Psychometrycznie zrównoważone jednosylabowe polskie listy słowne

Psychometrically Equivalent Polish Monosyllabic Word Recognition

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Streszczenie

Celem pracy było opracowanie i psychometryczne zrównoważenie list słów jednosylabowych w języku polskim do wykonywania badań audiometrii słownej. Z dwóch najczęściej używanych słowników języka polskiego oraz z dwóch najczęściej używanych w praktyce klinicznej list monosylabowych wybrano 250 słów jednosylabowych. Materiał słowny nagrano stosując technikę zapisu cyfrowego w wersji wypowiadanej zarówno przez mężczyznę jak i kobietę,. Lektorzy pochodzili ze środkowej Polski. Procentowa poprawność zrozumienia mowy została zmierzona na 10 poziomach natężenia, od -5 dB HL do 40 dB HL co 5 dB i sprawdzona na 30 prawidłowo słyszących osobach. Dla każdego z 250 jednosylabowych słów określono względną trudność jego zrozumiałości (identyfikacji). Do ostatecznego nagrania na dysku CD wybrano 200 jednosylabowych słów łatwiejszych w identyfikacji. Z tych słów utworzono cztery równoważne, fonetycznie zrównoważone listy obejmujące po 50 słów jednosylabowych oraz osiem list obejmujących 25 słów jednosylabowych (tzw. listy skrócone). Analiza statystyczna przeprowadzona za pomocą testu Chi2 wykazała brak statystycznie istotnych różnic w rozumieniu poszczególnych list i list skróconych. W celu zmniejszenia różnic w rozumieniu list pełnych i list skróconych dostosowano głośność 16 jednosylabowych list skróconych tak, aby próg wykrywalności każdej z list wynosił 7,5 dB HL (wartość średnia progów dla list skróconych wypowiadanych głosem męskim i wypowiadanych głosem żeńskim). Opracowane w pracy zrównoważone psychometrycznie polskie listy słowne do badania audiometrii słownej wypowiadane przez lektora mężczyznę i kobietę, są zawarte na dysku CD: Polskie Listy Słowne Audiometrii Mowy, Brigham Young University (Dysk 1.0).

Słowa kluczowe: rozpoznawanie słów, rozumienie mowy, język polski, równowaga, kompakt dysk, krzywe psychometryczne, spójność, wyrazy jednosylabowe, zrównoważenie fonetyczne.

Summary

This investigation was undertaken to develop, digitally record, evaluate, and psychometrically equate Polish monosyllabic word lists for use in measurement of auditory word recognition. Two hundred fifty monosyllabic words were selected from two Polish frequency usage dictionaries and from two common monosyllabic words lists. These words were digitally recorded by both male and female talkers native to central Poland. Percent correct word recognition was measured for each word at 10 intensity levels from -5 to 40 dB HL in 5 dB increments using 30 normally hearing subjects. Difficulty rankings were calculated for each of the 250 monosyllabic words. The 200 monosyllabic words that were easiest to identify were selected for inclusion in the final compact disc recordings. Four equivalent phonemically balanced word lists of 50 words each and eight half lists of 25 words each were formed from the selected monosyllabic words. A chi-square analysis revealed no statistically significant differences in audibility among the lists or half lists. In order to increase homogeneity of audibility of the lists and half lists, the thresholds of the 16 monosyllabic half-lists were adjusted so that the threshold of each list was equal to the midpoint (7.5 dB HL) between the mean threshold of the male half-lists and the mean threshold of the female half-lists. The psychometrically equivalent Polish monosyllabic word recognition lists, spoken by both male and female talkers, are included on the Brigham Young University Polish Speech Audiometry Materials (Disc 1.0) compact disc.

Key words: word recognition, speech discrimination, Polish, equivalency, compact disc, psychometric function, homogeneity, monosyllabic words, phonemic balance.

Auditory word recognition tests are an important diagnostic tool used during audiological testing. Routine comprehensive audiological evaluations are generally considered incomplete without measurement of auditory word recognition using speech stimuli. The auditory word recognition score is the percentage of a word list that is correctly repeated at a suprathreshold level.

There are a number of factors that have been identified which can influence the word recognition scores (WRS) including word selection and familiarity, usage frequency, and presentation level [Beattie (et al.) 1975; Campbell 1965; Hood, Poole 1980; Pisoni 1995], talker dialect, and lexical neighborhood [Brandy 1966; Cambron (et al.) 1991; Hood, Poole 1980; Kreul (et al.) 1969; Luce 1986; Penrod 1979], number of words included in the list [Elpern 1961; Grubb 1963a; 1963b; Resnick 1962], method of presentation [Beattie (et al.) 1975; Brandy 1966; Creston (et al.) 1966], and type of recording [Kamm (et al.) 1980; Ridgway 1986]. There has also been considerable discussion about the question of phonetic balance [Eldert, Davis 1951; Lehiste, Peterson 1959; Martin (et al.) 1998]. Recently, Martin, Champlin, and Perez [2000] concluded that whether a word list is phonetically balanced or not does not appear to influence word recognition scores for patients with normal hearing or sensorineural hearing impairment. They concluded that „the total score based on randomly selected words is not substantially different from total score based on carefully selected, PB word lists" [Martin et al. 2000, p. 492].

It has generally been concluded that recorded presentation of speech audiometry materials is preferable to monitored live voice presentation [ASHA 1988]. Recorded presentation of speech materials standardize the composition and presentation of the materials and allow for better control of the presentation intensity of the test stimuli and insure that the speech pattern of the recorded talker will be consistent from one client to the next, and from one clinic to the next.

It is important to consider several factors whenever developing speech audiometry materials. Words selected should be both familiar and moderately difficult to identify [Campbell 1965; Comstock, Martin 1984; Weisleder, Hodgson 1989; Zakrzewski, Jassem, Pruszewicz, Obrębowski 1975]. Talkers used to make recordings should use the standard or most common dialect of that language [Weisleder, Hodgson 1989]. If the word lists are to be recorded, a digital recording method should be used. Digital recordings offer numerous advantages over tape recordings. These advantages include improved signal-to-noise ratio; increased channel separation, dynamic range, and frequency response; reduced harmonic distortion; elimination of wow and flutter associated with tape playback mechanisms; longer storage life without degradation through use [Kamm et al 1980; Nakamishi; n.d.; Ridgway 1986; Sony 1991]. Perhaps one of the greatest advantage of a digital recording is that with the use of computers, the digital signal can be modified in a highly efficient and uniform manner including random access to tracks and even randomization of word order in lists using custom software [Harris, Goffi, Pedalini, Gygi, Merrill 2001; Kamm et al. 1980; Ridgway 1986].

To data there are no high quality digital recordings of speech stimuli that can be used to obtain measures of auditory word recognition in individuals whose native language is Polish. The purpose of the present investigation was to develop and evaluate high quality digital recordings of speech stimuli that can be used to measure auditory word recognition in patients whose native language is Polish. Psychometrically equivalent phonemically balanced lists (50 words each) and half-lists (25 words each) will be constructed using male and female Polish talkers.

Method

Subjects

All subjects participating in this study were natives of Poland. A total of 30 individuals (8 male, 22 female), ranging in age from 20 to 30 years (M = 23.8 years), participated in the evaluation of the monosyllabic words. Summary statistics of the subject thresholds are listed in Table 1. Each participant had pure tone air-conduction thresholds 15 dB HL at octave and midoctave frequencies from 125 to 8000 Hz and had static acoustic admittance between 0.3 and 1.4 mmhos with peak pressure between 100 and +50 daPa [ASHA 1990; Roup, Wiley, Safady, and Stoppenbach 1998].

Tab. 1. Age (in years) and pure tone thresholds (dB HL) descriptive statistics for the 30 subjects that participated in the monosyllabic study

	M	Minimum	Maximum	SD
Age	23.8	20.0	30.0	3.3
125 Hz	7.5	-5.0	15.0	6.3
250 Hz	6.0	-5.0	15.0	6.4
500 Hz	4.5	-5.0	15.0	5.3
750 Hz	4.0	-5.0	15.0	5.2
1000 Hz	3.8	-5.0	15.0	5.4
1500 Hz	0.8	-5.0	15.0	5.3
2000 Hz	-0.7	-10.0	5.0	4.3
3000 Hz	0.5	-5.0	10.0	4.8
4000 Hz	2.2	-10.0	15.0	7.0
6000 Hz	8.3	-10.0	15.0	5.8
8000 Hz	9.3	0.0	15.0	4.3

Materials

Word lists. Monosyllabic words were selected as the stimuli for auditory word recognition testing. A total of 400 monosyllabic words were compiled from two Polish frequency usage dictionaries and from two common monosyllabic word lists. The frequency usage dictionaries addressed conversational speech [Zgółkowa 1983] and journalistic texts [Knowles 1983]. The monosyllabic word lists selected included a list attributed to Taniewski, Kugler and Wysocki, and a list attributed to Zakrzewski [Bystrzanowska 1969; Bystrzanowska 1978].

Talkers. Initial recordings were made using five native Polish-speaking individuals, three males and two females. All talkers were from central Poland and spoke a standard Polish dialect. After the recordings were made, a panel of nine native Polish judges evaluated the performance of each talker. The judges were asked to indicate whether the vocal quality and accent of the talker was acceptable or unacceptable and then were asked to rank order the talkers from best to worst. The highest ranked talkers (one male, one female) were selected as the talkers for the recordings. Neither of the talkers who were selected received any unacceptable ratings, whereas two of the remaining three talkers not selected were considered to be unacceptable by one or more of the judges.

Recording. All recordings were made in the anechoic chamber located on the Brigham Young University campus in the Eyring Science Center. A Larson-Davis model 2541 microphone was positioned at a 0° azimuth and was covered by a 3" windscreen. The microphone was connected to a Larson-Davis model 900B preamp, and the preamp was coupled to a Larson-Davis model 2200C preamp power supply. The signal from the preamp power supply was routed through an Apogee AD-8000 24-bit analog-to-digital converter; the digitized signal was stored on a hard drive for later editing. A 44.1 kHz sampling rate with 24-bit quantization was used for all recordings, and every effort was made to utilize the full range of the 24-bit analog-to-digital converter. Once recorded, the words were edited using Sadie Disk Editor software [Studio Audio and Video Limited 1996].

During the recording sessions, the talker was asked to pronounce each word several times. A native Polish judge rated each word for perceived goodness of production, and the best production of each word was then selected for inclusion on the CD. If there were no satisfactory recordings of a word, that word was recorded a second time. After the rating process, the intensity of each word to be included on the CD was edited to yield the same intensity as that of the 1000 Hz calibration tone contained on the CD (ANSI 3.6-1996). The CD was produced on a Yamaha CDE 100II recordable CD-ROM drive using a 44.1 kHz sampling rate and 16-bit quantization. The NS high dither option in the Sadie Disk Editor software was used to convert the recordings from 24 to 16-bit quantization.

Procedures

Custom software was used to control randomization and timing of the presentation of the words. The signal was routed from a computer-controlled CD-ROM drive to the external inputs of a Grason Stadler model 1761 (GSI-61) audiometer. The stimuli were routed from the audiometer to the subject via TDH-50P headphones. Prior to testing each subject, the inputs to the audiometer were calibrated to 0 VU using the 1000 Hz calibration tone on track 1 of the Polish CD. All testing was carried out in a sound suite that met ANSI (1991) standards for maximum permissible ambient noise levels for the ears not covered condition.

Evaluation of monosyllabic words. The subjects were not familiarized with the monosyllabic words prior to testing. The 250 monosyllabic words were divided into ten lists of 25 words each. Ten presentation levels were selected at which to present the lists: -5 to 40 dB HL in 5 dB steps. One list was presented at each of the ten presentation levels. The order of the presentation of the lists and the order of the words within the list were randomized for each subject. Each word was presented an equal number of times at each intensity level across the entire subject population.

Prior to the administration of the auditory word recognition tests, the following instructions were given:

(Polish) *Będziesz słyszał słowa jednosylabowe w zestawach różniących się między sobą głośnością, od bardzo cichych do dobrze słyszalnych. Te najcichsze słowa mogą być trudne do usłyszenia. Zielony wskaźnik świetlny będzie się pojawiał podczas wymawiania każdego słowa. Proszę słuchać jak najuważniej i zapisywać wyraźnie usłyszane słowa w odpowiednich rubrykach formularza, używając drukowanych liter. Jeżeli nie jesteś pewien jakie słowo usłyszałeś, zachęcamy abyś zgadywał. Jeżeli nie domyśliłeś się słowa, w rubryce przeznaczonej dla tego słowa wpisz kreskę. Będziesz musiał szybko pisać twoje odpowiedzi aby być gotowym do słuchania następnego słowa. Czy masz jakieś pytania?*

(English) *You will hear monosyllabic words (1 syllable) at a number of different loudness levels. These loudness levels will vary from very soft to a more comfortable loudness level. At the very soft loudness levels it may be difficult for you to hear the words. The green indication light will come on informing you that a word has been presented. Please listen as carefully as you can and print legibly the words you hear in the spaces provided on the response sheets. If you are unsure of the word, you are encouraged to guess. If you have no guess, please draw a blank line in the space provided for that word. Do you have any questions?*

Calibration

The audiometer was calibrated prior to, weekly during and at the conclusion of data collection. Calibration was performed in accordance with the specifications of the American National Standards Institute (ANSI S3.6-1996). No calibration adjustments were required throughout the duration of the study.

Results

Monosyllabic Words

After the raw data were compiled, each monosyllabic word received a difficulty ranking. The ranking was based on the number of times each word was correctly identified across all intensity levels and subjects. The more often the word was identified correctly, the higher the ranking. Table 2 lists the difficulty ranking for each monosyllabic word from the male recording and Table 3 lists the difficulty ranking for each monosyllabic word from the female recording.

On receiving a difficulty ranking, the 200 words with the highest ranking were divided into four phonemically balanced lists of 50 words each. Table 4 (male) and Table 5 (female) contain the four phonemically balanced lists for each gender. The first four words from the rank-ordered list of 200 words were randomly assigned to one of the four lists. This process was repeated until each list contained 50 words. The lists were phonemically balanced by transferring words of equal difficulty among lists until each list contained approximately the same number of each of the 39 phonemes of the Polish language [Zakrzewski, Pruszewicz, Kubzdela 1971]. Figures 1 (male) and 2 (female) contain graphical representations of the number of each of the different phonemes in each list after they were phonemically balanced.

Eight half-lists of 25 words each were constructed after the creation of the four phonemically balanced lists. The eight male half-lists are found in Table 6; the eight female half-lists are found in Table 7. Two half-lists were formed from each full list by randomly designating the first word in a list as either an A or a B, designating the second word with the letter that was opposite from that assigned to the first word, and then counterbalancing the assignment of the remaining words. Once all words were assigned a letter, the full list could be divided into two half-lists: half-list A and half-list B. No attempt was made to balance the half-lists phonemically.

Once the monosyllabic lists and half-lists were created, the raw data were used to create psychometric functions for each of the lists and half-lists for both the male and female talkers. The raw psychometric functions for the male lists and half-lists can be found in Figures 3 and 4; the raw psychometric functions for the female lists and half-lists can be found in Figures 5 and 6. The raw data were reanalyzed using logistic regression to obtain regression slope and regression intercept values for each of the 4 lists and each of the 8 half--lists for both the male and female talker recordings. The values obtained for the regression slope and regression intercept for each list and half-list are presented in Table 8 (male talker) and Table 9 (female talker). The calculated regression slope and regression intercept values were then inserted into a modified logistic regression equation (Equation 1) that was designed to calculate percent correct performance at any specified intensity level.

Tab. 2. Polish Male Monosyllabic Words in Rank Order from Easiest to Most Difficult

Word	Rank	Word	Rank	Word	Rank	Word	Rank	Word	Rank
jak	29	coś	23	dno	21	zło	20	mak	17
ktoś	28	czar	23	gips	21	znak	20	metr	17
ciecz	27	dwa	23	herb	21	bój	19	muł	17
ćma	27	dzik	23	iść	21	brat	19	nit	17
kształt	27	gaj	23	kij	21	cynk	19	nos	17
mysz	27	gość	23	kosz	21	dar	19	pas	17
ość	27	grosz	23	łza	21	fakt	19	sen	17
świat	27	grzech	23	moc	21	fant	19	tron	17
szał	27	hak	23	móc	21	kit	19	wiek	17
sześć	27	koń	23	niech	21	koc	19	wół	17
cześć	26	kwiat	23	on	21	las	19	woń	17
dać	26	liść	23	park	21	lej	19	wrzask	17
dzień	26	miecz	23	plan	21	lot	19	wstać	17
dziś	26	nić	23	sklep	21	pień	19	wzór	17
nic	26	pies	23	spać	21	płyn	19	cło	16
rzecz	26	pieśń	23	sto	21	sejm	19	dwór	16
szyć	26	ruch	23	strój	21	ser	19	gach	16
żyć	26	śmiech	23	szyk	21	szwy	19	kurs	16
czek	25	tekst	23	teść	21	ton	19	lep	16
czynsz	25	ty	23	tło	21	wasz	19	lis	16
dom	25	złość	23	tor	21	zbir	19	pół	16
klucz	25	chwyt	22	twój	21	znać	19	port	16
kwit	25	dłoń	22	żart	21	czyn	18	pył	16
maj	25	dorsz	22	żbik	21	fach	18	włos	16
mech	25	drzwi	22	zły	21	len	18	zbój	16
sień	25	głos	22	zuch	21	leń	18	złom	16
słoń	25	gra	22	as	20	lin	18	dzban	15
żal	25	jacht	22	bal	20	młyn	18	płat	15
czas	24	kot	22	cel	20	mur	18	plus	15
czy	24	łoś	22	cham	20	piec	18	przejść	15
dach	24	mnich	22	dzwon	20	sam	18	wąs	15
deszcz	24	my	22	gnat	20	snop	18	zwać	15
dość	24	nikt	22	grzbiet	20	swój	18	łup	14
dzicz	24	pik	22	łach	20	syn	18	pot	14
grać	24	rdza	22	pan	20	ten	18	ul	14
ja	24	ryj	22	pech	20	tom	18	wór	14
kraj	24	rym	22	pion	20	wesz	18	za	14
mecz	24	stan	22	przy	20	widz	18	zjeść	14
nasz	24	szal	22	raj	20	wnuk	18	zwój	14
noc	24	szok	22	rok	20	wosk	18	bas	13
pięść	24	tak	22	sok	20	żer	18	bat	13
rzut	24	tam	22	stać	20	znów	18	wat	13
szept	24	trwać	22	stół	20	bar	17	wiec	13
szpik	24	wieś	22	świt	20	byt	17	po	12
to	24	wir	22	szef	20	dół	17	zdać	12
wał	24	żwir	22	tran	20	dym	17	post	11
źle	24	but	21	typ	20	gen	17	wpaść	11
bicz	23	byk	21	wójt	20	gwałt	17	wuj	9
bok	23	cień	21	żar	20	jar	17	wy	8
cios	23	dal	21	że	20	los	17	om	3

Tab. 3. Polish Female Monosyllabic Words in Rank Order from Easiest to Most Difficult

Word	Rank	Word	Rank	Word	Rank	Word	Rank	Word	Rank
drzwi	27	miecz	22	moc	20	herb	18	tron	16
rzecz	26	mur	22	my	20	kij	18	ty	16
czek	25	mysz	22	pion	20	kit	18	włos	16
cześć	25	ruch	22	przejść	20	lej	18	wuj	16
grosz	25	ryj	22	strój	20	muł	18	za	16
jak	25	śmiech	22	tekst	20	nasz	18	zwać	16
klucz	25	sześć	22	tran	20	niech	18	byt	15
kształt	25	szok	22	wasz	20	park	18	cło	15
rok	25	szpik	22	wesz	20	piec	18	gen	15
świat	25	szyk	22	żbik	20	syn	18	lep	15
szept	25	ul	22	zło	20	tak	18	nit	15
dwa	24	wy	22	zuch	20	ten	18	pot	15
gra	24	źle	22	as	19	teść	18	przy	15
łza	24	złość	22	byk	19	tor	18	sam	15
mecz	24	żyć	22	cel	19	typ	18	sejm	15
rdza	24	bok	21	dar	19	wnuk	18	snop	15
szał	24	chwyt	21	dom	19	żart	18	wół	15
szwy	24	czyn	21	gips	19	że	18	woń	15
żwir	24	dach	21	iść	19	złom	18	wrzask	15
ciecz	23	dłoń	21	jar	19	bój	17	zbir	15
cień	23	dorsz	21	las	19	cham	17	zdać	15
czynsz	23	dość	21	leń	19	cynk	17	zwój	15
deszcz	23	gnat	21	metr	19	dno	17	bas	14
gość	23	ja	21	móc	19	głos	17	bicz	14
grać	23	kosz	21	on	19	len	17	fant	14
grzbiet	23	łoś	21	pan	19	lin	17	koc	14
grzech	23	mech	21	pas	19	nic	17	post	14
hak	23	nić	21	pech	19	noc	17	rym	14
ość	23	nikt	21	pies	19	płat	17	stan	14
pięść	23	pień	21	pieśń	19	plus	17	swój	14
pik	23	sień	21	plan	19	tło	17	wąs	14
płyn	23	słoń	21	port	19	to	17	widz	14
sok	23	trwać	21	rzut	19	wat	17	wieś	14
świt	23	twój	21	sklep	19	wir	17	wór	14
szal	23	żal	21	szef	19	wójt	17	zjeść	14
szyć	23	żer	21	tam	19	zbój	17	pół	13
żar	23	bar	20	wał	19	znać	17	pył	13
coś	22	cios	20	wosk	19	bal	16	znów	13
dać	22	ćma	20	wzór	19	bat	16	dzwon	12
dzicz	22	czar	20	zły	19	fach	16	lis	12
dzień	22	czas	20	znak	19	kurs	16	po	12
dzik	22	czy	20	brat	18	los	16	ser	12
gaj	22	fakt	20	but	18	łup	16	tom	12
koń	22	jacht	20	dal	18	nos	16	wstać	12
kot	22	ktoś	20	dół	18	raj	16	dzban	11
kraj	22	kwit	20	dwór	18	spać	16	wiek	11
kwiat	22	łach	20	dym	18	stać	16	om	10
liść	22	maj	20	dziś	18	sto	16	sen	9
lot	22	młyn	20	gach	18	stół	16	wiec	1
mak	22	mnich	20	gwałt	18	ton	16	wpaść	0

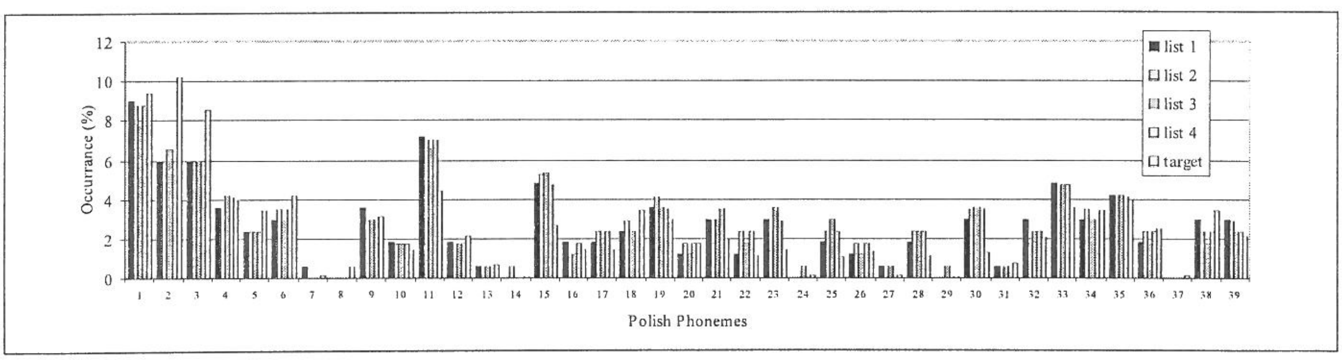

Fig. 1. Graphical representation of the number of phonemes in each male monosyllabic list

Tab. 4. Polish Male Monosyllabic Lists in Rank Order from Easiest to Most Difficult

List 1	List 2	List 3	List 4
jak	ktoś	ciecz	ćma
kształt	mysz	ość	świat
szał	sześć	cześć	rzecz
dać	nić	dziś	szyć
dzień	żyć	czek	czynsz
dom	klucz	kwit	maj
mech	sień	słoń	żal
czas	czy	dach	deszcz
dość	ja	grać	dzicz
kraj	mecz	nasz	szpik
pięść	noc	szept	wał
to	rzut	źle	cios
bicz	bok	coś	grosz
gość	czar	hak	koń
grzech	dwa	liść	nić
kwiat	dzik	miecz	śmiech
pies	gaj	pieśń	tekst
ty	złość	ruch	chwyt
gra	dorsz	dłoń	głos
mnich	kot	drzwi	jacht
rdza	pik	my	łoś
szal	rym	nikt	ryj
wieś	trwać	szok	stan
wir	żwir	tak	tam
but	cień	byk	dal
kij	gips	dno	iść
plan	moc	herb	kosz
strój	niech	łza	móc
szyk	sklep	on	park
teść	sto	spać	tło
tor	twój	żart	żbik
zły	zuch	as	bal
cel	łach	cham	gnat
pion	przy	dzwon	pan
sok	stać	grzbiet	pech
szef	tran	raj	rok
żar	że	stół	świt
zło	znak	typ	wójt
bój	brat	cynk	dar
fakt	fant	kit	koc
las	lej	lot	pień
płyn	sejm	szwy	ser
ton	wasz	zbir	znać
czyn	fach	len	leń
lin	młyn	mur	syn
piec	snop	swój	widz
sam	ten	tom	żer
wnuk	wosk	wesz	znów
metr	bar	jar	byt
woń	gwałt	wrzask	wzór

Tab. 5. Polish Female Monosyllabic Lists in Rank Order from Easiest to Most Difficult

List 1	List 2	List 3	List 4
drzwi	rzecz	czek	jak
grosz	świat	cześć	kształt
rok	szept	klucz	gra
dwa	rdza	łza	mecz
szał	szwy	żwir	deszcz
ciecz	czynsz	gość	grać
cień	grzbiet	grzech	hak
ość	świt	sok	płyn
pięść	szyć	szal	żar
pik	coś	dać	koń
dzicz	dzik	dzień	kot
kwiat	liść	gaj	kraj
miecz	lot	mysz	mur
ruch	mak	ryj	śmiech
sześć	szok	szpik	wy
ul	szyk	źle	złość
żyć	dłoń	chwyt	bok
dach	ja	dorsz	czyn
gnat	mech	kosz	dość
łoś	nić	nikt	pień
sień	słoń	trwać	twój
żal	żer	bar	cios
fakt	ćma	czas	czy
maj	czar	ktoś	kwit
moc	jacht	młyn	mnich
strój	łach	pion	przejść
wesz	my	tran	wasz
żbik	tekst	zło	zuch
byk	gips	dom	as
dar	leń	iść	cel
las	metr	móc	jar
on	pan	plan	pech
pas	pieśń	szef	port
pies	sklep	wał	rzut
zły	wzór	wosk	tam
znak	brat	but	dal
gach	dół	dym	dziś
kit	dwór	herb	kij
niech	gwałt	muł	nasz
tak	lej	piec	syn
ten	park	teść	tor
typ	wnuk	żart	że
złom	bój	cham	cynk
dno	głos	płat	lin
len	noc	wat	plus
nic	to	wójt	wir
tło	zbój	znać	bal
kurs	spać	nos	bat
łup	za	ton	stół
raj	zwać	wuj	włos

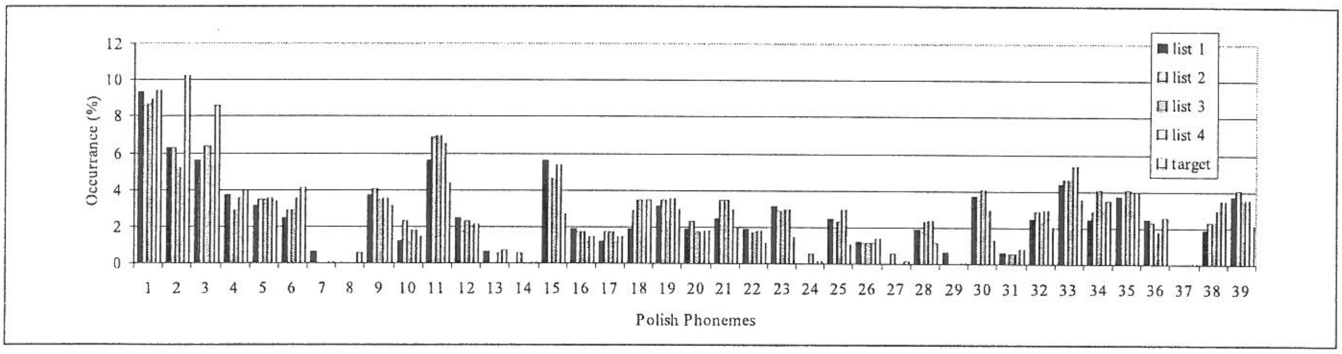

Fig. 2. Graphical representation of the number of phonemes in each female monosyllabic list

Tab. 6. Polish Male Monosyllabic Speech Discrimination Half-lists in Rank Order from Easiest to Most Difficult

1A	1B	2A	2B	3A	3B	4A	4B
jak	kształt	mysz	ktoś	ość	ciecz	świat	ćma
dać	szał	żyć	sześć	czek	cześć	czynsz	rzecz
dzień	dom	klucz	nić	kwit	dziś	maj	szyć
czas	mech	ja	sień	grać	słoń	dzicz	żal
dość	kraj	mecz	czy	nasz	dach	szpik	deszcz
to	pięść	bok	noc	coś	szept	grosz	wał
bicz	gość	czar	rzut	hak	źle	koń	cios
kwiat	grzech	gaj	dwa	pieśń	liść	tekst	nić
pies	ty	złość	dzik	ruch	miecz	chwyt	śmiech
mnich	gra	pik	dorsz	my	dłoń	łoś	głos
rdza	szal	rym	kot	nikt	drzwi	ryj	jacht
wir	wieś	cień	trwać	byk	szok	dal	stan
but	kij	gips	żwir	dno	tak	iść	tam
strój	plan	sklep	moc	on	herb	park	kosz
szyk	teść	sto	niech	spać	łza	tło	móc
zły	tor	łach	twój	cham	żart	gnat	żbik
cel	pion	przy	zuch	dzwon	as	pan	bal
szef	sok	że	stać	stół	grzbiet	świt	pech
żar	zło	znak	tran	typ	raj	wójt	rok
fakt	bój	lej	brat	lot	cynk	pień	dar
las	płyn	sejm	fant	szwy	kit	ser	koc
czyn	ton	młyn	wasz	mur	zbir	syn	znać
lin	piec	snop	fach	swój	len	widz	leń
wnuk	sam	bar	ten	jar	tom	byt	żer
metr	woń	gwałt	wosk	wrzask	wesz	wzór	znów

Tab. 7. Polish Female Monosyllabic Speech Discrimination Half-lists in Rank Order from Easiest to Most Difficult

1A	1B	2A	2B	3A	3B	4A	4B
drzwi	grosz	rzecz	świat	czek	cześć	kształt	jak
dwa	rok	rdza	szept	łza	klucz	deszcz	gra
szał	ciecz	szwy	czynsz	żwir	gość	grać	mecz
ość	cień	świt	grzbiet	sok	grzech	żar	hak
pięść	pik	szyć	coś	szal	dać	koń	płyn
kwiat	dzicz	liść	dzik	gaj	dzień	mur	kot
miecz	ruch	lot	mak	mysz	ryj	śmiech	kraj
ul	sześć	szyk	szok	źle	szpik	bok	wy
żyć	dach	dłoń	ja	chwyt	dorsz	czyn	złość
łoś	gnat	nić	mech	nikt	kosz	twój	dość
sień	żal	słoń	żer	trwać	bar	cios	pień
maj	fakt	czar	ćma	ktoś	czas	mnich	czy
moc	strój	jacht	łach	młyn	pion	przejść	kwit
żbik	wesz	tekst	my	zło	tran	as	wasz
byk	dar	gips	leń	dom	iść	cel	zuch
on	las	pan	metr	plan	móc	port	jar
pas	pies	pieśń	sklep	szef	wał	rzut	pech
znak	zły	brat	wzór	but	wosk	dziś	tam
gach	kit	dół	dwór	dym	herb	kij	dal
tak	niech	lej	gwałt	piec	muł	tor	nasz
ten	typ	park	wnuk	teść	żart	że	syn
dno	złom	głos	bój	płat	cham	plus	cynk
len	nic	noc	to	wat	wójt	wir	lin
kurs	tło	spać	zbój	nos	znać	stół	bal
łup	raj	za	zwać	ton	wuj	włos	bat

Tab. 8. Mean Performance for Polish Male Monosyllabic Speech Discrimination Lists and Half-Lists

List	a[a]	b[b]	Slope at 50%[c]	Slope from 20 to 80%[d]	Thres-hold[e]	Change in dB[f]
1	1.31	-0.21	5.3	4.6	6.2	-1.3
2	1.37	-0.22	5.5	4.8	6.3	-1.3
3	1.63	-0.25	6.3	5.4	6.5	-1.0
4	1.59	-0.24	6.1	5.3	6.5	-1.0
1A	1.34	-0.22	5.4	4.7	6.2	-1.3
1B	1.28	-0.21	5.2	4.5	6.2	-1.3
2A	1.65	-0.24	6.1	5.3	6.8	-0.7
2B	1.15	-0.20	5.0	4.3	5.7	-1.8
3A	1.79	-0.26	6.5	5.6	6.9	-0.6
3B	1.49	-0.24	6.1	5.3	6.1	-1.4
4A	1.63	-0.24	5.9	5.1	6.9	-0.6
4B	1.55	-0.25	6.3	5.4	6.2	-1.3
M	1.48	-0.23	5.8	5.0	6.4	-1.1
Minimum	1.15	-0.26	5.0	4.3	5.7	-1.8
Maximum	1.79	-0.20	6.5	5.6	6.9	-0.6
Range	0.64	0.06	1.5	1.3	1.2	1.2
SD	0.19	0.02	0.5	0.4	0.4	0.4

a[a] = regression slope. b[b] = regression intercept. [c]Performance intensity function slope (%/dB) at 50% was calculated from 49.99 to 50.01%. [d]Performance intensity function slope (%/dB) from 20-80%. [e]Intensity required for 50% intelligibility. [f]Change in intensity required to adjust the threshold of a list to the target of 7.5 dB

Tab. 9. Mean Performance for Polish Female Monosyllabic Speech Discrimination Lists and Half-Lists

List	a[a]	b[b]	Slope at 50%[c]	Slope from 20 to 80%[d]	Thre-shold[e]	Change in dB[f]
1	2.09	-0.24	6.0	5.2	8.7	1.2
2	2.08	-0.24	5.9	5.1	8.8	1.3
3	1.95	-0.22	5.5	4.8	8.9	1.4
4	2.16	-0.24	6.0	5.2	9.0	1.5
1A	2.13	-0.25	6.2	5.3	8.6	1.1
1B	2.05	-0.24	5.9	5.1	8.7	1.2
2A	1.88	-0.21	5.4	4.6	8.8	1.3
2B	2.35	-0.26	6.6	5.7	8.9	1.4
3A	1.90	-0.22	5.4	4.7	8.8	1.3
3B	1.99	-0.22	5.6	4.9	8.9	1.4
4A	2.30	-0.25	6.2	5.4	9.3	1.8
4B	2.03	-0.23	5.9	5.1	8.7	1.2
M	2.08	-0.24	5.9	5.1	8.8	1.3
Minimum	1.88	-0.26	5.4	4.6	8.6	1.1
Maximum	2.35	-0.21	6.6	5.7	9.3	1.8
Range	0.47	0.05	1.3	1.1	0.7	0.7
SD	0.14	0.01	0.4	0.3	0.2	0.2

a[a] = regression slope. b[b] = regression intercept. [c]Performance intensity function slope (%/dB) at 50% was calculated from 49.99 to 50.01%. [d]Performance intensity function slope (%/dB) from 20-80%. [e]Intensity required for 50% intelligibility. [f]Change in intensity required to adjust the threshold of a list to the target of 7.5 dB

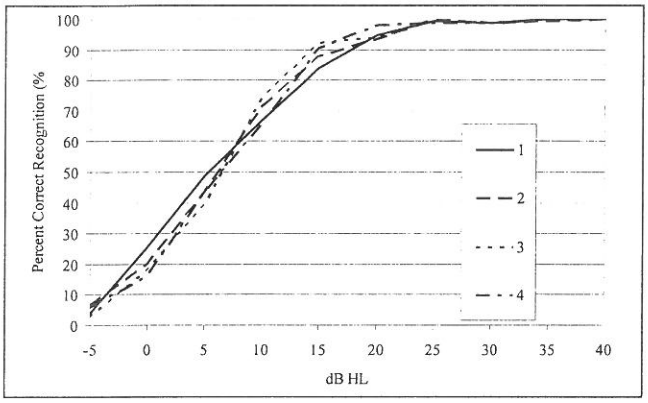

Fig. 3. Raw psychometric functions for the male Polish talker monosyllabic lists

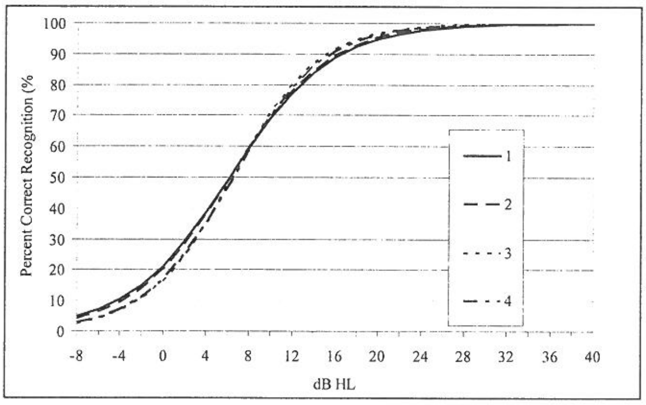

Fig. 7. Smoothed psychometric functions for the male Polish talker monosyllabic lists

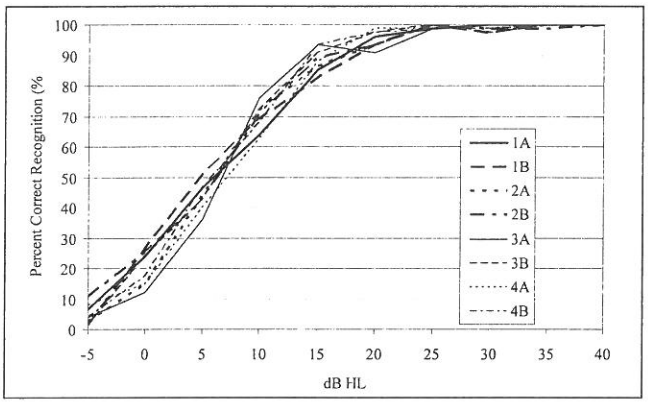

Fig. 4. Raw psychometric functions for the male Polish talker monosyllabic half-lists

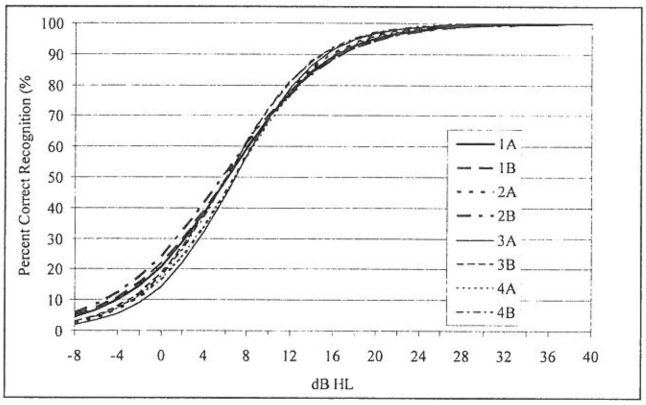

Fig. 8. Smoothed psychometric functions for the male Polish talker monosyllabic half-lists

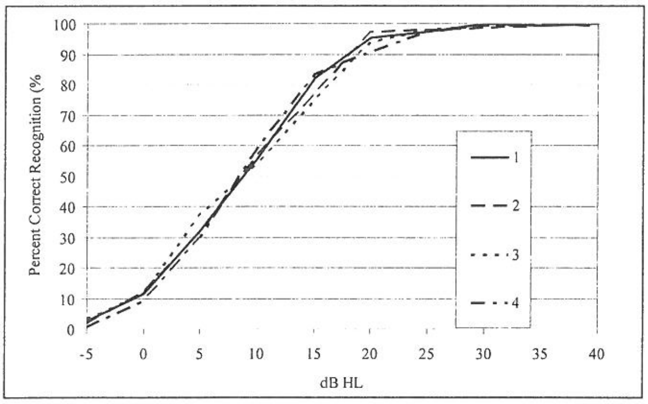

Fig. 5. Raw psychometric functions for the female Polish talker monosyllabic lists

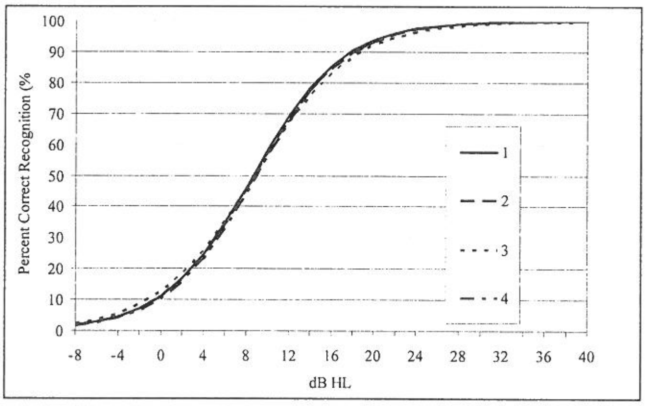

Fig. 9. Smoothed psychometric functions for the female Polish talker monosyllabic lists

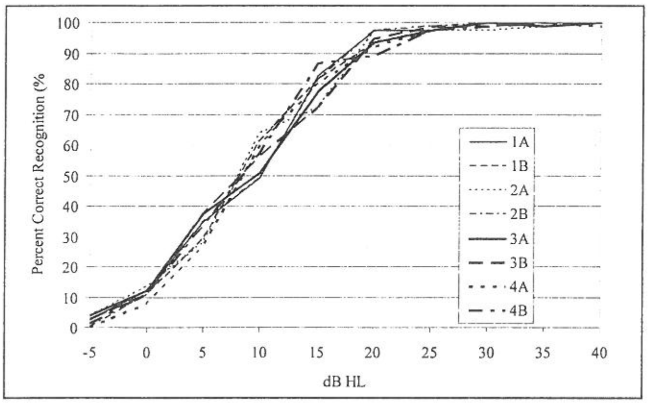

Fig. 6. Raw psychometric functions for the female Polish talker monosyllabic half-lists

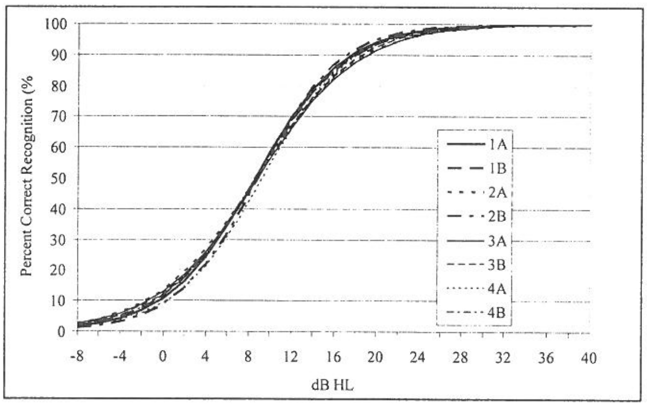

Fig. 10. Smoothed psychometric functions for the female Polish talker monosyllabic half-lists

$$\% = (1 - \frac{\exp(a + b * dB)}{1 + \exp(a + b * dB)}) * 100 \quad (1)$$

In Equation 1, a is the regression slope, b is the regression intercept, and dB is the presentation intensity level in dB HL. For a more detailed discussion of the derivation of Equation 1 the reader is referred to Harris et al. [2001].

By inserting the regression slope, regression intercept, and intensity level into Equation 1, it is possible to predict the percent correct word recognition at any specified intensity level. Percent correct word recognition was predicted for each of the bisyllabic lists and half-lists for a range of -8 to 40 dB HL in 2 dB increments. Smoothed psychometric functions were then produced using the predicted percentages. The smoothed psychometric functions for the male lists and half-lists are found in Figures 7 and 8; the smoothed psychometric functions for the female lists and half-lists are found in Figures 9 and 10. The threshold (presentation intensity required for 50% word recognition performance), the slope at threshold, and the slope from 20 to 80% were calculated for the bisyllabic lists and half lists by inserting the desired proportions into Equation 2. The data for the threshold, slope at threshold, and slope from 20 to 80% for each psychometric function are presented in Table 8 (male) and Table 9 (female).

$$dB = \frac{\log \frac{p}{1-p} - a}{b} \quad (2)$$

After the lists and half-lists were compiled, a chi-square (X2) analysis was performed in order to determine if there were any significant differences among the lists or half-lists for both the male (Table 10) and female (Table 11) talker recordings. No significant differences were found among the four lists or the eight half-lists for either the male or female talker (all p>0.05). While there were no statistically significant differences among the lists or half-lists, intensity level adjustments were made digitally using Sadie Disk Editor software [Studio Audio and Video Limited 1996] in an attempt to increase the psychometric equivalency of the lists and half lists. The thresholds of each word in the 8 bisyllabic lists (4 male, 4 female) and the 16 bisyllabic half-lists (8 male, 8 female) were digitally adjusted so that the 50% threshold of each list was equal to the approximate midpoint (7.5 dB HL) between the mean threshold of the eight male half lists and the mean threshold of the eight female half lists. The intensity adjustments made to each word in the 4 lists and 8 half--lists are presented in Table 8 (male) and Table 9 (female). The predicted psychometric functions for the adjusted male talker bisyllabic lists and half lists after intensity adjustment are presented in Figures 11 and 12; the psychometric functions for the female talker bisyllabic lists and half lists after intensity adjustment are presented in Figures 13 and 14. Figure 15 contains mean psychometric functions for the combined male and combined female bisyllabic lists both before and after intensity adjustment to equate performance. Inspection of Figure 15 indicates that the predicted psychometric functions were identical for the male and female talker lists after making intensity adjustments to equate performance.

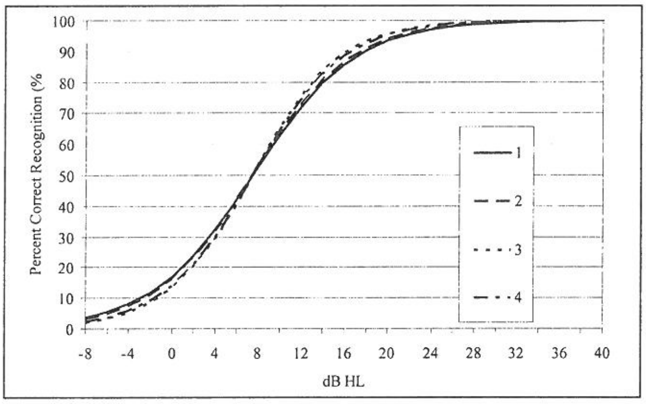

Fig. 11. Predicted psychometric functions for the male Polish talker monosyllabic lists after intensity adjustment

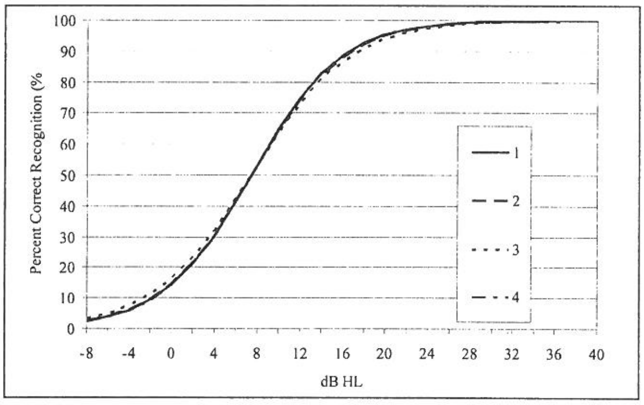

Fig. 13. Predicted psychometric functions for the female Polish talker monosyllabic lists after intensity adjustment

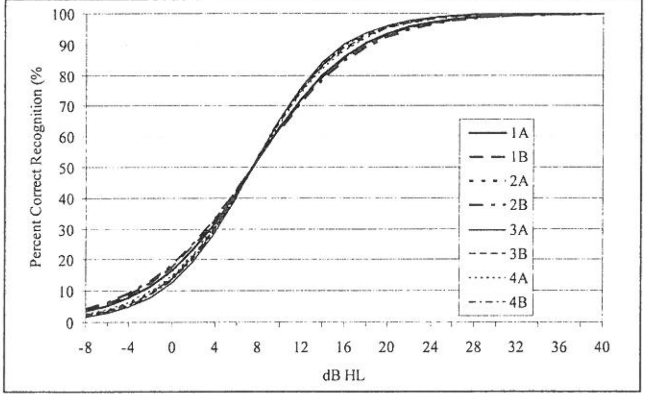

Fig. 12. Predicted psychometric functions for the male Polish talker monosyllabic half-lists after intensity adjustment

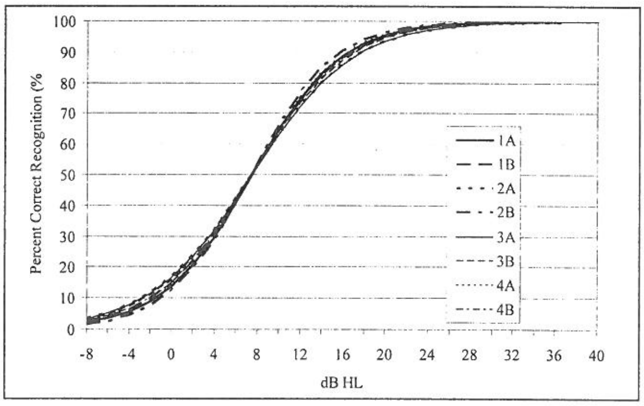

Fig. 14. Predicted psychometric functions for the female Polish talker monosyllabic half-lists after intensity adjustment

Tab. 10. Statistical Comparisons Among Male Monosyllabic Lists and Half-Lists

Comparison	df	X^2	p
1 and 2	1	0.0038	0.9509
1 and 3	1	0.0990	0.7530
1 and 4	1	0.1944	0.6593
2 and 3	1	0.0640	0.8002
2 and 4	1	0.1439	0.7045
3 and 4	1	0.0159	0.8995
1a and 1b	1	0.0000	1.0000
1a and 2a	1	0.3903	0.5321
1a and 2b	1	0.2879	0.5916
1a and 3a	1	0.5096	0.4753
1a and 3b	1	0.0719	0.7886
1a and 4a	1	0.6448	0.4220
1a and 4b	1	0.0319	0.8581
1b and 2a	1	0.3903	0.5321
1b and 2b	1	0.2879	0.5916
1b and 3a	1	0.5096	0.4753
1b and 3b	1	0.0719	0.7886
1b and 4a	1	0.6448	0.4220
1b and 4b	1	0.0319	0.8581
2a and 2b	1	1.3484	0.2456
2a and 3a	1	0.0079	0.9290
2a and 3b	1	0.7972	0.3719
2a and 4a	1	0.0318	0.8585
2a and 4b	1	0.6456	0.4217
2b and 3a	1	1.5633	0.2112
2b and 3b	1	0.0720	0.7884
2b and 4a	1	1.7940	0.1804
2b and 4b	1	0.1280	0.7205
3a and 3b	1	0.9643	0.3261
3a and 4a	1	0.0079	0.9290
3a and 4b	1	0.7967	0.3721
3b and 4a	1	1.1473	0.2841
3b and 4b	1	0.0080	0.9288
4a and 4b	1	0.9638	0.3262

Tab. 11. Statistical Comparisons Among Female Monosyllabic Lists and Half-Lists

Comparison	df	X^2	p
1 and 2	1	0.0997	0.7522
1 and 3	1	0.1953	0.6586
1 and 4	1	0.3979	0.5282
2 and 3	1	0.0159	0.8995
2 and 4	1	0.0993	0.7526
3 and 4	1	0.0357	0.8502
1a and 1b	1	0.0080	0.9288
1a and 2a	1	0.0718	0.7888
1a and 2b	1	0.0718	0.7888
1a and 3a	1	0.1275	0.7210
1a and 3b	1	0.1275	0.7210
1a and 4a	1	0.7963	0.3722
1a and 4b	1	0.0080	0.9288
1b and 2a	1	0.0319	0.8583
1b and 2b	1	0.0319	0.8583
1b and 3a	1	0.0717	0.7888
1b and 3b	1	0.0717	0.7888
1b and 4a	1	0.6449	0.4219
1b and 4b	1	0.0000	1.0000
2a and 2b	1	0.0000	1.0000
2a and 3a	1	0.0080	0.9289
2a and 3b	1	0.0080	0.9289
2a and 4a	1	0.3900	0.5323
2a and 4b	1	0.0319	0.8583
2b and 3a	1	0.0080	0.9289
2b and 3b	1	0.0080	0.9289
2b and 4a	1	0.3900	0.5323
2b and 4b	1	0.0319	0.8583
3a and 3b	1	0.0000	1.0000
3a and 4a	1	0.2865	0.5925
3a and 4b	1	0.0717	0.7888
3b and 4a	1	0.2865	0.5925
3b and 4b	1	0.0717	0.7888
4a and 4b	1	0.6449	0.4219

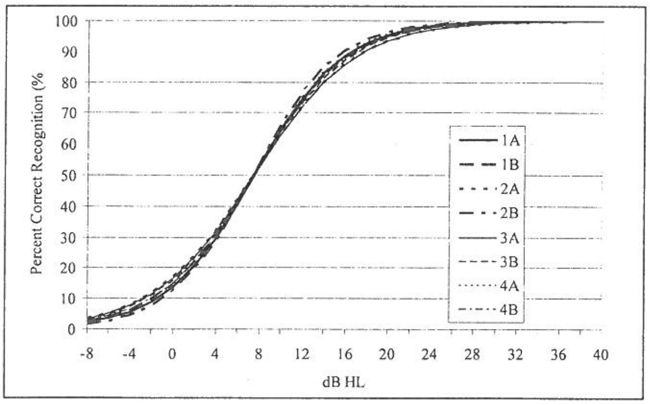

Fig. 15. Mean psychometric functions for male and female Polish talker monosyllabic lists: before and after intensity adjustment

Discussion

The main purpose of this study was to develop a set of homogeneous Polish monosyllabic word lists for use in measuring auditory word recognition. Inspection of Figures 11-14 indicate that we have been able to develop a set of lists and sublists which have very homogeneous performance with respect to audibility and psychometric function slope. A chi-square analysis was performed to determine whether there were any statistically significant differences among the monosyllabic lists or half-lists. No significant differences were found among the four lists or the eight half lists, as can be seen in Tables 10 (male) and 11 (female).

Slopes from 20 to 80% for the monosyllabic lists and half-lists ranged from 4.3 to 5.6 %/dB (M = 5.0 %/dB) for the male recordings and from 4.6 to 5.7 %/dB (M = 5.1 %/db) for the female recordings. Others have reported means for English auditory word recognition materials that are slightly lower than those of the Polish recordings. Beattie, Edgerton, and Svihovec [1977] reported a mean slope of 4.2 %/dB for the NU-6 word lists and a mean slope of 4.6 %/dB for the CID W-22 word lists. Wilson and Oyler [1997] found the following when evaluating the recordings from the Auditec of St. Louis CD: 4.4 %/dB (NU-6 word lists) and 4.8 %/dB (CID W-22 word lists).

A great deal of research remains to be done in the field of Polish speech audiometry materials. Future research could examine the similarities between the mean SRT obtained with the 25 adjusted bisyllabic words from this study and the mean PTA of the test subjects. More research could also be done with the monosyllabic lists. A comparison could be made between the auditory word recognition score obtained when the ten most difficult words of a list are presented and the score obtained when the whole list is presented. If the score obtained when the ten most difficult words are presented is similar to the score obtained when the whole list is presented, test time could be shortened by presenting only the ten most difficult words. Future research could also include examining list equivalency for hearing impaired individuals.

In addition to the research that can be conducted on the current Polish speech audiometry materials, there is also a need to develop new Polish speech materials. For example, speech materials could be created for children on the basis of word familiarity. Many of the present-day speech materials for Polish children contain words not highly familiar to children [M. Malesińska, personal communication, December 16, 1999]. There is also a need to develop high-quality recordings of Polish speech materials used in aural rehabilitation for those with cochlear implants.

In summary, we have been able to develop digitally recorded monosyllabic Polish auditory word recognition lists and half-lists that are very homogeneous with respect to audibility and psychometric function slope. These lists can be used to evaluate auditory word recognition in individuals whose native language is Polish. The monosyllabic lists and half-lists for both the male and female talkers are contained on the CD entitled Brigham Young University Polish Speech Audiometry Materials (Disc 1.0).

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