Development of Suprathreshold Word Recognition Test for Russian-Speaking Patients

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Abstract
This paper describes the development and normalization of a computerized word recognition test for speakers of the Russian language: the Russian Picture Identification Task (RPIT). The test uses a picture-pointing response, in which a patient selects, on a computer screen, a picture corresponding to a target word from a foil of four rhyming alternatives. The auditory portion of the test is recorded digitally and is recalled from a clinician's computer by clicking a mouse on the English translation of the target word. Thus, an English-speaking clinician can assess reliably word recognition abilities of Russian-speaking patients—a task that has become important in view of the recent surge of immigration from the former Soviet Union. Normative performance of normal-hearing native speakers of Russian was obtained in oral response conditions and picture-pointing conditions intended for clinical use. Psychometric functions provide norms for clinical decision making. Error patterns, individual confusions, and cognitive aspects of the experiment are discussed.

Key Words: Multilingual, multimedia, speech recognition

Abbreviations: RPIT = Russian Picture Identification Task; RVS = Relative Value Score of phonetic similarity of members of word groupings

In today's complex and multicultural world, the ability to serve populations from different cultural backgrounds is becoming increasingly important for a successful clinical practice. Audiologists frequently are confronted with the necessity to perform audiologic evaluations on individuals who have no or limited knowledge of English. An audiologic battery typically includes suprathreshold word recognition tests that require the patient to repeat words presented at a comfortable level. Because conventional word recognition tests require some type of linguistic interaction between the clinician and the patient, information regarding the hearing acuity for speech for non-English speakers is difficult to obtain using conventional English materials.

To accommodate non-English-speaking individuals, McCullough et al (1995) suggested the adoption of a computer-controlled word identification paradigm in which the patient responds to speech stimuli by pointing to a picture on a response foil that contains the target word and three rhyming alternatives. With this identification task, the audiologist only scores the pointing response by comparing the target word with the selected picture and does not have to know the particular foreign language. A similar strategy using the Picture Identification Task materials (Wilson and Antablin, 1980, 1982) has been successful in estimating the word recognition abilities of adults who are nonverbal as the result of cerebral vascular accidents.

The present study is part of a broader project aimed at providing the clinical audiologist...
with the computerized Picture Identification Task test in a variety of languages, thus enabling the clinician to draw reliable information pertaining to the suprathreshold word recognition ability of a foreign-language speaker. The study addresses the needs of the Russian language-speaking community and the clinicians working with them. Since the demise of the Soviet Union, a significant number of Russian émigrés have entered the United States. Major centers of emigrant population include New York City, Los Angeles, Boston, and the San Francisco Bay Area. In these centers, audiologists routinely encounter Russian patients, and the need for a valid Russian word recognition test is evident.

The present study involved the construction and standardization of the Russian Picture Identification Task (RPIT) in the multimedia format. Specifically, the first part of this project consisted of selecting monosyllabic and bisyllabic rhyming target word alternatives and implementing auditory (target word recordings) and visual (picture response plates) portions of the test. Special consideration was given to the frequency of use of the selected items in the everyday Russian language. Second, two experiments were carried out to obtain normative performance of young normal-hearing Russian speakers on the PIT. The purpose of Experiment I was to describe the performance of Russian speakers in an open-set (recognition—auditory stimulation, oral/written response) condition. The purpose of Experiment II was to describe the performance of Russian speakers in a closed-set (identification—auditory stimulation, picture-pointing, four-alternative, forced-choice response) condition.

Data analysis undertaken for these experiments included evaluation of the effects of phonetic similarity between target alternatives, the syllabic composition of the test items, and adequacy of pictorial representation of the target words. Additionally, qualitative evaluation of the cognitive strategies employed by the subjects in the closed-set paradigm was achieved through a questionnaire.

**GENERAL METHODS**

**Test Materials**

The 100 test items (target words) for the RPIT were chosen on the basis of the following criteria: (1) test items were common, familiar monosyllabic or bisyllabic words; (2) test items represented the breadth of phonemes in Russian; (3) test items were easily and unambiguously pictured; and (4) test items had three rhyming alternatives that also met the above criteria.

The 100 words that satisfied the above criteria were selected and arranged in 25 four-word groupings. Target words consisted of 86 nouns (83 singular, 3 plural), 16 action verbs (15 in the infinitive, 1 in the imperative), 1 participle, and 1 adverb. Of the 25 four-word groupings, 14 consisted of monosyllabic words; the remaining 11 consisted of the bisyllabic words. The average length of the target word was four phonemes.

The phonetic composition of the target words was compared to the data from the phoneme frequencies list of the Russian language (Kucera and Monroe, 1968). The pattern of the phonemic balance in the RPIT generally conformed to the Kucera and Monroe data. When phonetic notation differences were taken into account, the discrepancies in the percentages of the phoneme usage between RPIT and the Kucera and Monroe data were typically between 1 percent and 3 percent. This reflected variability in possible interpretation of the vowel quality in the unstressed position and additional constraints placed in the word selection by rhyming and linguistic category. Since the overall conformity of the RPIT phonemic composition to the Kucera and Monroe data was present, the RPIT was judged representative of the breadth of phonemes in the Russian language and generally followed the pattern of the phonemic distribution in the Russian language.

A complex interplay of the rhyming patterns existed in the test items. In order to satisfy other criteria for test item selection, rhyming criteria were relaxed to include words that "sounded" similar but might differ from their alternatives by more than one sound at the end or the beginning of the word. Since different error patterns were hypothesized to occur for these "nonstrict" rhyming alternatives, a comparison of these error patterns with the error patterns in the foils with "strict" rhyming scheme was conducted.

The frequency of occurrence of the potential target words was assessed by four methods. Thirty-three percent of the target words were included in the list of the first 1000 most commonly used words in Russian (Amery and Kirilenko, 1983) and 66 percent were included in the list of 4000 most commonly used words in Russian (Shansky, 1986). Only 24 percent of the words did not appear in any of the word lists. A
A separate pilot study was conducted in which 15 adults (mean age = 40 years, age ranging from 22 to 80 years) and five children (mean age = 5.9 years, ranging from 4 to 9 years) were asked to rate the familiarity of the 100 target words and 56 alternative selections. None of the pilot study subjects participated in the main experiments later. The adults were given the list of the words in alphabetical order and were instructed to grade their frequency of use in everyday speech on a scale of 1 to 4—“1” being “frequently used” and “4” being “rarely used in everyday speech.” Children were read the words and asked to indicate whether they knew the meaning of the word. This pilot study indicated that all of the target words, including the 24 words that did not appear in any published frequently used word lists, were rated as common in everyday speech (grades 1 and 2) by all of the subjects. All of the target words were familiar to young children who participated in the pilot study. Overall, the words selected for the potential RPIT constituted familiar words that are frequently used in everyday speech.

The 100 target words were divided into two 50-word lists according to the following format: (1) each list contained two words from each four-word foil and (2) each list was (within limits) phonemically balanced (i.e., represented the breadth of Russian phonemes). Since the combination of initial and final rhyme schemes existed in some groups of target words, the type of rhyming also was taken into account when the two 50-word lists were devised. The initially rhyming foils were divided so that their final, nonrhyming parts were phonemically balanced between the lists; the division of the finally rhyming foils was similarly phonemically balanced for the initial parts. Lists A and B of the RPIT with English translation and transcription are presented in the Appendix.

Recording and Editing Procedures

The target words were recorded using a female speaker with a standard St. Petersburg pronunciation. The carrier phrase “pokazhite gde...” (“Show me where is...”) was recorded separately. Recordings were carried out in a double-walled sound booth (Acoustic Systems, Model RC143) with a condenser microphone (AKG Acoustics, Model C460B) and a preamplifier (Symmetrix, Model 202) mounted on a microphone stand 15 cm away from the speaker.

The output of the preamplifier was digitized (Antex, Model SX-10; 16-bit, 20,000 samples/sec) and stored for editing. The edited audio files were recorded onto digital audiotape (Sony, Model PCM 2500A, B).

Subjects

Twenty-one young, normal-hearing, Russian-speaking subjects participated in the study. All of the subjects learned and used Russian as their first language. They had permanently resided in the United States for no longer than 6 years (16 subjects) or visited the country for a period of 1 year or less (three subjects). One male subject resided in the United States for 15 years since the age of 13 but used Russian as his primary language of communication both at home and at work.

All subjects had normal otoscopic examination. There was no history of ear pathology, and hearing sensitivity was within normal limits (thresholds at <15 dB HL at octave intervals from 250 to 8000 Hz).

EXPERIMENT I

The goal of Experiment I was to establish the normative performance of young normal-hearing native Russian speakers on the RPIT in a recognition response paradigm (open set). Since no visual cues were present in this condition, the percent correct recognition scores yielded specific information about acoustic and linguistic parameters of the test items. Obtaining psychometric functions for the open-set conditions permitted comparison of the relative difficulty of separate test items and the effects of syllabic composition on the percent correct performance in Russian with similar data in other languages.

Subjects

Five males and five females (ages 11–33, mean age = 24.8 years) served as listeners in the oral, open-set conditions.

Procedures

During a 1-hour session, each subject listened to a 50-word list presented at each 6-dB increment from 20 dB SPL to 56 dB SPL. The odd-numbered subjects listened to list A at 20, 32, 44, and 56 dB SPL and to list B at the remaining three levels. The even-numbered subjects listened to list B at 20, 32, 44, and 56 dB SPL and to list A at the remaining three levels. To minimize learning
effects, twice-repeated randomization was used at 20 dB SPL (near threshold) and 56 dB SPL (clearly suprathreshold) for both groups of subjects. The test ear was alternated among the subjects. They wrote their responses on an answer sheet that was scored by the Russian-speaking experimenter.

Results

A repeated-measures analysis of variance (ANOVA) demonstrated no significant difference among performances of the 10 subjects on lists A and B (F [1, 68] = 3.67, p > .05). The data from lists A and B, therefore, were combined for further analysis. The standard deviations for the open-set condition ranged from 2.6 percent at 20 dB SPL to 18.9 percent at 32 dB SPL. The psychometric function for combined lists A and B in the open-set condition is shown in open squares in Figure 1. The line connecting the datum points is the best-fit, third-degree polynomial. The slope of the function between 20 percent and 80 percent correct points is 3.7 percent per dB and the 50 percent correct point is 34.0 dB SPL. Coincidentally, these parameters are very close to those reported recently for the Hirsh recording of the CID W-22 materials, viz., a slope of 3.1 percent per dB and a 50 percent correct point at 33.4 dB SPL (Heckendorf et al., 1997). Thus, the Russian words used in the open-set response paradigm produced a psychometric function that falls within the range of psychometric functions for similar English materials used to evaluate word recognition abilities.

EXPERIMENT II

The goal of Experiment II was to establish the normative performance of young, normal-hearing native Russian speakers on the RPIT in closed-set, picture-pointing conditions. In these conditions, the subjects performed the task in the form intended for clinical use. Obtaining psychometric functions for the closed-set conditions provided the norms to be used in the clinical decision making and yielded specific information about test composition.

Subjects

Eight females and seven males (ages 20–34, mean age = 29.1 years), four of whom participated in the open-set experiment, served as subjects for the picture-pointing, closed-set conditions.
experiment. Each four-picture response foil contained two target words for each list. Thus, presentation of one 50-word list required using each of the 25 screens twice. The lists were presented at seven ascending sound pressure levels of 14, 20, 26, 32, 38, 44, and 50 dB SPL. List order and test ear were counterbalanced among subjects. At the end of the experiment, subjects completed a short questionnaire aimed at assessing the cognitive and visual processing constraints of the task. Questions concerned the ease of understanding and overall quality of the pictures and are discussed below in detail.

**Results**

A repeated measures ANOVA demonstrated no significant difference between performances by the 15 subjects on lists A and B ($F_{1,109} = 2.68$, $p > .05$). Thus, the data from lists A and B were again combined for further analysis. The mean performance of the subjects ranged from 29.1 percent correct at 14 dB SPL, which was slightly above chance for the task (25%), to 99.9 percent correct at 50 dB SPL, at which all but one subject achieved a 100 percent correct score. Standard deviations ranged from 0.0 at 50 dB SPL to 14.9 at 28 dB SPL. The mean percent correct performance for the RPIT in closed-set conditions is plotted in Figure 1 (open circles). The psychometric function thus obtained was fitted with a third-degree polynomial from which a slope of 2.78 percent dB was calculated between 30 and 80 percent correct points. Fifty percent correct point was at 19.4 dB SPL.

**DISCUSSION**

The goal of the present study was to describe normative performance on the newly developed Russian auditory/visual picture identification materials. Normative performance was evaluated for two presentation conditions: open set (auditory stimulus, oral response mode) and closed set (auditory stimulus picture-pointing response mode).

**Comparison of the Open-Set and Closed-Set Performance**

As evident from the psychometric functions presented in Figure 1, closed-set performance was consistently better than open-set performance. Relative to the psychometric function for the open-set condition, the psychometric function for the closed-set materials was displaced by 14.7 dB at the 30 percent correct point and by 10.4 dB at the 80 percent correct point. Closed-set conditions were administered in a four-alternative, forced-choice paradigm, giving a chance performance of 25 percent correct. Open-set conditions did not impose any lower limits on performance, and performance of the subjects was indeed near zero for the lowest presentation level. The slopes on the linear portion between 30 and 80 percent correct points were 3.7 percent/dB and 2.8 percent/dB for the open-set and closed-set conditions, respectively. The observed differences between open-set and closed-set performance were consistent with the statistical nature of the testing paradigms.

Similar relationships between open-set and closed-set conditions were noted for Spanish and English word recognition/identification materials presented in a similar format (Wilson and Antablin, 1980; McCullough et al, 1995).

**Error Analysis**

Since a combination of monosyllables and bisyllables and different rhyming patterns existed in the RPIT, a detailed error analysis was undertaken to evaluate the effects of the syllabic composition and the degree of phonetic similarity on the performance of normal-hearing subjects.

For the open-set condition, the oral responses of the subjects were recorded by the Russian-speaking experimenter and the total number of errors for each target word was computed as a function of presentation level. For the closed-set condition, the number of times each target word in a four-word response was substituted for another member of the foil was recorded during the experiment and later computed as a function of presentation level. Additionally, the overall number of confusion errors per foil using data from seven presentation levels (20–56 dB SPL) was computed to be used in the error analysis.

For closed-set conditions, the analysis of errors in individual foils was undertaken to establish the relationship between these patterns and the rhyming and syllabic properties of the foils. It was hypothesized that the number of syllables in the words comprising a foil, rhyming patterns within a foil, and the degree of phonetic similarity between the items in a foil would be reflected in the number of confusions made by subjects at each presentation level (Hirsh et al, 1952).
**Effect of Phonetic Similarity and Syllable Length**

To evaluate the effects of phonetic similarity of words within foils on identification performance, each foil was ranked according to the degree of acoustic similarity between the words on the foil. A relative value score (RVS) of 2 was assigned to a word that varied by one phoneme only from the other words in a foil. A RVS of 1 was assigned to words that varied by two phonemes and a RVS of 0.5 was assigned to phonetically similar, but not exactly rhyming, alternatives. Thus, the maximum score of 8 was possible with those foils having the most similar phonetic composition, whereas lower RVS scores reflected progressively dissimilar phonetic composition of the foils. The mean percent correct achieved on the six minimally varied foils with a RVS of 8 (foils 1, 2, 3, 4, 5, and 8) was compared to the mean percent correct achieved on the four maximally varied foils that had the smallest RVS (foils 9, 13, 15, and 21).

![Figure 2](image1.png)  
**Figure 2** Psychometric functions calculated separately for four minimally (filled diamonds) and maximally (filled triangles) phonetically dissimilar response foils.

Figure 2 illustrates the psychometric functions derived for the six minimally phonetically varied (filled diamonds) and the four maximally phonetically varied (filled triangles) four-word groupings. Equal performance on the minimally and maximally varied foils was obtained when the presentation level for the maximally varied condition was 4.0 to 4.8 dB lower than the presentation level for the minimally varied condition. The psychometric functions for the minimally and maximally varied foils improved at similar rates (2.8%/dB and 2.9%/dB), subjects demonstrated similar rate of performance growth with level for bisyllabic and monosyllabic four-word groupings. Equal performance on the monosyllabic and bisyllabic stimuli were achieved when the monosyllabic materials were presented at levels 3.6 to 4.8 dB higher than the levels of the bisyllabic materials. Thus, as Fletcher and Steinberg (1929) reported for English words, there is an inverse relation between the number of syllables in a word (phonetic contextual clues) and the presentation level at which the word is recognized correctly. Performance on monosyllabic foils was also more varied compared to bisyllables, with standard deviations of 11 percent to 20 percent correct.

![Figure 3](image2.png)  
**Figure 3** Psychometric functions for the monosyllabic (open squares) and bisyllabic (open circles) response foils.

To evaluate the effect of syllable length on performance, percent correct scores of monosyllabic and bisyllabic foils were averaged and compared to each other. Figure 3 illustrates the psychometric functions calculated separately for 14 monosyllabic (open squares) and 11 bisyllabic (open circles) four-word groupings.

As indicated by nearly identical slopes of linear portions of the psychometric functions (2.8%/dB and 2.9%/dB), subjects demonstrated similar rate of performance growth with level for bisyllabic and monosyllabic four-word groupings. Equal performance on the monosyllabic and bisyllabic stimuli were achieved when the monosyllabic materials were presented at levels 3.6 to 4.8 dB higher than the levels of the bisyllabic materials. Thus, as Fletcher and Steinberg (1929) reported for English words, there is an inverse relation between the number of syllables in a word (phonetic contextual clues) and the presentation level at which the word is recognized correctly. Performance on monosyllabic foils was also more varied compared to bisyllables, with standard deviations of 11 percent to 20 percent correct.
15 percent (9%-7% for the bisyllables). Apparently, the minimal level of phonetic information redundancy in the monosyllabic foils (compared to bisyllables) created more inter-subject and interfoil variability.

**Individual Confusions**

To evaluate the relative difficulty of the individual target words in the response foils, a qualitative analysis of individual patterns of confusions was performed, which provided some insights into the origins of confusions in the closed-set condition. Specifically, some confusions were made consistently between a pair of words in a foil (i.e., “marka” [post-stamp] and “maslo” [butter] were confused more often than the much more closely phonetically corresponding “marka” and “maska” [mask] or “maslo” and “maska”). The most common and consistent confusions included “maslo” [butter] and “marka” [post-stamp] in foil 11; “kom” [snowball]—“kol” [stake], “kom”—“kot” [cat] in foil 25; “lapa” [paw]—“lampa” [lamp] in foil 19; “parta” [desk]—“pasta” [toothpaste] in foil 12; “osa” [wasp]—“rosa” [dew] in foil 10; and “nos” [nose]—“notch” [night] in foil 5.

It is possible that combination of relative difficulty of the pictures in a foil and/or cognitive strategies used by the subjects to select a response in near-absence of auditory cues (see section below) affected the performance in the forced-choice, closed-set paradigm. No systematic phonetic influences were observed in these confusion patterns. Foils 4, 7, 8, 14, 20, 22, and 24 demonstrated a nondiscriminative pattern of confusions, in which all four words in a foil were equally likely to be confused with one another. The individual percent correct performance for these foils demonstrated slower growth than the mean. Not surprisingly, these foils were comprised of monosyllabic words that are rich in fricatives. These foils, therefore, were especially difficult, yet they also yielded near-perfect performance scores at levels above 38 dB SPL.

Some individual words in a foil were likely to be confused with any other item in that foil, yet its three alternatives were easier to identify. Such words included “notch” [night] in foil 5, “maslo” [butter] in foil 11, “d’ad’a” [uncle, man] in foil 21, “kiska” [she-cat] in foil 16, “druk” [friend] in 18, and “pup” [navel] in foil 8. In foil 14, the word “zver” [animal] was missed 29 times, making it the most commonly missed word in the closed-set condition. The words commonly missed in closed-set conditions were not necessarily the most commonly missed in an open-set condition, yet a correspondence in error patterns between the conditions was observed. The above-mentioned word “zver” was also among the most commonly missed in the open-set condition; words containing sibilant and affricate sounds were often missed in both conditions. It was hypothesized that in cases when visual/cognitive and contextual clues were sufficient to counteract phonetic uncertainty, target items yielded better relative performance in the closed-set conditions; words most commonly missed in open-set condition were not the most commonly missed in the closed-set condition. In order to evaluate this hypothesis and to assess the cognitive aspects of the closed-set, picture-pointing task, subjects were asked to comment on the adequacy of visual representation of the test items at the completion of the test.

**Cognitive Aspects of Experimental Paradigm**

The relationship between cognitive and visual cues to the performance of the subjects in a picture identification task was noted by a number of researchers (Wilson and Antablin, 1980; Comstock and Martin, 1984). To assess (albeit informally) the cognitive and visual processing constraints on the closed-set, picture-pointing RPIT, the subjects were requested to answer the following questions while each response foil was being shown to them again after the completion of the test:

1. Can you name each of the four objects or actions depicted on the screen?
2. Does the picture of each object or action resemble your mental representation of this object/action? If not, how would you represent it on screen?
3. Was the word represented by this picture evident to you before you actually heard it (or were able to hear it) during the test?
4. Did you use the elimination strategy (“three other pictures cannot represent this word, then it must be this picture”) for any of the pictures on the screen?
5. If you did not hear the word and had to guess “at random,” did you notice which picture of these four you were likely to choose? Can you tell why?

The responses to this questionnaire were scored on the separate blank scoring sheet.
attached to the test scoring sheets. Overall analysis of the subjects' response on the post-test questionnaire indicated that when guessing in the absence or near-absence of auditory cues on the subthreshold test levels, subjects appeared to select the answer based on the visual features of the pictures. In most cases, the subjects were inclined to make the "easiest" choice based on complexity, level of abstraction, and number of distractions present in the images. For example, in foil 1, subjects were more likely to point at the picture of a poppy (mak) or lobster (rak) than to the pictures of two bottles of nail polish (lak) or a walking man (shak), since the former were bright color drawings of single objects with minimal small details.

The pictures representing actions (i.e., "myt" [wash], "krast" [steal], or "sosat" [suck]) or action-related nouns (i.e., "spor" [argument], represented by a picture of two people pointing fingers and shouting at each other, or "shak" [stride], represented by a picture of a walking man), contained more detailed and abstract features and were least likely to be selected when subjects were to guess the target word.

When asked to identify the picture in the absence of the auditory target, most subjects reported having trouble identifying the word "blisko" [near], represented by a close-up of a box on a background of many boxes shown in perspective. The picture for "lak" [nail varnish]—a very common Russian word and object—presented problems to men, but not to women. The pictures for human relationships, like "friend," "uncle," "father," were reported by some subjects as difficult to identify and/or distinguish. Yet no picture was uniformly reported as inadequate by all subjects; almost all subjects reported idiosyncratic problems. One subject identified a picture for "onion" as garlic; another female subject objected to the representation of the word "bake" as a woman making dough, reasoning that baking and making dough were separate actions. With these exceptions, subjects reported that the pictures adequately represented the target words.

It appeared from the qualitative analysis that, in cases when acoustic cues were ambiguous or missed entirely, the subjects were more likely to point to a brighter, simpler, bigger picture. Since, clinically, the test is administered at the suprathreshold levels when all alternatives are potentially audible, and an appropriate response could be chosen by elimination, this problem becomes relatively unimportant.

The clinical administration of the RPIT in the suprathreshold, forced-choice, closed-set conditions is recommended for evaluation of the Russian-speaking patient population to obtain an unbiased estimate of the word recognition abilities of this population. The diagnostic value of this test remains to be established in clinical settings by assessing patients with hearing loss.

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REFERENCES


## APPENDIX

### Russian Picture Identification Task

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