 bisyllabic words were selected from this pool of data and from another 100 bisyllabic words (common words in everyday speech) that were not selected from any established source for familiarity. No database on the word familiarity of Greek words exists to the time of this writing.

To further improve the criterion of familiarity, only the most familiar words were included. The most familiar words were obtained from the ratings of 50 male and 50 female judges from 3 age groups (12-25 years, 26-50 years, and 51- 75 years; average age, 38.8 years; SD, 20.18) on a 3-point scale of familiarity. Words with a negative image (eg, terms associated with disease or criminality) were excluded. All 200 words selected to be in the final 4 lists were rated as most familiar.

### Variability of test scores

The variability of test scores depends on both the sample size (the number of scorable items in the test) and the level of performance (the percent correct). The smaller the test list, the larger the test-retest difference score needed to exceed the 95% confidence limits (binomial distribution model) for percentage scores. Confidence limits based on that relationship are used to determine whether 2-word recognition scores are significantly different from each other on an individual-patient basis[12, 13, 14]. If the difference between 2 scores is within the applicable confidence limits, then that difference cannot be considered statistically significant.

The only method of reducing variability and therefore increasing reliability is to increase the number of items on a test. However, the duration of the test is also an important factor to consider. To comply with the previously listed factors, the maximum number of words in each list was 50. For each word correctly understood, the patient received a score of 2%.

### Equal distribution of stress

Stress is a suprasegmental linguistic feature of speech. In many languages (including Greek), stress indicates which information in an utterance is most important. Stress emphasizes the most important syllable in a word, marks syntactic contrasts (phrase endings, interrogation versus declaration), signals attitudes and feelings[15], and highlights differences in meaning. For example, the first syllable in the noun **/jɛros/**, which means "old man" in Modern Greek, is likely to have a higher fundamental frequency and a greater duration and amplitude than that of the same syllable in the adjective **/jɛros/**, which means “strong.”

In Modern Greek, stress is placed on one syllable in multisyllabic words. The stressed vowels and consonantal phonemes in Modern Greek are phonetically slightly longer than those that are unstressed, but that difference is not distinctive[16]. A stressed phoneme will not cause the perception of a different phoneme and thus will not affect the phonemic balance. For example, the word **/jɛros/** can have, depending on the meaning, a stress that is placed on the first or the second syllable. In either case, the listener perceives the same 5 phonemes (**/j/**, /ɛ/, **/r/**, **/o/**, **/s/**).

It is important to remember that the more specific the items of the test lists, the more the test results reflect an accurate measurement of peripheral hearing. Linguistic competence substantially affects the results of tests using more information in the acoustic signal, such as heavily suprasegmental features (stress, intonation, duration), and such tests become a measure of both peripheral and central processes. As a result, we endeavored to distribute syllabic stress equally in each list. In every list, 25 words in which stress is placed on the first syllable were selected, as were 25 words in which stress is placed on the second syllable.

Phonemic dissimilarity

To ensure that every bisyllable selected in each list could not be easily confused with another bisyllable in the same list, there were no minimal pairs in each list with the stress on the same syllable. When the stress is on different syllables, there is a minimum difference of 1 phoneme.

Equal average difficulty

To examine list equivalency, the 4 lists were administered monaurally (to the right ear) at 10-dB increments (range, 10-40 dBHL) to 10 subjects whose hearing was within normal limits. All participants (average age, 23.1 years; SD, 1.73) were native speakers of Modern Greek and had no history or signs of a neurologic disorder. All had pure tone thresholds of ≤ 15 dB HL at all frequencies from 250 Hz to 8000 Hz. All testing was performed in a sound chamber that exceeded standards for the ambient noise level for audiometric rooms.

All words were recorded in a double-walled Industrial Acoustic Company booth by an adult male speaker with professional experience as a radio announcer. A professional unidirectional microphone, a FireWire Solo sound card interfaced to a PC computer, and digital signal processing software (Adobe Audition. Version 1. Adobe Systems Incorporated. San Jose, CA) were used for all recording and editing tasks. All words were monitored for minimum required suprasegmental features during recording. A carrier phrase with a 1-second interval separating the phrase from the target word was recorded before each word. A 5-second interval separated the presentation of each word. The words were digitized at a sampling frequency of 44.100K Hz and 16-bit resolution. The editing of each word involved equalization of the root mean square (RMS) amplitude that was scanned with a window width of 50 ms. Specifically, each average RMS power value, which represents the average power of the entire waveform selection and is a good measure of the overall loudness, was measured and was then multiplied by an appropriate dB factor to achieve the equal average RMS power value. In this way, each stimulus word was brought at an equivalent overall loudness level. A 1000-Hz calibration tone of 60 seconds’ duration was synthesized and scaled to the overall RMS level of the 200 test words.

## RESULTS

The initial four 50-word lists were reordered and adjusted numerous times so that the final 4 lists (Table 4) better satisfied the criteria of phonemic balance,

**Table 4. The final four Modern Greek word lists for use in suprathreshold word recognition testing.**

| List 1 | | | | List 2 | | | |
|---|---|---|---|---|---|---|---|
| Stress 1st syllable | | Stress 2nd syllable | | Stress 1st syllable | | Stress 2nd syllable | |
| IPA | Modern Greek | IPA | Modern Greek | IPA | Modern Greek | IPA | Modern Greek |
| kota | κότα | foni | φωνή | dzaci | τζάκι | celi | κελί |
| θima | θύμα | nisi | νησί | cefi | κέφι | epta | επτά |
| spiti | σπίτι | peði | παιδί | texni | τέχνη | boja | μπογιά |
| tiçi | τύχη | xara | χαρά | resta | ρέστα | tiri | τυρί |
| telos | τέλος | poto | ποτό | ðixti | δίχτυ | skufi | σκουφί |
| nici | νίκη | scia | σκιά | niçi | νύχι | miðen | μηδέν |
| treno | τρένο | sçini | σχοινί | pede | πέντε | γati | γατί |
| limni | λίμνη | xarti | χαρτί | anθos | άνθος | zoi | ζωή |
| erγo | έργο | mali | μαλλί | tria | τρία | kuti | κουτί |
| tsai | τσάι | vuli | βουλή | petsa | πέτσα | sira | σειρά |
| feta | φέτα | γlika | γλυκά | iʎos | ήλιος | ponos | πονός |
| zesti | ζέστη | afti | αυτί | sela | σέλα | esi | εσύ |
| etos | έτος | nero | νερό | θia | θεία | puli | πουλί |
| mati | μάτι | ðuʎa | δουλειά | mines | μήνες | ura | ουρά |
| pagos | πάγκος | θeos | Θεός | mana | μάνα | kako | κακό |
| beno | μπαίνω | papus | παππούς | miti | μύτη | ceros | καιρός |
| nanos | νάνος | krasi | κρασί | petra | πέτρα | efçes | ευχές |
| meli | μέλι | proi | πρωί | nota | νότα | γonis | γονείς |
| ðema | δέμα | timi | τιμή | pina | πείνα | laos | λαός |
| mera | μέρα | pezos | πεζός | jena | γέννα | moro | μωρό |
| kupa | κούπα | jakas | γιακάς | topi | τόπι | osta | οστά |
| ceo | καίω | vuno | βουνό | viða | βίδα | psomi | ψωμί |
| dzeni | Τζένη | eðo | εδώ | kuɲa | κούνια | lefta | λεφτά |
| teras | τέρας | naos | ναός | eðra | έδρα | gremos | γκρεμός |
| tenda | τέντα | eɲa | εννιά | zoni | ζώνη | palto | παλτό |

familiarity, and phonemic dissimilarity. Each of the new word lists consisted of 50 open-set bisyllables. Word recognition scores were assessed with the recorded materials. Comparison of the word recognition curves for mean scores and standard deviations of the 4 lists revealed that the lists were essentially equivalent for clinical purposes (Table 5).

Monaural (right ear) performance functions showed performance on the 4 lists at 4 hearing levels ranging from 10 dBHL to 40 dBHL in 10-dBHL increments. Mean word scores increased with an average slope per decibel of 3.37% in the first list, 3.35% in the second list, 3.31% in the third list, and 3.36% in the fourth list in the rapidly increasing portion of the function between 10 and 30 dBHL (Figure).

## DISCUSSION

The degree of hearing impairment inferred from the results of a pure-tone audiogram cannot depict the degree of disability in speech communication caused

| List 3 | | | | List 4 | | | |
|---|---|---|---|---|---|---|---|
| Stress 1st syllable | | Stress 2nd syllable | | Stress 1st syllable | | Stress 2nd syllable | |
| IPA | Modern Greek | IPA | Modern Greek | IPA | Modern Greek | IPA | Modern Greek |
| pino | πίνω | ceri | κερί | çeri | χέρι | arni | αρνί |
| θεa | θέα | cilo | κιλό | ðεka | δέκα | ftεra | φτερά |
| poði | πόδι | sxoli | σχολή | tsεpi | τσέπη | kapnos | καπνός |
| pita | πίτα | kafεs | καφές | ðεndro | δέντρο | kluvi | κλουβί |
| supa | σούπα | trεlos | τρελός | εma | αίμα | skεpi | σκεπή |
| εna | ένα | taksi | ταξί | ɲata | νιάτα | papas | παπάς |
| mεsi | μέση | psiçi | ψυχή | ora | ώρα | pani | πανί |
| tsada | τσάντα | stoa | στοά | triti | Τρίτη | θεa | θεά |
| zoo | ζώο | akti | ακτή | mεlon | μέλλον | sica | συκιά |
| stεma | στέμμα | potε | ποτέ | skoni | σκόνη | lεpta | λεπτά |
| frεno | φρένο | luri | λουρί | nεa | νέα | ʝεros | γερός |
| pana | πάνα | timεs | τιμές | turta | τούρτα | avli | αυλή |
| θici | θήκη | klaði | κλαδί | θεsi | θέση | okto | οκτώ |
| dzami | τζάμι | εmis | εμείς | dziros | τζίρος | tapsi | ταψί |
| nista | νύστα | scini | σκηνή | ɣuna | γούνα | stoli | στολή |
| xtεna | χτένα | εvro | ευρώ | ðio | δύο | εɣo | εγώ |
| uzo | ούζο | kupi | κουπί | çoni | χιόνι | fito | φυτό |
| çina | χήνα | ɣria | γριά | nixta | νύχτα | fili | φιλί |
| nεos | νέος | ftino | φτηνό | εxo | έχω | miso | μισό |
| ðisi | δύση | jali | γυαλί | gazi | γκάζι | ciʎa | κοιλιά |
| ðεno | δένω | psito | ψητό | stεji | στέγη | stεno | στενό |
| ɣata | γάτα | εʎa | ελιά | pεna | πένα | nona | νονά |
| buti | μπούτι | maga | μαγκιά | bota | μπότα | ðεksi | δεξί |
| nεvro | νεύρο | ʝεɲa | γενιά | musi | μούσι | zumi | ζουμί |
| mεtro | μέτρο | nεfro | νεφρό | imε | είμαι | cimas | κιμάς |

**Table 5. Mean percent of the monaural (right ear) correct scores and standard deviations for the first, second, third, and fourth lists**

| | 10 dBHL | 20 dBHL | 30 dBHL | 40 dBHL | | | |
|---|---|---|---|---|---|---|---|
| List No. | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| List 1 | 31.2 | 3.16 | 79.80 | 3.19 | 98.60 | 1.65 | 99.80 | 0.63 |
| List 2 | 31.8 | 3.82 | 77.40 | 2.99 | 98.80 | 1.69 | 100.00 | 0.00 |
| List 3 | 32 | 3.27 | 78.80 | 2.35 | 98.20 | 1.99 | 100.00 | 0.00 |
| List 4 | 32 | 2.74 | 78.60 | 3.53 | 99.20 | 1.69 | 99.80 | 0.63 |

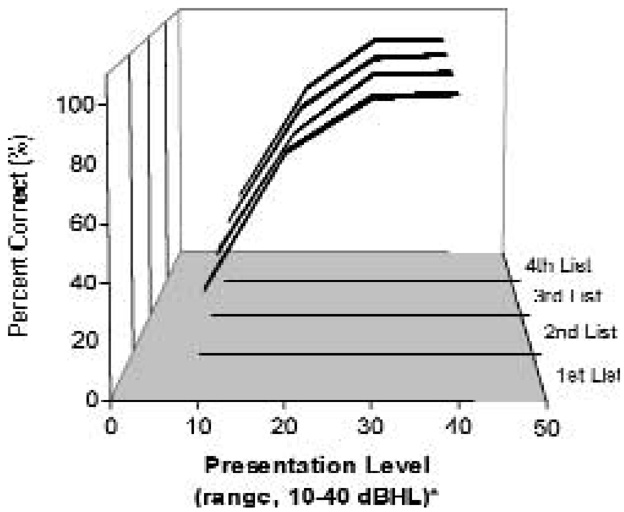


**Figure.** Mean percent of monaural (right ear) correct performance as a function of the presentation level*.

by hearing loss. Because difficulty in hearing and understanding speech evokes the greatest complaints from patients with hearing impairments, it is logical that tests of hearing function should be performed with speech stimuli. A large number of suprathreshold word recognition tests are available for clinical use according to the restrictions and variations of different languages. Such tests provide a wide choice of test parameters, such as the type of speech material (eg, monosyllabic or bisyllabic words, nonsense syllables, sentences), the test format (open set or closed set), and the item scored (words, syllables, phonemes, key words in sentences, subjective intelligibility)[17]. The speech test developed in this study retains those features. Also, the performance functions used are generally consistent with those commonly encountered in the literature for traditional WRS test materials. The new word lists are intended for people older than 12 years. When compared with older word lists for the assessment of WRS, this test offers considerable improvements in phonemic balance, familiarity, and variability. In addition, it increases reliability by increasing each list size to 50 scorable items while retaining the fundamental characteristics of the most widely accepted WRS tests. In addition, the new word lists provide the foundation for development of specialized (degraded) speech tests for the assessment of auditory processing disorders. An assessment procedure of this sort reduces extrinsic redundancy (spoken language) by filtering and by time alteration of the speech signal such as compression or interruption. Several methods have been used to distort the speech signal for central auditory tests. Speech has been periodically filtered, compressed in time, interrupted and masked.

Recently, Iliadou and colleagues (2006) developed 3 PB lists, each of which contains 50 bisyllabic words in Modern Greek. The phonemic balance was calculated according to a corpus of 1000 bisyllabic words extracted from written materials (the 1000 most frequent two-syllable words from the Computational Lexicon of Modern Greek) [18]. In that study, lists 1, 2, and 3 contained 239, 242, and 245 phonemes, respectively, which are about 13% to 15% more phonemes per list than those in the lists developed in our study.

The clinician who performs WRS testing must remember that the variability of WRS increases as the number of test items decreases. On the other hand, a long testing time may negatively affect both the test validity and overall clinical use. The problem of deciding how many items each list should contain is essentially a trade-off between precision and test duration. Most audiologists prefer to test with half lists (25 words), with a weight of 4% per word, which reflects a lack of understanding of the implications of the Thornton and Raffin application of the binomial distribution. Those investigators have demonstrated the need for the frequent use of full lists (50 words) to ensure reliable test scores. The largest standard deviations of a binomial distribution for WRSs occur around 50%. The most reliable scores occur at the upper (near 100%) and lower (near zero percent) limits, and audiologists should have greater confidence in those scores after the presentation of half lists (25 words). Differences in scores obtained from different treatments, for example hearing amplification devices, need to be quite large in the 50% region than for scores close to either extreme (100% or zero percent) before significance can be attached to them. Therefore, depending on the number of items used, it is risky for professionals to assume that an increase or decrease in a given patient's WRS represents a real change in speech recognition ability. Similarly, professionals should be cautious when selecting and verifying amplification device fittings that are based on the results of a WRS. Moreover, statements such as "You understand 66% of speech." are oversimplified because they ignore important variables such as contextual cues, speech-reading abilities, speaker intelligibility, etc.

The results of this study indicate that the lists used are reliable and valid for suprathreshold word recognition score testing, a finding that holds considerable promise for successful clinical use. Further investigations with larger numbers of subjects (those whose hearing is within the normal range as well as individuals whose hearing is impaired) are required to determine the validity and reliability of those lists. Greater experience with the lists will show whether they vary in the degree of difficulty. Finally, the methods that we used to develop our lists could also be used as a guideline in the development of audiometric materials for WRS testing in other languages.

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