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Shawn L. Nissen
Shawn_Nissen@byu.edu

Richard W. Harris

Alycia Dukes

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Word Recognition Materials for Native Speakers of Taiwan Mandarin

Shawn L. Nissen
Richard W. Harris
Alycia Dukes
Brigham Young University, Provo, UT

Purpose: To select, digitally record, evaluate, and psychometrically equate word recognition materials that can be used to measure the speech perception abilities of native speakers of Taiwan Mandarin in quiet.
Method: Frequently used bisyllabic words produced by male and female talkers of Taiwan Mandarin were digitally recorded and subsequently evaluated using 20 native listeners with normal hearing at 10 intensity levels (–5 to 40 dB HL) in increments of 5 dB.
Results: Using logistic regression, 200 words with the steepest psychometric slopes were divided into 4 lists and 8 half-lists that were relatively equivalent in psychometric function slope. To increase auditory homogeneity of the lists, the intensity of words in each list was digitally adjusted so that the threshold of each list was equal to the midpoint between the mean thresholds of the male and female half-lists.
Conclusions: Digital recordings of the word recognition lists and the associated clinical instructions are available on CD upon request.

Key Words: word recognition, Taiwan Mandarin, Chinese, speech audiometry, psychometric function

The purpose of the following study was to develop and evaluate word recognition materials that can be used to assess the hearing abilities of individuals who speak Taiwan Mandarin, a regional dialect of Mandarin Chinese. Speech audiometry materials have been recently developed for Pŭtōnghuà (Nissen, Harris, Jennings, Eggett, & Buck, 2005a, 2005b), a standard dialect of Mandarin commonly spoken in mainland China. However, there are many individuals living throughout the world who speak dialects of Mandarin that are linguistically distinct from Pŭtōnghuà; for these individuals, such speech audiometry materials may not provide a valid and accurate evaluation of their hearing abilities.

Previous findings from Weisleder and Hodgson (1989) indicate that regional differences in dialect between the talker and listener may affect the validity of word recognition results. The authors evaluated the performance of four Spanish word recognition lists with listeners from differing regional linguistic backgrounds. The lists were produced by a talker of Mexican origin, whereas the listeners were from Mexico, Panama, Venezuela, Spain, Honduras, and Columbia. It was found that listeners originating from the same country as the talker performed better than participants from the other Spanish-speaking countries, even though all the listeners reported the talker to be mutually intelligible. Differences between listener performances were most pronounced in more difficult listening environments. These findings indicate that even small differences in regional dialect between the talker and listener may affect the validity of acquired word recognition results.

Mandarin is a term that refers to a group of Chinese dialects spoken in many different areas of the world, many of which exhibit unique linguistic characteristics and distinct regionalisms. In general, dialects of Mandarin are considered *tonal,* in that words and meaningful morphological units are formed by combining a comparatively basic segmental structure with an overriding suprasegmental tone. Individual syllables generally have an optional initial consonant followed by a nuclear vowel that can occur as a monophthong, diphthong, or in some cases a triphthong (e.g., /i, ou, iou/; Chao, 1968). Some syllables have a coda consisting of a relatively limited set of nasals. In addition, Mandarin is an isolated language, whereby each orthographic character is a free morpheme that carries unique meaning (C. N. Li & Thompson, 1987). In theory, each Mandarin character has unique meaning and can stand alone; however, the majority of the lexicon is composed of polysyllabic compound words (Zhou & Marslen-Wilson, 1995).

While Taiwan Mandarin and Pŭtōnghuà are considered by linguists to be generally *mutually intelligible* with regard to expressed meaning, each dialect contains marked differences in syntax, lexicon, phonology, and orthographic representation

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(D. C. C. Li, 1983). Syntactically, Taiwan Mandarin differs from Pǔtōnghuà in the tendency of speakers to mark the contrast between perfective and imperfective cases, and habitual and future action, yet to neutralize differences between present and past action verbs (Cheng, 1985). In addition, the two dialects exhibit differences in the use of auxiliary verbs and common verbs such as *have, come,* and *go* (Cheng, 1985; D. C. C. Li, 1985). There are also differences in the lexicon of each dialect. For example, the Taiwan Mandarin word *cùantōng* (竄通), meaning "an exchange," is often ambiguous for many speakers of Pǔtōnghuà, which more commonly uses vocabulary such as jiāo liú (交流) or *hùhùan* (互換) to express a similar meaning (D. C. C. Li, 1985). Phonologically, the dialects differ in terms of consonant, vowel, and tone production. Taiwan Mandarin often replaces retroflex initials with dentals, switches /n/ and /ŋ/ in the final position of words, and commonly merges vowel categories (e.g., /y/ with /i/). Some researchers have even suggested that the vowel structure of Taiwan Mandarin is different from that of other dialects of Mandarin spoken in mainland China (Wan & Jaeger, 2003). When compared with other dialects of Mandarin, Taiwan Mandarin has been characterized as having a relatively low tone registry and a less frequent use of a neutral or fifth tone for unstressed syllables (Fon & Chiang, 1999; Kubler, 1985; Peng, 1991). In addition, two different orthographic systems are often used to visually represent Pǔtōnghuà and Taiwan Mandarin. Traditional Chinese characters are utilized in Taiwan, Hong Kong, and many overseas communities, whereas in the 1950s, mainland China officially adopted a writing system of simplified characters (C. N. Li & Thompson, 1987).

The origin of linguistic differences between the two dialects is due in part to the geographic isolation and political separation of Taiwan from mainland China. Dialectal differences between Taiwan Mandarin and Pǔtōnghuà may also be a result of a period of Japanese colonization prior to World War II and the influence of indigenous speakers (e.g., Taiwanese). The national language of Taiwan was changed to Taiwan Mandarin in 1949, despite a large number of native speakers of Japanese, Taiwanese, and Beijing Mandarin (Lee, 1981). From 1949 to 1960, the Taiwan provincial government campaigned to promote the use of Taiwan Mandarin as the sole means of communication for instruction in the school systems in Taiwan. These sociolinguistic factors have led to a dialect of Mandarin that is unique to the native speakers of Taiwan. (For a more comprehensive discussion about the linguistic differences between the two dialects and their origins, see Cheng, 1985; Fon & Chiang, 1999; D. C. C. Li, 1983; Nissen, Harris, & Slade, 2007; Peng, 1991.)

An appropriate hearing evaluation for an individual from Taiwan should involve speech audiometry materials in his or her specific regional dialect. Thus, the aim of this study was to develop high-quality digitally recorded word recognition materials in Taiwan Mandarin. The specific objectives were as follows: (a) to identify one female individual and one male individual from Taiwan who spoke Mandarin Chinese with a standard Taiwan dialect to serve as talkers for the recordings; (b) to compose a list of familiar bisyllabic Mandarin words to be used in word recognition testing; (c) to create high-quality digital recordings of the bisyllabic words; (d) to collect normative data on the bisyllabic words; and (e) to construct psychometrically equivalent lists (50 words each) and half-lists (25 words each) of bisyllabic Mandarin words from both the female and male talkers.

Method

Participants

Twenty native speakers of Taiwan Mandarin (3 male and 17 female) ranging in age from 18 to 39 years ($M = 25.8$ years) participated in evaluating the materials developed in this study. Participants were recruited within the United States and had recently originated from various regions of Taiwan (e.g., Taibei, Taichung, Kaohsiung). In addition, all participants reported speaking a standard dialect of Taiwan Mandarin on a daily basis since arriving in the United States. All of the participants were found to have pure-tone air-conduction thresholds ≤ 15 dB HL at octave and midoctave frequencies from 125 to 8000 Hz and static acoustic admittance between 0.3 and 1.4 mmhos with peak pressure between –100 and +50 daPa (American Speech-Language-Hearing Association, 1990; Roup, Wiley, Safady, & Stoppenbach, 1998). The mean pure-tone average (arithmetic average of pure-tone thresholds at 500, 1000, and 2000 Hz) for the 20 participants was 5.0 dB HL. Each participant also passed a screening test, which included an otoscopic evaluation, an ipsilateral acoustic reflex of 95 dB HL or better in the test ear at 1000 Hz, and the signing of an informed consent form.

Materials

Word lists. Monosyllabic words are often used for word recognition testing in English; however, this study utilized bisyllabic words in developing materials for speakers of Taiwan Mandarin, for the following reasons: First, previous studies involving the development of speech audiometry materials using native Mandarin speakers from mainland China found that bisyllabic words have relatively steeper mean psychometric slopes (Nissen et al., 2005a, 2005b). Second, although each written Chinese character can express unique lexical meaning, the majority word type in spoken Mandarin (approximately 73.6%) is bisyllabic (Institute of Language Teaching and Research, 1986). Finally, the same pronunciation (e.g., *shi*) is often used for multiple different Chinese characters; thus, it would be inconvenient to evaluate a participant's written responses to monosyllabic Mandarin word lists (Mathews, 1944).

A preliminary word corpus of 300 frequently used bisyllabic words was drawn from the Academia Sinica Balanced Corpus of Modern Chinese (Academia Sinica Computing Center, 1997). This corpus contains approximately 5 million words, balanced across the topics of philosophy, science, society, art, life, and literature. According to the Sinica corpus, the initial set of words selected for this study were all ranked within the top 400 most frequently used modern Chinese words, with an average frequency percentage of .0004, ranging from a low of .0002 to a high of .0038. These words were then rated by 3 native speakers of Taiwan Mandarin on a scale of 1 to 5 based on how familiar a word would be to a Mandarin speaker from Taiwan (1 = *extremely familiar,* 2 = *very familiar,* 3 = *somewhat familiar,* 4 = *infrequently*

used, and 5 = *rarely used*). Of the 300 original bisyllabic words, 60 words were eliminated from final evaluation for the following reasons: (a) The specific word was not rated as extremely familiar by any of the native judges, (b) it was judged to be culturally or politically insensitive, or (c) it had the same pronunciation but different meaning (homophonic words) as another word in the corpus.

Talkers. Initial audio recordings of conversational speech were produced by 6 native talkers of Taiwan Mandarin (3 female and 3 male), all of whom originated from Taiwan and reported speaking a standard dialect of Taiwan Mandarin. A panel of 8 native speakers then evaluated the speech production of each of the 6 talkers. The native judges were instructed to rank the recordings of each talker from best to worst based on the perceived clarity of pronunciation, vocal quality, and standard Taiwan Mandarin dialect. The highest ranked male and female speakers were chosen as the talkers for all subsequent recordings.

Recordings. The talker recordings were made in a double-walled sound booth located on the Brigham Young University campus in Provo, UT. A Larson Davis Model 2541 microphone, positioned approximately 15 cm from the talker at a 0° azimuth and covered by a 7.62-cm windscreen, was utilized for all recordings. The microphone signal was amplified by a Larson Davis Model 900B microphone preamplifier, which was coupled to a Larson Davis Model 2200C preamplifier power supply. An Apogee AD-8000 analog-to-digital converter was used to digitize the audio signals, which were subsequently 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.

The talkers were asked to pronounce each bisyllabic word at least four times. To avoid possible list effects and declination of intonation, the first and last repetitions of each word were excluded from the study. A native judge then rated the medial repetitions of each bisyllabic word for perceived quality of production, and the highest rated production of each word was selected for further evaluation. Any words that were judged to be poorly recorded were rerecorded or eliminated from the study prior to listener evaluation. The intensity of each bisyllabic word to be included in the listener evaluation was then edited as a single utterance using Sadie Disk Editor software (Studio Audio & Video, 2004) to yield the same equivalent continuous sound level (Leq) as that of a 1-kHz calibration tone using a Larson Davis Model 824 sound level meter.

Procedures

The randomization and presentation of the words were controlled using custom software. The experimental stimuli were routed from a computer hard drive to the external input of a Grason-Stadler Model 1761 audiometer using a Lynx L22 sound card. The stimuli were then routed via TDH-50P headphones from the audiometer to the participants. Testing was conducted in a double-walled sound suite meeting American National Standards Institute (ANSI S3.1-1999) standards for maximum permissible ambient noise levels for the ears-not-covered condition using one third octave-band measurements (ANSI, 1999). Prior to each testing session, the inputs to the audiometer were calibrated to 0 VU using the 1-kHz calibration tone through customized computer software. In accordance with ANSI S3.6-2004 standards (ANSI, 2004), the audiometer was also calibrated weekly during and at the conclusion of data collection. No changes in calibration were necessary throughout the course of data collection.

Evaluation of Bisyllabic Words

The participants were not familiarized with the bisyllabic words prior to testing. The 240 bisyllabic words were randomly grouped into 10 lists of 24 words each. These 10 lists were used for presentation to the first 10 participants. The 240 words were then randomly combined in a second group of 10 different lists for presentation to the next group of 10 participants. Ten presentation levels were selected for the lists: –5 to 40 dB HL in 5-dB steps. One list was presented at each level. The order of the presentation of the lists and the order of the words within the list were randomized for each participant. Each word was presented an equal number of times at each intensity level across the entire participant population. Prior to administration of the word recognition test, the following instructions were given to the participants in Mandarin:

> You will hear bisyllabic words at several different loudness levels. At the very soft levels it may be difficult for you to hear the words. Please listen carefully and repeat the words you hear. If you are unsure of the word, you are encouraged to guess. If you have no guess, please remain quiet until the next word is presented. Do you have any questions?

The accuracy of the participants' verbal responses was judged to be correct or incorrect by a native speaker of Taiwan Mandarin who was highly familiar with the word corpus and the testing procedures. An orthographic display of each test item was made available to the native judge during and after each stimulus presentation. The scoring of each test item was immediately recorded by the native judge using custom software.

Results

Word recognition scores have been traditionally derived by utilizing full word lists consisting of 50 test items. However, some audiologists utilize only half of the 50 full-list items to reduce clinical testing time and decrease the influence of patient fatigue (Penrod, 1994). To accommodate both methods of assessment, the final word recognition materials were organized into four lists (50 words each) and eight half-lists (25 words each) for both the male and female talker recordings.

The 200 words with the greatest number of correct identifications were selected and subsequently divided into four counterbalanced lists of 50 words each through random block assignment. This was accomplished by first assigning a ranking to each bisyllabic word based on the number of times it was correctly identified across all participants and intensity levels. The first four words from the rank-ordered list of 200 words were then randomly assigned to one of the four

lists. This list assignment procedure was repeated with the next four rank-ordered words until each of the four word recognition lists contained 50 words each. Eight half-lists were created from the four word recognition lists by dividing each list into 25 consecutive pairs of words based on their relative position in the list. For example, Pair 1 consisted of the first and second word in the list, Pair 2 the third and fourth word, and so on. The first word from the first pair was then allocated to Half-List A and the second to Half-List B. For each subsequent pair, this allocation was reversed. The male and female word recognition lists (Appendix A) and half-lists (Appendix B) are provided in both traditional characters and Hanyu Pinyin romanization.

The combined dichotomous perception data from each word in a list or half-list were analyzed with logistic regression to calculate regression slopes and intercepts for each of the four lists and eight half-lists for both male and female talker recordings, which are presented in Tables 1 and 2, respectively. Percentage correct recognition values were calculated for each list and half-list by inserting the regression slope and intercept values into a modified logistic regression equation (Equation 1). This equation is designed to calculate percentage of correct performance at any specified intensity level. In Equation 1, P is percentage of correct recognition, a is the regression intercept, b is the regression slope, and i is the presentation intensity level in dB HL.

$$P = \left(1 - \frac{\exp(a + b \times i)}{1 + \exp(a + b \times i)}\right) \times 100. \quad (1)$$

The percentage of correct word recognition was predicted for each of the bisyllabic lists and half-lists at a range of intensity levels (–8 to 40 dB HL in 2-dB increments). A psychometric function for each list and half-list was created using these predicted percentages of word recognition. In addition, the threshold (presentation intensity required for 50% word recognition), the slope at threshold, and the slope from 20% to 80% were calculated for each of the bisyllabic lists and half-lists by inserting the desired proportions into Equation 2. In Equation 2, i is the presentation level in dB HL, p is the proportion of correct recognition, a is the regression intercept, and b is the regression slope.

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

As shown in Table 1, for the male talker recordings, the psychometric function slopes at the 50% location ranged from 8.7% to 10.2%/dB (M = 9.6%/dB) for the lists and from 8.4% to 11.3%/dB (M = 9.6%/dB) for the half-lists. The slope values for the female talker recordings are found in Table 2, which range from 7.6% to 8.2%/dB (M = 7.8%/dB) for the lists and from 7.2% to 8.6%/dB (M = 7.9%/dB) for the half-lists. Slopes of the psychometric functions were slightly lower when measured from the 20% to 80% points of the functions instead of calculating the slopes at the threshold midpoint, with slope values ranging from 7.6% to 8.8%/dB (M = 8.3%/dB) for the male talker lists and from 7.3% to 9.8%/dB (M = 8.3%/dB) for the half-lists; for the female talker

Table 1. Mean performance of Taiwan Mandarin male bisyllabic lists and half-lists.

List	Intercept[a]	Slope[b]	Slope at 50%[c]	Slope from 20% to 80%[d]	50% threshold[e]	Change to midpoint[f]
1	2.2178	−0.4078	10.2	8.8	5.4	1.0
2	2.2178	−0.4078	10.2	8.8	5.4	1.0
3	1.8779	−0.3496	8.7	7.6	5.4	0.9
4	1.9625	−0.3649	9.1	7.9	5.4	0.9
M	2.0690	−0.3825	9.6	8.3	5.4	0.9
Minimum	1.8779	−0.4078	8.7	7.6	5.4	0.9
Maximum	2.2178	−0.3496	10.2	8.8	5.4	1.0
Range	0.3399	0.0582	1.5	1.3	0.1	0.1
SD	0.1753	0.0299	0.7	0.6	0.0	0.0
1A	2.0085	−0.3733	9.3	8.1	5.4	0.9
1B	2.4885	−0.4531	11.3	9.8	5.5	1.0
2A	2.0573	−0.3822	9.6	8.3	5.4	0.9
2B	2.4104	−0.4389	11.0	9.5	5.5	1.0
3A	1.8019	−0.3359	8.4	7.3	5.4	0.9
3B	1.9625	−0.3649	9.1	7.9	5.4	0.9
4A	1.8779	−0.3496	8.7	7.6	5.4	0.9
4B	2.0573	−0.3822	9.6	8.3	5.4	0.9
M	2.0830	−0.3850	9.6	8.3	5.4	0.9
Minimum	1.8019	−0.4531	8.4	7.3	5.4	0.9
Maximum	2.4885	−0.3359	11.3	9.8	5.5	1.0
Range	0.6866	0.1172	2.9	2.5	0.1	0.1
SD	0.2432	0.0410	1.0	0.9	0.1	0.1

[a]Regression intercept.
[b]Regression slope.
[c]Psychometric function slope (%/dB) at 50% was calculated from 49.999% to 50.001%.
[d]Psychometric function slope (%/dB) from 20% to 80%.
[e]Intensity required for 50% intelligibility.
[f]Change in intensity required to adjust the 50% threshold of a list to the mean 50% threshold for male and female lists (4.5 dB HL).

Table 2. Mean performance of Taiwan Mandarin female bisyllabic lists and half-lists.

List	Intercept[a]	Slope[b]	Slope at 50%[c]	Slope from 20% to 80%[d]	50% threshold[e]	Change to midpoint[f]
1	1.0684	−0.3054	7.6	6.6	3.5	−1.0
2	1.1768	−0.3288	8.2	7.1	3.6	−0.9
3	1.0794	−0.3082	7.7	6.7	3.5	−1.0
4	1.1157	−0.3133	7.8	6.8	3.6	−0.9
M	1.1101	−0.3139	7.8	6.8	3.5	−0.9
Minimum	1.0684	−0.3288	7.6	6.6	3.5	−1.0
Maximum	1.1768	−0.3054	8.2	7.1	3.6	−0.9
Range	0.1083	0.0233	0.6	0.5	0.1	0.1
SD	0.0488	0.0104	0.3	0.2	0.0	0.0
1A	1.1137	−0.3169	7.9	6.9	3.5	−1.0
1B	1.0265	−0.2950	7.4	6.4	3.5	−1.0
2A	1.2164	−0.3434	8.6	7.4	3.5	−0.9
2B	1.1412	−0.3156	7.9	6.8	3.6	−0.9
3A	1.1627	−0.3295	8.2	7.1	3.5	−0.9
3B	1.0067	−0.2900	7.3	6.3	3.5	−1.0
4A	1.2164	−0.3434	8.6	7.4	3.5	−0.9
4B	1.0332	−0.2892	7.2	6.3	3.6	−0.9
M	1.1146	−0.3154	7.9	6.8	3.5	−0.9
Minimum	1.0067	−0.3434	7.2	6.3	3.5	−1.0
Maximum	1.2164	−0.2892	8.6	7.4	3.6	−0.9
Range	0.2097	0.0542	1.4	1.2	0.1	0.1
SD	0.0843	0.0224	0.6	0.5	0.0	0.0

[a]Regression intercept.
[b]Regression slope.
[c]Psychometric function slope (%/dB) at 50% was calculated from 49.999% to 50.001%.
[d]Psychometric function slope (%/dB) from 20% to 80%.
[e]Intensity required for 50% intelligibility.
[f]Change in intensity required to adjust the 50% threshold of a list to the mean 50% threshold for male and female lists (4.5 dB HL).

lists, values ranged from 6.6% to 7.1%/dB (M = 6.8%/dB) and from 6.3% to 7.4%/dB (M = 6.8%/dB) for the half-lists.

A logistic regression yielding a chi-square statistic was utilized to investigate whether there were any significant differences among the lists or half-lists for each talker. In terms of statistical power, the chi-square analysis for the full lists was able to detect a 10% difference in correct responses between lists with a probability of .997 and for the half-lists a 10% difference in correct responses between lists with a probability of .913. The results of the analysis indicated that there were no significant differences among the 50-word lists for the male and female talkers, $\chi^2(3, N = 20) = 1.97$, $p = .578$, and $\chi^2(3, N = 20) = 0.26$, $p = .965$, respectively. Results also indicated that there were no significant differences found among the 25-word half-lists for the male and female talkers, $\chi^2(7, N = 20) = 3.75$, $p = .808$, and $\chi^2(7, N = 20) = .98$, $p = .995$, respectively. There were also no significant within-talker Intensity × List interactions noted.

Although there were no statistically significant differences found among the word recognition lists or half-lists for each talker, digital intensity-level adjustments were made to each list using Sadie Disk Editor software (Studio Audio & Video, 2004) to increase the psychometric equivalency of the materials. The intensity of each word from the male and female bisyllabic lists and half-lists was adjusted digitally so that the 50% threshold of each list was equal to the midpoint (4.5 dB HL) between the mean threshold of the eight male half-lists and the mean threshold of the eight female half-lists. Lists of the digital adjustments for both the male and female talker lists are presented in Tables 1 and 2. The psychometric functions for the lists and half-lists after intensity adjustment are illustrated in Figure 1. Figure 2 contains mean psychometric functions for the combined male and combined female bisyllabic lists both before and after intensity adjustment to equate performance.

Discussion

The purpose of the current study was to construct a set of psychometrically equivalent bisyllabic Taiwan Mandarin word recognition lists and half-lists for use in word recognition testing. As shown in Figures 1 and 2, the developed materials were relatively homogenous in performance with regard to audibility and psychometric function slope. Results from a two-way chi-square analysis indicated that there were no statistically significant differences among lists or half-lists within the male or female talker materials. Some differences were found between the male and female talker materials in terms of mean performance, with the psychometric function slopes at threshold (50%) and from 20% to 80% for both the lists and half-lists being steeper for the male recordings when compared with the female recordings.

When measured from the 20% to 80% points of the psychometric function, the Taiwan Mandarin word recognition lists developed in this study were found to have slightly higher slopes (8.3%/dB for the male talker and 6.8%/dB for

Figure 1. Psychometric functions for the four Taiwan Mandarin bisyllabic lists and eight half-lists for male talker and female talker recordings after intensity adjustments to produce 50% performance at 4.5 dB HL.

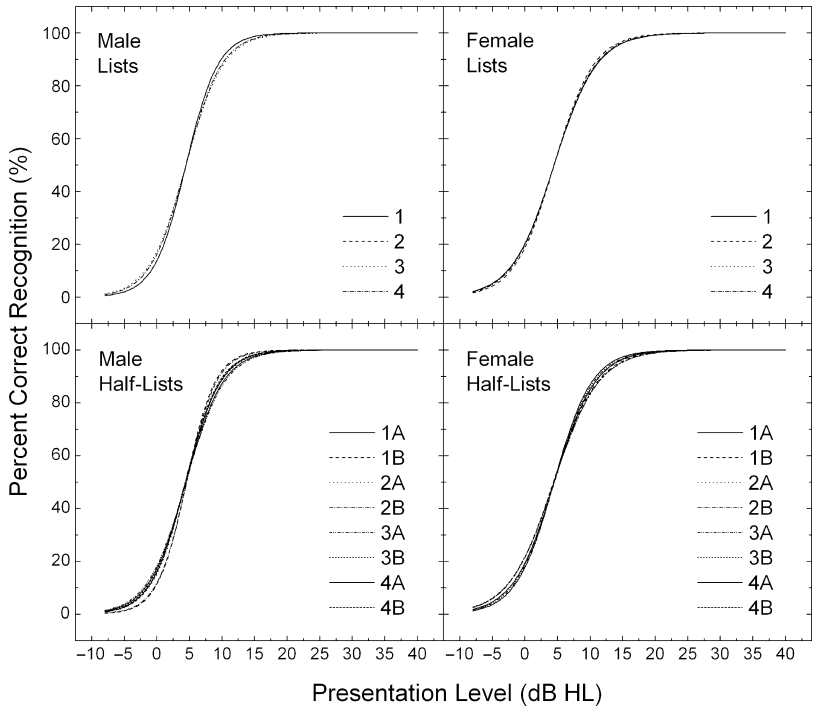
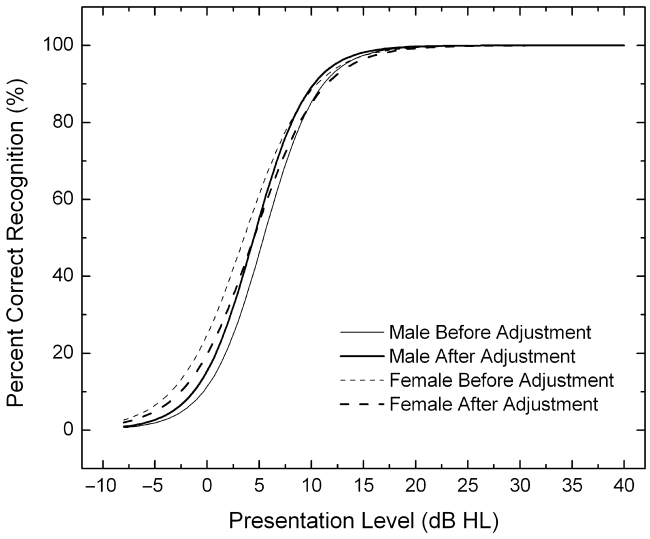


Figure 2. Mean psychometric functions for male and female Taiwan Mandarin talker bisyllabic lists before and after intensity adjustment.



the female talker) than values reported for several types of English word recognition materials. Previous research has reported that the Northwestern University Auditory Test No. 6 (NU-6) and Central Institute for the Deaf (CID) W-22 English word lists have mean slopes of 4.2%/dB and 4.6%/dB, respectively (Beattie, Edgerton, & Svihovec, 1977), while more recently Wilson and Oyler (1997) have reported mean values of 4.4%/dB and 4.8%/dB.

Of particular interest is how the psychometric slope values of these materials will compare with previously developed word recognition materials for speakers of Pŭtōnghuà (Nissen et al., 2005a), a regional dialect of Mandarin spoken in mainland China. In terms of list and half-list performance, the materials developed for Taiwan Mandarin speakers exhibit slightly steeper psychometric function slopes than the materials developed in Pŭtōnghuà. The overall mean psychometric slope values at threshold (50%) averaged across the male and female talkers was 7.8%/dB for Pŭtōnghuà and 8.7%/dB for Taiwan Mandarin materials (lists and half-lists). The mean slopes from 20% to 80% in Pŭtōnghuà were reported as 6.8%/dB as compared to 7.5%/dB for the materials developed in Taiwan Mandarin.

A possible reason why the psychometric slopes of Taiwan Mandarin were higher than those of English may be due to the different underlying structure of the language (e.g., Mandarin is considered a tonal language). In addition, the present study utilized bisyllabic words rather than monosyllabic words, as are typically used in English word recognition materials, thereby providing the listeners with more acoustic information

with which to perceive the words. The relatively small differences in psychometric slope found between the Taiwan Mandarin materials developed in this study and previously developed materials in Pǔtōnghuà may be due to individual variation in the dialect or articulation of the talkers or in the speech perception abilities of the listeners. Although Pǔtōnghuà is considered to be the standard dialect of Mandarin in mainland China and is commonly utilized in media broadcasting (Campbell, 1991), a listener's native dialect may contain subtle regionalisms that differ from the pronunciation of the talker, even if both live within the same geographic area.

Although the overall psychometric slope values are similar between the two dialects, it would be of interest to conduct a direct examination of how speakers of Pǔtōnghuà (mainland China) would perform on these Taiwan Mandarin word recognition materials and vice versa. To date, there has been limited research on how a regional dialect might affect word recognition testing (Schneider, 1992; Weisleder & Hodgson, 1989). In the study by Weisleder and Hodgson, findings indicated that a regional dialect can affect the validity of word recognition testing in Spanish; however, Schneider found the effects of regional dialect to not significantly affect the speech recognition scores of Spanish-speaking children. Thus, there remains a need to investigate the validity of using materials from a nonregional, yet mutually intelligible, dialect to evaluate an individual's word recognition abilities in Mandarin. In addition, it would be of value to determine whether a native speaker of one Mandarin dialect is able to accurately administer and score word recognition testing for speakers of a different regional dialect.

This study is an initial attempt to create and evaluate materials for word recognition testing in Taiwan Mandarin; however, we readily acknowledge that there remains a need to continue to examine the effectiveness of these materials and to develop additional types of speech audiometry materials in Taiwan Mandarin. For example, the word recognition lists developed in this study were evaluated using listeners with normal hearing in a quiet environment. It is possible that list performance will vary in listeners with a hearing impairment or in a noisy environment (e.g., Jerger, 2006; McArdle & Wilson, 2006; Wilson & McArdle, 2005). In addition, the test–retest reliability and confidence limits of these materials require further evaluation.

The aim of this study was to produce speech audiometry materials for adult listeners; thus, the validity of using these materials for younger individuals is unknown. Some of the lexical items contained within the lists and half-lists may be unfamiliar to children, such as the words 經濟 (*economy*) or 政治 (*politics*). Ashoor and Prochazka (1985) developed Arabic speech audiometry materials that were created specifically for children. These materials were selected from children's books and evaluated by younger listeners. It is evident that the materials developed in this study need further examination to determine whether they are appropriate for children.

Despite the limitations mentioned above, we believe the creation and evaluation of these materials are an essential step in providing audiologists the tools to evaluate the hearing abilities of speakers of Taiwan Mandarin in a linguistically appropriate manner. Although pure-tone testing is a quick and often reliable method to measure frequency-specific information about a patient's hearing impairment, a more comprehensive audiologic evaluation often includes measuring an individual's ability to perceive and process speech in his or her native language. Thus, the specific aims of this project were to create high-quality digitally recorded bisyllabic Taiwan Mandarin word recognition lists and half-lists of familiar words spoken by both a male and female talker. The recorded word lists and half-lists are relatively homogenous in regard to audibility and psychometric function slope. The threshold variability across the lists of each talker was reduced by digital adjustments in individual word intensity. (The speech audiometry materials developed and described in this study are contained on a CD titled *Brigham Young University Taiwan Mandarin Speech Audiometry Materials*; Harris & Nissen, 2006.)

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Contact author: Shawn L. Nissen, Department of Communication Disorders, 138 Taylor Building, Brigham Young University, Provo, UT 84602. E-mail: shawn_nissen@byu.edu.

Individuals or institutions interested in obtaining copies of the *Brigham Young University Taiwan Mandarin Speech Audiometry Materials* CD may inquire by e-mail to speech_audiometry@byu.edu or by mail to the following address: Department of Communication Disorders, 136 TLRB, Brigham Young University, Provo, UT 84602.

Appendix A (p. 1 of 2)

Taiwan Mandarin Word Lists in Traditional Chinese Characters and Hanyu Romanization

Male Talker Lists

List 1	List 2	List 3	List 4
後來 我們	開發 方法	內容 清楚	溝通 嚴重
台灣 能夠	加上 昨天	開始 成功	東西 新聞
科技 成立	然後 原來	電話 最近	工程 不會
現在 還是	設備 已經	或者 不要	參加 情況
負責 過去	雖然 國際	應該 美國	感覺 大學
相關 老師	專業 好像	生活 價值	成為 能力
開放 管理	了解 課程	記者 自我	達到 母親
這樣 需要	獲得 動物	支持 注意	過程 自由
就是 事件	事實 如果	社會 怎麼	發生 經過
他們 產生	重要 起來	今天 學習	未來 所以
當然 處理	電腦 一定	其實 非常	目標 面對
電視 這裡	配合 方式	人生 作業	增加 文化
快樂 語言	發現 空間	投資 不同	完全 安全
變成 希望	完成 不能	故事 什麼	媽媽 解決
時間 那麼	可是 同學	受到 不斷	學生 下午
學校 行為	或是 同時	以後 香港	最後 選擇
接受 時候	真正 成長	身體 一樣	幾乎 繼續
甚至 也許	事業 值得	爸爸 原因	交通 可以
改變 但是	工作 只要	問題 有關	觀念 時代
活動 基本	標準 得到	傳統 造成	準備 沒有
包括 機會	程度 都市	階段 這麼	結果 行動
公園 特別	存在 必須	建築 父母	計畫 經濟
朋友 訓練	發展 現象	教授 政治	國家 教育
先生 一直	考慮 喜歡	大家 實在	可能 覺得
家庭 另外	報導 產品	世界 比較	本身 出現

List 1		List 2		List 3		List 4	
hòulái	wǒmen	kāifā	fāngfǎ	nèiróng	qīngchu	gōutōng	yánzhòng
táiwān	nénggòu	jiāshàng	zuótiān	kāishǐ	chénggōng	dōngxī	xīnwén
kējì	chénglì	ránhòu	yuánlái	diànhuà	zuìjìn	gōngchéng	búhuì
xiànzài	háishì	shèbèi	yǐjīng	huòzhě	búyào	cānjiā	qíngkuàng
fùzé	guòqù	suīrán	guójì	yīnggāi	měiguó	gǎnjué	dàxué
xiāngguān	lǎoshī	zhuānyè	hǎoxiàng	shēnghuó	jiàzhí	chéngwéi	nénglì
kāifàng	guǎnlǐ	liǎojiě	kèchéng	jìzhě	zìwǒ	dádào	mǔqīn
zhèyàng	xūyào	huòdé	dòngwù	zhīchí	zhùyì	guòchéng	zìyóu
jiùshì	shìjiàn	shìshí	rúguǒ	shèhuì	zěnme	fāshēng	jīngguò
tāmen	chǎnshēng	zhòngyào	qǐlai	jīntiān	xuéxí	wèilái	suǒyǐ
dāngrán	chǔlǐ	diànnǎo	yīdìng	qíshí	fēicháng	mùbiāo	miànduì
diànshì	zhèlǐ	pèihé	fāngshì	rénshēng	zuòyè	zēngjiā	wénhuà
kuàilè	yǔyán	fāxiàn	kōngjiān	tóuzī	bùtóng	wánquán	ānquán
biànchéng	xīwàng	wánchéng	bùnéng	gùshì	shénme	māma	jiějué
shíjiān	nàme	kěshì	tóngxué	shòudào	bùduàn	xuésheng	xiàwǔ
xuéxiào	xíngwéi	huòshì	tóngshí	yǐhòu	xiānggǎng	zuìhòu	xuǎnzé
jiēshòu	shíhou	zhēnzhèng	chéngzhǎng	shēntǐ	yīyàng	jīhū	jìxù
shènzhì	yěxǔ	shìyè	zhíde	bàba	yuányīn	jiāotōng	kěyǐ
gǎibiàn	dànshì	gōngzuò	zhǐyào	wèntí	yǒuguān	guānniàn	shídài
huódòng	jīběn	biāozhǔn	dédào	chuántǒng	zàochéng	zhǔnbèi	méiyǒu
bāokuò	jīhuì	chéngdù	dūshì	jiēduàn	zhème	jiéguǒ	xíngdòng
gōngyuán	tèbié	cúnzài	bìxū	jiànzhù	fùmǔ	jìhuà	jīngjì
péngyou	xùnliàn	fāzhǎn	xiànxiàng	jiàoshòu	zhèngzhì	guójiā	jiàoyù
xiānsheng	yìzhí	kǎolǜ	xǐhuan	dàjiā	shízài	kěnéng	juéde
jiātíng	lìngwài	bàodào	chǎnpǐn	shìjiè	bǐjiào	běnshēn	chūxiàn

Appendix A (p. 2 of 2)

Taiwan Mandarin Word Lists in Traditional Chinese Characters and Hanyu Romanization

Female Talker Lists

List 1	List 2	List 3	List 4
開始 不能	電話 不同	安全 不斷	傳統 必須
工程 成功	好像 成為	感覺 但是	過程 處理
問題 得到	媽媽 東西	然後 都市	快樂 非常
報導 改變	專業 溝通	參加 觀念	爸爸 國際
當然 還是	大學 基本	產生 教授	大家 過去
發展 今年	電視 幾乎	發生 機會	管理 階段
建築 考慮	故事 空間	交通 就是	後來 目標
教育 時間	結果 實際	開發 容易	記者 生命
老師 世界	了解 條件	開放 現在	生活 完全
同學 訓練	什麼 新聞	同時 壓力	事實 學習
完成 應該	相關 嚴重	文化 意義	選擇 一直
原來 政治	也許 這樣	增加 知道	自我 原因
程度 資料	成立 成長	作業 直接	包括 投資
動物 朋友	達到 行動	出現 需要	除了 造成
負責 一般	方法 昨天	公園 努力	國家 電腦
課程 美國	活動 存在	或者 自由	加上 時代
可是 或是	可能 不要	科技 語言	可以 如何
面對 現象	沒有 價值	例如 規定	歷史 覺得
清楚 有關	目的 運動	起來 今天	人生 準備
設備 本身	社會 配合	身體 值得	甚至 母親
時候 獲得	受到 經驗	雖然 家庭	所以 醫院
未來 怎麼	特別 父母	我們 希望	他們 其實
行為 這裡	以後 情況	學生 經過	下午 影響
只是 公司	重要 最近	知識 台灣	支持 接受
標準 工作	表現 內容	變成 團體	最後 地方

List 1		List 2		List 3		List 4	
kāishǐ	bùnéng	diànhuà	bùtóng	ānquán	bùduàn	chuántǒng	bìxū
gōngchéng	chénggōng	hǎoxiàng	chéngwéi	gǎnjué	dànshì	guòchéng	chǔlǐ
wèntí	dédào	māma	dōngxī	ránhòu	dūshì	kuàilè	fēicháng
bàodào	gǎibiàn	zhuānyè	gōutōng	cānjiā	guānniàn	bàba	guójì
dāngrán	háishì	dàxué	jīběn	chǎnshēng	jiàoshòu	dàjiā	guòqù
fāzhǎn	jīnnián	diànshì	jīhū	fāshēng	jīhuì	guǎnlǐ	jiēduàn
jiànzhù	kǎolǜ	gùshì	kōngjiān	jiāotōng	jiùshì	hòulái	mùbiāo
jiàoyù	shíjiān	jiéguǒ	shíjì	kāifā	róngyì	jìzhě	shēngmìng
lǎoshī	shìjiè	liǎojiě	tiáojiàn	kāifàng	xiànzài	shēnghuó	wánquán
tóngxué	xùnliàn	shénme	xīnwén	tóngshí	yālì	shìshí	xuéxí
wánchéng	yīnggāi	xiāngguān	yánzhòng	wénhuà	yìyì	xuǎnzé	yìzhí
yuánlái	zhèngzhì	yěxǔ	zhèyàng	zēngjiā	zhīdao	zìwǒ	yuányīn
chéngdù	zīliào	chénglì	chéngzhǎng	zuòyè	zhíjiē	bāokuò	tóuzī
dòngwù	péngyou	dádào	xíngdòng	chūxiàn	xūyào	chúle	zàochéng
fùzé	yīnbān	fāngfǎ	zuótiān	gōngyuán	nǔlì	guójiā	diànnǎo
kèchéng	měiguó	huódòng	cúnzài	huòzhě	zìyóu	jiāshàng	shídài
kěshì	huòshì	kěnéng	búyào	kējì	yǔyán	kěyǐ	rúhé
miànduì	xiànxiàng	méiyǒu	jiàzhí	lìrú	guīdìng	lìshǐ	juéde
qīngchu	yǒuguān	mùdì	yùndòng	qǐlai	jīntiān	rénshēng	zhǔnbèi
shèbèi	běnshēn	shèhuì	pèihé	shēntǐ	zhíde	shènzhì	mǔqīn
shíhou	huòdé	shòudào	jīngyàn	suīrán	jiātíng	suǒyǐ	yīyuàn
wèilái	zěnme	tèbié	fùmǔ	wǒmen	xīwàng	tāmen	qíshí
xíngwéi	zhèlǐ	yīhòu	qíngkuàng	xuésheng	jīngguò	xiàwǔ	yīngxiǎng
zhǐshì	gōngsī	zhòngyào	zuìjìn	zhīshi	táiwān	zhīchí	jiēshòu
biāozhǔn	gōngzuò	biǎoxiàn	nèiróng	biànchéng	tuántǐ	zuìhòu	dìfāng

Appendix B (p. 1 of 2)

Taiwan Mandarin Word Half-Lists in Traditional Chinese Characters and Hanyu Romanization

Male Talker Half-lists

1A	1B	2A	2B	3A	3B	4A	4B
後來	台灣	加上	開發	內容	開始	東西	溝通
現在	科技	然後	設備	或者	電話	工程	參加
負責	相關	專業	雖然	應該	生活	成為	感覺
這樣	開放	了解	獲得	支持	記者	達到	過程
就是	他們	重要	事實	社會	今天	未來	發生
電視	當然	電腦	配合	人生	其實	目標	增加
快樂	變成	完成	發現	投資	故事	媽媽	完全
學校	時間	可是	或是	以後	受到	學生	最後
接受	甚至	事業	真正	身體	爸爸	交通	幾乎
活動	改變	工作	標準	傳統	問題	觀念	準備
包括	公園	存在	程度	階段	建築	計畫	結果
先生	朋友	發展	考慮	大家	教授	國家	可能
家庭	我們	方法	報導	世界	清楚	嚴重	本身
成立	能夠	昨天	原來	最近	成功	新聞	不會
還是	過去	國際	已經	不要	美國	大學	情況
管理	老師	好像	課程	自我	價值	能力	母親
需要	事件	如果	動物	注意	怎麼	經過	自由
處理	產生	起來	一定	非常	學習	所以	面對
這裡	語言	空間	方式	作業	不同	安全	文化
那麼	希望	不能	同學	不斷	什麼	解決	下午
行為	時候	成長	同時	香港	一樣	繼續	選擇
但是	也許	值得	只要	有關	原因	可以	時代
基本	機會	都市	得到	造成	這麼	行動	沒有
訓練	特別	必須	現象	政治	父母	經濟	教育
一直	另外	產品	喜歡	實在	比較	出現	覺得

1A	1B	2A	2B	3A	3B	4A	4B
hòulái	táiwān	jiāshàng	kāifā	nèiróng	kāishǐ	dōngxī	gōutōng
xiànzài	kějì	ránhòu	shèbèi	huòzhě	diànhuà	gōngchéng	cānjiā
fùzé	xiāngguān	zhuānyè	suīrán	yīnggāi	shēnghuó	chéngwéi	gǎnjué
zhèyàng	kāifàng	liǎojiě	huòdé	zhīchí	jìzhě	dádào	guòchéng
jiùshì	tāmen	zhòngyào	shìshí	shèhuì	jīntiān	wèilái	fāshēng
diànshì	dāngrán	diànnǎo	pèihé	rénshēng	qíshí	mùbiāo	zēngjiā
kuàilè	biànchéng	wánchéng	fāxiàn	tóuzī	gùshì	māma	wánquán
xuéxiào	shíjiān	kěshì	huòshì	yǐhòu	shòudào	xuésheng	zuìhòu
jiēshòu	shènzhì	shìyè	zhēnzhèng	shēntǐ	bàba	jiāotōng	jīhū
huódòng	gǎibiàn	gōngzuò	biāozhǔn	chuántǒng	wèntí	guānniàn	zhǔnbèi
bāokuò	gōngyuán	cúnzài	chéngdù	jiēduàn	jiànzhù	jihuà	jiéguǒ
xiānsheng	péngyou	fāzhǎn	kǎolǜ	dàjiā	jiàoshòu	guójiā	kěnéng
jiātíng	wǒmen	fāngfǎ	bàodào	shìjiè	qīngchu	yánzhòng	běnshēn
chénglì	nénggòu	zuótiān	yuánlái	zuìjìn	chénggōng	xīnwén	búhuì
háishi	guòqù	guójì	yǐjīng	búyào	měiguó	dàxué	qíngkuàng
guǎnlǐ	lǎoshī	hǎoxiàng	kèchéng	zìwǒ	jiàzhí	nénglì	mǔqīn
xūyào	shìjiàn	rúguǒ	dòngwù	zhùyì	zěnme	jīngguò	zìyóu
chǔlǐ	chǎnshēng	qǐlai	yīdìng	fēicháng	xuéxí	suǒyǐ	miànduì
zhèlǐ	yǔyán	kōngjiān	fāngshì	zuòyè	bùtóng	ānquán	wénhuà
nàme	xīwàng	bùnéng	tóngxué	bùduàn	shénme	jiějué	xiàwǔ
xíngwéi	shíhou	chéngzhǎng	tóngshí	xiānggǎng	yīyàng	jìxù	xuǎnzé
dànshì	yěxǔ	zhíde	zhǐyào	yǒuguān	yuányīn	kěyǐ	shídài
jīběn	jīhuì	dūshì	dédào	zàochéng	zhème	xíngdòng	méiyǒu
xùnliàn	tèbié	bìxū	xiànxiàng	zhèngzhì	fùmǔ	jīngjì	jiàoyù
yìzhí	lìngwài	chǎnpǐn	xǐhuan	shízài	bǐjiào	chūxiàn	juéde

Appendix B (p. 2 of 2)

Taiwan Mandarin Word Half-Lists in Traditional Chinese Characters and Hanyu Romanization

Female Talker Half-lists

1A	1B	2A	2B	3A	3B	4A	4B
工程	開始	電話	好像	感覺	安全	傳統	過程
問題	報導	專業	媽媽	然後	參加	爸爸	快樂
發展	當然	大學	電視	發生	產生	大家	管理
建築	教育	結果	故事	交通	開發	記者	後來
同學	老師	了解	什麼	同時	開放	生活	事實
完成	原來	也許	相關	文化	增加	自我	選擇
動物	程度	成立	達到	出現	作業	包括	除了
負責	課程	活動	方法	公園	或者	加上	國家
面對	可是	可能	沒有	例如	科技	可以	歷史
清楚	設備	社會	目的	起來	身體	甚至	人生
未來	時候	受到	特別	我們	雖然	所以	他們
行為	只是	重要	以後	學生	知識	支持	下午
不能	標準	表現	不同	不斷	變成	最後	必須
成功	得到	東西	成為	但是	都市	非常	處理
還是	改變	溝通	基本	教授	觀念	國際	過去
今年	考慮	空間	幾乎	機會	就是	目標	階段
世界	時間	實際	條件	現在	容易	生命	完全
訓練	應該	嚴重	新聞	壓力	意義	一直	學習
資料	政治	這樣	成長	直接	知道	原因	投資
朋友	一般	昨天	行動	需要	努力	電腦	造成
或是	美國	存在	不要	語言	自由	時代	如何
現象	有關	運動	價值	規定	今天	準備	覺得
獲得	本身	配合	經驗	家庭	值得	母親	醫院
怎麼	這裡	情況	父母	希望	經過	影響	其實
工作	公司	最近	內容	團體	台灣	接受	地方

1A	1B	2A	2B	3A	3B	4A	4B
gōngchéng	kāishǐ	diànhuà	hǎoxiàng	gǎnjué	ānquán	chuántǒng	guòchéng
wèntí	bàodào	zhuānyè	māma	ránhòu	cānjiā	bàba	kuàilè
fāzhǎn	dāngrán	dàxué	diànshì	fāshēng	chǎnshēng	dàjiā	guǎnlǐ
jiànzhù	jiàoyù	jiéguǒ	gùshì	jiāotōng	kāifā	jìzhě	hòulái
tóngxué	lǎoshī	liǎojiě	shénme	tóngshí	kāifàng	shēnghuó	shìshí
wánchéng	yuánlái	yěxǔ	xiāngguān	wénhuà	zēngjiā	zìwǒ	xuǎnzé
dòngwù	chéngdù	chénglì	dádào	chūxiàn	zuòyè	bāokuò	chúle
fùzé	kèchéng	huódòng	fāngfǎ	gōngyuán	huòzhě	jiāshàng	guójiā
miànduì	kěshì	kěnéng	méiyǒu	lìrú	kējì	kěyǐ	lìshǐ
qīngchu	shèbèi	shèhuì	mùdì	qǐlai	shēntǐ	shènzhì	rénshēng
wèilái	shíhou	shòudào	tèbié	wǒmen	suīrán	suǒyǐ	tāmen
xíngwéi	zhǐshì	zhòngyào	yīhòu	xuésheng	zhīshi	zhīchí	xiàwǔ
bùnéng	biāozhǔn	biǎoxiàn	bùtóng	bùduàn	biànchéng	zuìhòu	bìxū
chénggōng	dédào	dōngxī	chéngwéi	dànshì	dūshì	fēicháng	chǔlǐ
háishì	gǎibiàn	gōutōng	jīběn	jiàoshòu	guānniàn	guójì	guòqù
jīnnián	kǎolǜ	kōngjiān	jīhū	jīhuì	jiùshì	mùbiāo	jiēduàn
shìjiè	shíjiān	shíjì	tiáojiàn	xiànzài	róngyì	shēngmìng	wánquán
xùnliàn	yīnggāi	yánzhòng	xīnwén	yālì	yìyì	yìzhí	xuéxí
zīliào	zhèngzhì	zhèyàng	chéngzhǎng	zhíjiē	zhīdao	yuányīn	tóuzī
péngyou	yībān	zuótiān	xíngdòng	xūyào	nǔlì	diànnǎo	zàochéng
huòshì	měiguó	cúnzài	búyào	yǔyán	zìyóu	shídài	rúhé
xiànxiàng	yǒuguān	yùndòng	jiàzhí	guīdìng	jīntiān	zhǔnbèi	juéde
huòdé	běnshēn	pèihé	jīngyàn	jiātíng	zhíde	mǔqīn	yīyuàn
zěnme	zhèlǐ	qíngkuàng	fùmǔ	xīwàng	jīngguò	yǐngxiǎng	qíshí
gōngzuò	gōngsī	zuìjìn	nèiróng	tuántǐ	táiwān	jiēshòu	dìfāng