CONFUSIONS OF CANTONESE TONES IN TEENAGERS WITH SENSORINEURAL HEARING IMPAIRMENT

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ABSTRACT

The goals of this study were to find out how the identifiability of Cantonese tones was affected by the degree of hearing impairment and for two stimulus conditions. Twenty-two subjects were assigned to three subject groups: normal hearing (n = 8), moderate-to-severe hearing loss (n = 6), and profound hearing loss (n = 8). A tonal identification task of the segmental unit /fu/ and the So & Varley Lexical Comprehension Test (So & Varley, 1991) were employed. All stimuli were presented in isolation and in carrier sentences. As expected, average performance fell with increasing hearing impairment. A significant effect for the sets of stimuli was found in the So & Varley Lexical Comprehension Test for the two hearing-impaired groups - the moderate-to-severe-hearing-loss subjects performed better in the carrier phrase condition and the profound-hearing-loss subjects in isolation. Stimuli, therefore, should be taken into consideration in assessment and intervention with subjects with different degree of hearing impairment.

Cantonese is a tonal language which has six contrasting tones (Kao, 1971). Tone 1 has been described as high-level (HL), tone 2 as high-rising (HR), tone 3 as mid-level (ML), tone 4 as low-falling (LF), tone 5 as low-rising (LR) and tone 6 as low-level (LL). On the surface, the existence of six distinct tones might well result in confusion among them, especially when words are embedded in phrases and sentences where intonational contour is also a feature. Indeed, people sometimes misidentify Cantonese tones that have similar fundamental frequency levels or fundamental frequency contours, e.g. they always confuse the ML tone with the LL tones, and the HR tone with the LR tones (Fok, 1974).

Fok's (1974) tests on the perception of Cantonese tones serve as the point of departure for the current investigation. Since tonal confusion is found among normal subjects, it is even more important to know how hearing-impaired listeners perform. Will they have similar error patterns to normal people or will they show differences ? How does the degree of hearing impairment affect their perception of Cantonese tones ? Answers to these questions are crucial for the rehabilitation of the hearing-impaired.

Previous research focused most on the effect of hearing impairment on the perception of consonants (e.g. Bilger & Wang, 1976; Broothroyd, 1984; Wang et al., 1978) and vowels (Hack & Erber, 1982). Considerably less emphasis has been placed on the perception of tones in languages like Cantonese. Gandour et al. (1984) have investigated the perception of tones in people with sensorineural hearing loss. The language in their study was Thai. Its results indicated that listeners with mild and moderate sensorineural hearing impairment made similar tonal confusion errors to normal-hearing listeners. However, for the severe-hearing-loss group, the pattern of tonal confusions was differed completely from the normal group's. As little work has been done on the perception of Cantonese tones in hearing impaired subjects, the current study focuses on this area.

Studies of speech perception in hearing-impaired listeners have mainly used single words as stimuli (e.g. Gandour et al., 1984; Bilger & Wang, 1976). However, other dimensions other than the acoustic properties of phonemes may affect performance. Erber & McMahan (1976) have pointed out that the auditory and visual intelligibility of words depend on the context in which they occur. In other words, the stimulus condition is an important variable in identification. So, the current study includes : stimuli presented alone and others in carrier sentences. An understanding of the differences in performance with different sets of stimuli can help clarifying the directions to be taken in future assessment and auditory and speech training for the hearing-impaired people.

Accordingly, the purpose of this study is to investigate the effects of hearing impairment and of sets of stimuli on a listener's ability to identify Cantonese tones. The study asks two questions. First, how does the degree of hearing impairment affect a person's ability to label the six Cantonese tones?

Second, are stimuli easier to recognize when they are presented alone or when they appear in carrier sentences ? The approach to these questions will compare each subject group's tonal identification scores for the two sets of stimuli. A confusion matrix for each subject group and each set of stimuli will also be examined to determine whether the mistakes that occur are only be due to chance or follow a pattern.

METHOD

Subjects

Subjects in this study were 13 - 16 years old teenagers currently attending remedial classes in deaf schools or integrated classes in normal schools. They were free from secondary handicaps (e.g. a visual problem, mental retardation) that might affect the perception of spoken language. Information about their hearing thresholds was obtained from the audiograms provided by their school records. Only subjects who had their audiograms done in the last two years were included. The ear with the better three frequency average thresholds was selected for measurement of hearing impairment and two groups of subjects were identified according to their pure-tone average : moderate-to-severe hearing loss (56 - 84 dB HL); and (2) profound hearing loss (96 - 114 dB HL). The mean pure-tone thresholds and pure-tone average for the subjects are given in Table 1.

TABLE 1. Mean pure-tone thresholds and pure-tone average (in dB HL) in the better ear for the two hearing-impaired groups.

			Pure Tone Thresholds					
Subjects		*Age*	*250Hz*	*500Hz*	*1kHz*	*2kHz*	*4kHz*	*PTA*
Mod-Sev	*x*	14;6	65.8	67.5	75.0	76.7	76.7	73.0
(n = 6)	*SD*	1.2	11.7	9.5	9.1	13.4	16.2	9.9
Profound	*x*	14;3	87.5	97.5	105.0	108.1	110.0	103.5
(n = 8)	*SD*	0.3	3.5	8.3	5.6	9.0	10.5	7.2

Mod-Sev : Moderate-to-severe

All the subjects had sensorineural hearing impairment and had aided-thresholds within the frequency spectrum of speech. Their hearing ages ranged from three years to twelve years. Originally, each group had eight subjects but two subjects were excluded from the moderate-to-severe-hearing-loss group because their hearing aids were lost at the time of the experiment. As a result, a total of 14 hearing-impaired subjects (nine females and five males) took part in the study.

A group of eight normal-hearing subjects (six females and two males) were included to extend the average of the experiment. They had the same age range and education level (F.2 or F.3) as the hearing-impaired subjects. No hearing problem was reported by these subjects and they were believed to be free from secondary handicaps.

Listening Procedure

There were two tasks in this experiment and all the stimuli were spoken by an adult female native speaker of Cantonese. The stimuli were recorded onto tape using a Sony TCD-5M tape recorder in a sound-treated booth to reduce environmental noise. Task 1 involved the identification of words of the citation forms of /fu^1/ 'man', /fu^2/ 'tiger', /fu^3/ 'trousers', /fu^4/ 'to help', /fu^5/ 'woman', and /fu^6/ 'father'. Subjects responded by pointing to the correct words from six choices. Task 2 used the So & Varley Lexical Comprehension Test (So & Varley, 1991) (SVLCT) which has 39 test plates. Each test plate shows four pictures, one target, one tonal distractor, one segmental distractor and one semantic distractor. The subjects responded by pointing to the correct picture and the examiner marked down the answers on a record form.

All the stimuli were presented in isolation and in carrier sentences. The carrier sentence used in the study was :

tsi^2	ha^5	'X'	pei^2	$ŋɔ^5$	$tɐi^2$
point			to	I	see

Point to the word : 'X'

The stimulus words were placed in the medial position to prevent the rise or drop of intonation (e.g. drop of intonation at the end of a sentence) that might affect the perceived tone values (Vance, 1976).

A total of four test tapes were prepared - two for each task. Each tape in Task 1 contained 36 trials, six repetitions of each stimulus tone, either in isolation or in carrier sentences. The tonal stimuli on each tape were presented in random order generated by the computer. In the second task, the order of the stimuli in isolation was the same as the original test but the order of the stimuli in carrier sentences was presented randomly following a sequence from a computer.

The subjects were asked to read or name the stimuli first to confirm that they knew all the stimulus items. The result indicated that all of them knew the items.

The stimuli were played through a Sony TCD-5M cassette recorder and the subjects were tested individually. The stimuli were presented at 60 dB SPL (measured by a sound level meter) - the intensity of speech in normal conversation. Because different subjects had different hearing threshold levels, they adjusted the volume of their hearing aids at the beginning of the test. This assumed that the hearing aid user knows best his/her hearing aid. Thus, the subjects were responsible for adjusting the volume to obtain their most comfortable listening level. The adjusted volume was used in the entire experiment.

Half of the subjects in each subject group did Task 1 first and Task 2 the second. Within this half, half of them received the stimulus words in isolation first and then the carrier sentence. Subjects heard each test stimulus twice before making a decision. They were encouraged to guess if they were not sure. A block of two practice trials were administered before proceeding with the actual test. No feedback on performance was given. Brief rest periods were scheduled between test tapes. The entire experiment lasted approximately 30 minutes.

RESULTS

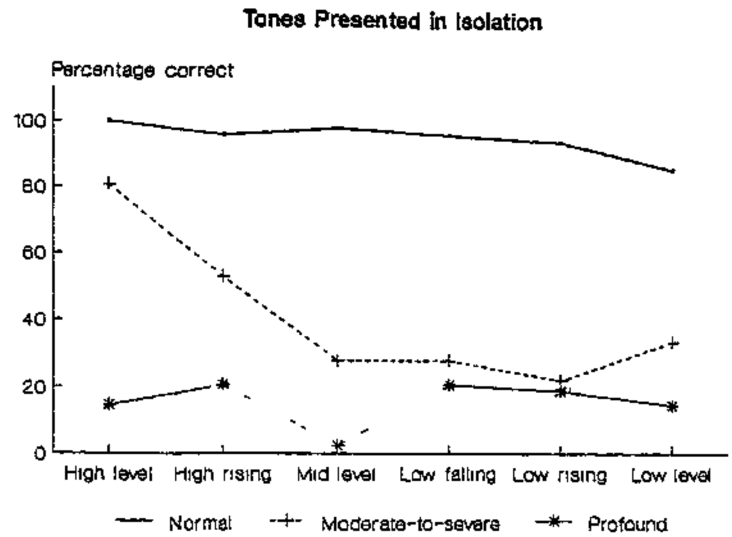
Tonal Identification Task

Tone identifiability. Table 2 displays, for each subject group, the mean correct scores and standard deviations when the tones were presented in isolation and in carrier phrases. Overall identifiability was highest for the normal group. For the hearing-impaired groups, the correct identification score worsened as the degree of hearing impairment became more severe.

TABLE 2. Mean correct scores and standard deviations for tones presented in isolation and in carrier phrases for each subject group.

	Isolation (36)		*Carrier Phrases (36)*	
Subjects	*x*	*SD*	*x*	*SD*
Normal	34.1 (94.8%)	± 1.7	33.9 (94.1%)	± 2.2
Mod-Sev	14.7 (40.7%)	± 1.9	17.3 (48.2%)	± 3.8
Profound	6.0 (16.7%)	± 1.2	6.1 (17.0%)	± 2.4

Figure 1 shows a comparison among the three groups of the identifiability of individual tones in isolation and in carrier phrases. In both stimulus conditions, the mean percentage of correct identification of the tones, except the LL tone, exceeded 90% for the normal group only. The moderate-to-severe-hearing-loss group managed to identify correctly the HL tone and the HR tone at levels higher than 50%. They also identified the ML tone in carrier phrases at level higher than 50%. For the profound-hearing-loss group, the mean percentage of correct identification of each tone was below 25% in both stimulus conditions.



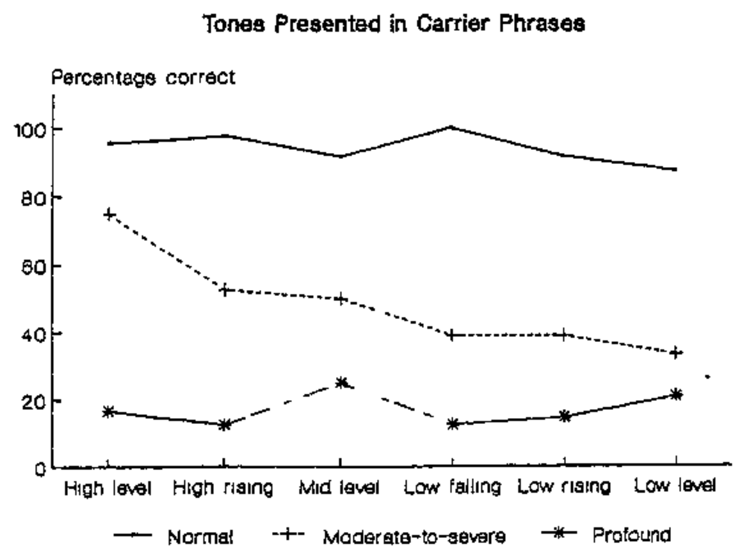


FIGURE 1. Mean % of correct identification of each tone for the three subject groups.

A two-way analysis of variance confirmed the significance of the main effect of the degree of hearing loss [$F(2, 19) = 727.09$, $p < 0.001$]. The main effect of the sets of stimuli, and the interaction between the degree of hearing loss and the sets of stimuli were not statistically significant.

The dependence of tone identification measure on pure-tone-threshold was further examined by using correlational analysis. Correlations, significant at the 0.001 level ($df = 19$), were found between hearing loss and identification of tones in isolation ($r = -0.99$), and hearing loss and identification of tones in carrier phrases ($r = -0.98$).

Tonal confusions. Table 3 displays the total number of responses to each of the six Cantonese tones, presented in isolation and in carrier phrases, in a confusion matrix for each subject group. The stimuli were listed on the left vertical axis and the responses on the top horizontal axis. Correct responses to the stimuli were put in the cells along the main diagonal of the matrix, incorrect responses in the off-diagonal cells. Mistakes occurred but their significance varied. For example, of all the 48 presentations of the ML tone in isolation to the normal subjects, it was taken as the LL tone once. This mistake might only be due to chance. In order to determine whether the confusion was significant or not, the following test was done (Fok, 1974, P.61). Suppose that n out of N presentations were correct, the remaining scores would be evenly distributed over the remaining five cells if the confusion was made by chance. The expected number in the cell would then be (N - n)/5 and the standard deviation of the number in the cell would be

TABLE 3. Confusion matrices of Cantonese tones presented in isolation and in carrier phrases for each subject group.

Normal-hearing group

Isolation

Stimuli	HL	HR	ML	LF	LR	LL	Sum
HL	48						48
HR		46			2*		48
ML			47			1	48
LF				46		2*	48
LR		2			45	1	48
LL			5*	1	1	41	48
	48	48	52	47	48	45	

Carrier Phrases

Stimuli	HL	HR	ML	LF	LR	LL	Sum
HL	46					2*	48
HR		47				1	48
ML	1		44			3*	48
LF				48			48
LR		2			44	2	48
LL			3	2	1	42	48
	47	49	47	50	46	49	

Moderate-to-severe-hearing-loss group

Isolation

Stimuli	HL	HR	ML	LF	LR	LL	Sum
HL	29	1	1	2	3		36
HR	2	19	4		3	8*	36
ML	7	2	10	6	7	4	36
LF	2	2	13*	10	5	4	36
LR	1	9*	6	5	8	7	36
LL	2		11*	10*	1	12	36
	43	33	45	33	27	35	

Carrier Phrases

Stimuli	HL	HR	ML	LF	LR	LL	Sum
HL	27	4			3	2	36
HR		19	5	3	4	5	36
ML	1		18	6	4	7	36
LF	4	5	8	14	1	4	36
LR	4	2	8	4	14	4	36
LL	4		12*	5	3	12	36
	40	30	51	32	29	34	

Profound-hearing-loss group

Isolation

Stimuli	HL	HR	ML	LF	LR	LL	Sum
HL	7	4	18*	3	6	10	48
HR	5	10	10	6	10	7	48
ML	5	7	5	12	8	11	48
LF	9	7	7	10	7	8	48
LR	6	9	7	11	9	6	48
LL	9	5	5	13	9	7	48
	41	42	52	55	49	49	

Carrier Phrases

Stimuli	HL	HR	ML	LF	LR	LL	Sum
HL	8	8	11	5	3	13	48
HR	6	6	7	13	8	8	48
ML	6	6	12	8	11	5	48
LF	9	7	5	6	14*	7	48
LR	11	10	4	11	7	5	48
LL	7	6	11	6	8	10	48
	47	43	50	49	51	48	

* *significantly different from chance, p = 0.05*

$$\sqrt{\frac{N-n}{5}\left(1-\frac{N-n}{5N}\right)}\,.$$

For the confusion to be significant at the 0.05 level, with a normal distribution of responses, the value in an off-diagonal cell had to be 1.96 times the standard deviation above the expected number. That is,

$$\frac{N-n}{5}+1.96\sqrt{\frac{N-n}{5}\left(1-\frac{N-n}{5N}\right)}$$

where n = number of correct identification

and N = column total.

The confusion figure in each cell can thus be examined and its significance appraised.

The following shows the percentage of time that significant tonal confusions were made by each subject group for the two sets of stimuli :

	Isolation	Carrier Phrases
Normal	LL —> ML (10.4%) HR —> LR (4.2%) LF —> LL (4.2%)	HL —> LL (4.2%) ML —> LL (6.3%)
Mod-Sev	LL —> ML (30.6%) —> LF (27.8%) HR —> LL (22.2%) LF —> ML (36.1%) LR —> HR (25.0%)	LL —> ML (33.3%)
Profound	HL —> ML (37.5%)	LF —> LR (29.2%)

The results indicate that less significant confusions occurred when the tones were presented in carrier phrases, especially for the moderate-to-severe-hearing-loss group. Pooling across subject groups, the HL tone was found to have the highest percentage of correct identification : 63.6% in isolation and 61.4% in carrier phrase.

Pooling across the stimulus conditions, it was found that when the tones were presented in isolation, the HL and LF tones were heard as the ML tone in 14.4% and 15.2% of the time, respectively, and the LL tone as the LF tone in 18.2% of the time. When the tones were presented in carrier phrase, the HL tone was taken as the LL tone in 12.9% of the time while the LL tone as the ML tone in 19.7% of the time. In short, the patterns of tonal confusions were very different in the two sets of stimuli.

Table 4 shows, for each subject group, the mean correct and error scores and their standard deviations for words presented in isolation and in carrier phrases. The normal group was 100% accuracy in identifying all the stimulus words while for the other two groups, the overall identifiability of the words varied inversely with the degree of hearing impairment.

TABLE 4. Mean correct and error scores and their standard deviations for words presented in isolation (Iso) and in carrier phrases (Carr) for the three subject groups.

Response Categories			*Normal*	*Moderate-to-severe*	*Profound*
Target					
	Iso	*x*	39.0 (100%)	23.7 (60.7%)	17.9 (45.9%)
		SD	0.0	± 7.0	± 4.6
	Carr	*x*	39.0 (100%)	27.5 (70.5%)	13.8 (35.3%)
		SD	0.0	± 4.5	± 5.2
Tonal					
	Iso	*x*		8.3 (21.4%)	8.9 (22.8%)
		SD	NO	± 3.2	± 1.6
	Carr	*x*	ERRORS	3.7 (9.4%)	9.8 (25.0%)
		SD		± 1.4	± 3.9
Segmental					
	Iso	*x*		5.7 (14.5%)	6.1 (15.7%)
		SD	NO	± 4.3	± 2.7
	Carr	*x*	ERRORS	6.0 (15.4%)	8.4 (21.5%)
		SD		± 3.4	± 3.7
Semantic					
	Iso	*x*		1.3 (3.4%)	6.1 (15.7%)
		SD	NO	± 1.5	± 3.8
	Carr	*x*	ERRORS	1.8 (4.7%)	7.1 (18.3%)
		SD		± 2.6	± 4.0

Figure 2 shows a comparison of the correct scores among the two stimulus conditions for each subject group. The differences in percentage correct for the normal, moderate-to-severe-, and profound-hearing-loss groups were 0%, 9.8% and 11.6%, respectively. Obviously the identical results for the normal group preclude statistical analyses.

A two-way analysis of variance confirmed the significance of the main effect of hearing impairment [$F(2, 19) = 66.21$, $p < 0.001$] and the interaction between hearing impairment and stimulus conditions [$F(2, 19) = 17.44$, $p <$

0.005]. For the moderate-to-severe-hearing-loss group, stimuli presented in carrier phrases resulted in more correct identifications while for the profound-hearing-loss group, stimuli presented in isolation resulted in more correct responses. The main effect of the stimulus conditions was not significant.

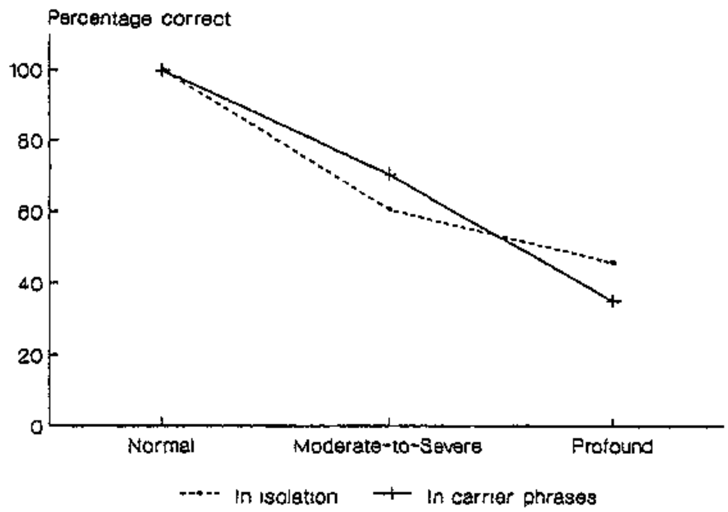


FIGURE 2 Mean % correct for each set of stimuli for the three subject groups.

Figures 3 shows the distribution of error scores for the two sets of stimuli for the two hearing-impaired groups. A two-way analysis of variance revealed the significance of the main effect of hearing impairment on all the error scores : tonal error [$F(2, 19) = 59.75$, $p < 0.001$], segmental error [$F(2, 19) = 18.05$, $p < 0.001$] and semantic error [$F(2, 19) = 17.30$, $p < 0.001$]. There was no main effect of the stimulus conditions on the error scores. A significant interaction between the degree of hearing impairment and the sets of stimuli was found only in the tonal error scores [$F(2, 19) = 13.85$, $p < 0.001$] : the moderate-to-severe-hearing-loss subjects made more tonal errors in the isolation condition and the profound-hearing-loss subjects in the carrier phrase condition.

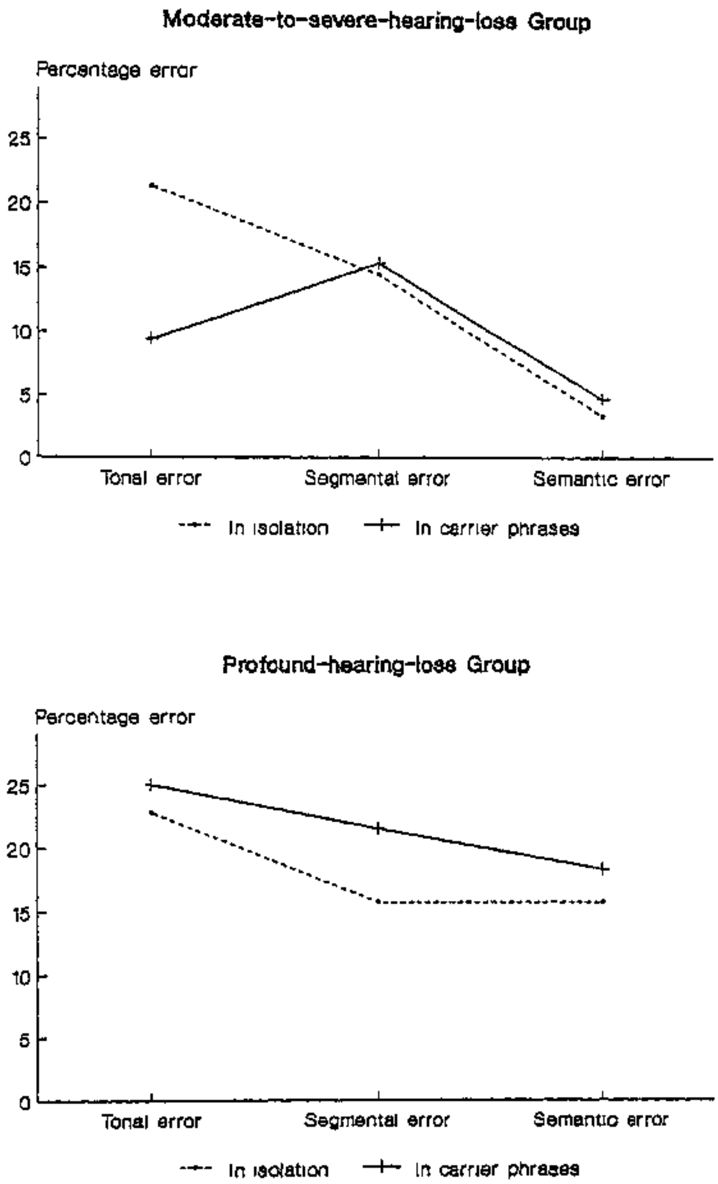


FIGURE 3. Mean % errors for the stimuli presented in isolation and in carrier phrases for the two hearing-impaired groups.

A correlational analysis yielded significant correlations, in both sets of stimuli, between :

		isolation	carrier phrases
target scores)		−0.89	−0.95
tonal errors)	& degree of	+0.83	+0.87
segmental errors)	hearing loss	+0.68	+0.79
semantic errors)		+0.74	+0.75

A t-test was performed to test for differences between the means of different error scores for the two hearing-impaired groups. In the isolation condition, the moderate-to-severe-hearing-loss group made significantly more tonal errors than semantic errors [$t(5) = 5.53$, $p < .01$] and more segmental errors than semantic errors [$t(5) = 3.25$, $p < .05$]. The difference between the total tonal errors and the total segmental errors was not statistically significant. For the profound-hearing-loss subjects, they only made significantly more tonal errors than segmental errors [$t(7) = 2.81$, $p < .05$]. When the stimuli were presented in carrier phrases, the moderate-to-severe-hearing-loss group only made significantly more segmental errors than semantic errors [$t(5) = 2.57$, $p = .05$]. For the profound-hearing-loss group, the differences between all types of error scores were not statistically significant.

DISCUSSION

Effects of Hearing Impairment on Tone Identification

The present study shows that the number of tonal confusion errors increases as the degree of hearing impairment becomes more severe. Similar results are reported by Gandour et al. (1984) in examining the perception of phonemic tones by hearing impaired subjects in Thai.

The above finding can be explained by the diminished auditory sensitivity resulted from hearing impairment. One function of the peripheral auditory system is to convert the auditory speech signal into a neural code for input to the central nervous system for processing. When this function is disrupted by sensorineural hearing impairment, part of the information in the speech signal will be coded inaccurately. The inability of the auditory system to preserve speech information, therefore, results in tone recognition difficulty. As the degree of hearing impairment increases, more information is coded inaccurately. So the profound hearing loss group showed the poorest performance among the three subject groups in the present experiment.

As the acoustic cues for tones are confined to the low-frequency region of speech (Yiu, 1989) and hearing-impaired persons rarely have abnormal auditory thresholds at low frequencies (Davis & Hardick, 1986), people may argue that profoundly deaf listeners can also perceive tonal contrasts. Nevertheless, the present study does not support this claim. Erber (1979) has shown that profound-hearing-loss subjects perceived speech signals mainly through vibrotactile sensation. However, frequency discrimination by the tactile sense is very poor compared with that by the auditory sense (Silverman, 1971). So, even though tones are in the low-frequency region of speech, the profoundly deaf subjects cannot make use of the low-frequency residual hearing in perceiving them. The fact that the profound-hearing-loss subjects performed at chance level in the tone identification task further suggests that this group of people has great problems in perceiving tonal contrast in speech.

Further examination of the hearing-impaired subjects' audiograms indicates that there is no strong relationship between the number of tonal errors and the configuration of hearing loss. That is, subjects with better hearing in the low-frequency region did not perform better in the current study. Since the present study did not include subjects with high-frequency hearing loss and low-frequency hearing loss, no comparison can be made and the relationship between tone perception and the configuration of hearing loss clearly required further research.

Effects of Stimulus Conditions on Tone Identification

The results of the SVLCT indicate that the sets of stimuli had significant effect on tone identification by the hearing-impaired subjects. Carrier phrases seem to facilitate tonal identification in the moderate-to-severe-hearing-loss subjects. This result is contradictory to the belief that tones are easily confused when they interact with intonation, e.g. in sentences. Since tones are manifested by relative pitch (Vance, 1976), perhaps the tonal clues in the rest of the carrier phrase act as references from which the listeners can figure out the actual tone presented. In addition, coarticulatory cues facilitate word identification (Goldman et al., 1980). Therefore, the presence of more coarticulatory cues in carrier phrases may facilitate tone identification for the moderate-to-severe-hearing-loss group.

The profound-hearing-loss subjects, in contrast, performed better in the isolation condition of the SVLCT. Erber (1979) demonstrates that profound-hearing-loss people can only detect the gross intensity variations in the waveform envelope of speech. Thus, in the present experiment, they may only hear the carrier sentence as a series of energy burst and the acoustic pattern of the target word, therefore, cannot be detected or recognised. The observation that the subjects frequently gave responses before the stimuli appeared in the carrier phrases further support the fact that profound-hearing-loss subjects were not able to detect the target word in a carrier sentence.

Patterns of Tonal Confusions

In the tonal identification task, the performance of the normal-hearing group is in basic agreement with that of normal listeners in previous studies on Cantonese tone perception (Fok, 1974). For example, the subjects confused the ML tone with the LL tone, and the HR tone with the LR tone. Apart from these, they made two additional confusions that were not reported in Fok's studies : the HL tone was mistaken as the LL tone, and the LF tone as the LL tone. Since voice quality and intensity can affect tonal distinctions (Vance, 1977), the difference in the findings of the current study and Fok's (1974) investigation may be attributed to the individual female speaker as she might vary her voice pitch or intensity from time to time when recording the stimuli.

From the confusion matrices shown in Table 3, it can be concluded that the deficit in tone perception by the hearing-impaired is qualitative, quantitative, or both. When the stimuli were presented in isolation, the moderate-to-severe-hearing-loss subjects made different patterns of tonal errors to the normal-hearing subjects. The moderate-to-severe-hearing-loss subjects also made more number of errors. Thus, their performance differed from the normal-hearing subjects both in kind and in degree. In the carrier phrase condition, the moderate-to-severely hearing impaired subjects made similar patterns of tonal confusions to the normal-hearing group. The number of errors remained relatively high. Thus, their performance differed from that of the normal group not as much in kind as in degree. This differences in performance of the moderate-to-severe-hearing-loss group for the two sets of stimuli appear to suggest that carrier phrases provide additional cues for tonal identification.

The profound-hearing-loss subjects, in contrast, confused all tones in both sets of stimuli. Apart from the diversified tonal confusions, they also made greater number of errors. Thus, their performance differed from the normal group's both qualitatively and quantitatively. This result further suggests that profoundly deaf listeners cannot perceive the tonal contrasts in words through the auditory means only.

Response Bias in the Tonal Identification Task

Pooling across the subject groups, the HL tone was found to have the highest percentage of correct identification. There were two subjects in the moderate-to-severe-hearing-loss group who identified all the HL tone stimuli correctly in one set of stimuli or both. This response bias could be attributed to the relative frequency of occurrence of the HL tone in Cantonese. In four 15-minute samples of speech, 36.5% of the words spoken were with the HL tone and the HR tone (Fok, 1974). People tend to use the better perceived tone more often, or to perceive more accurately the tone that were used more frequently. Thus, the HL tone is better perceived. Apart from the relative high frequency of occurrence, the HL tone has a high initial frequency that starts well at a level above the rest of the tones (Fok, 1974). The distinctiveness of the HL tone, therefore, facilitates its identification.

Tonal Identification Task Verses So & Varley Lexical Comprehension Test

All the subjects in the present experiment performed better in the SVLCT (compare Tables 2 & 4). There are two reasons that may account for the difference. Firstly, there are six response options in the tonal identification task and four in the SVLCT. As listeners always consider all the choices before making a decision, it is obvious that auditory processing is more demanding in the tonal identification task. Secondly, the only difference in the six choices of the tonal identification test is the tone. In order to make a correct choice, the subjects can only make use of the tonal cues. In contrast, the choices in the SVLCT differ from each other in terms of the tones, segmental units or semantic meaning. More cues, therefore, are available for identification. As a result, the subjects performed better in the SVLCT.

Interestingly enough, the normal group got full scores in both sets of stimuli of the SVLCT. Does it mean that they have no problems in tone identification ? The answer is probably no. The results from the tonal identification task indicate that normal subjects also confuse Cantonese tones. In fact, the SVLCT does not contain all tone pairs. For example, for the stimulus words with the ML tone, no test plate has a tonal distractor of the LL tone. Confusions between these two tones, therefore, cannot be detected. The relatively easier of the SVLCT, as explained previously, may also account for the excellent performance of the normal-hearing subjects.

Types of Errors Made by the Hearing Impaired Subjects

In the SVLCT, the moderate-to-severe-hearing-loss subjects only made significant difference in the mean tonal errors for the two sets of stimuli. The number of segmental and semantic errors remained nearly the same in the two stimulus conditions. Thus, the better performance in the carrier phrase condition cannot be attributed to the difference in the number of segmental and semantic errors.

Further examination of the segmental errors reveals that the moderate-to-severe- and the profound-hearing-loss groups only made 9.4% and 25.3% of segmental errors on vowels, respectively. The rest of the segmental errors were in the initial or final consonants. This result is predictable because vowels are the most intense phonemes and most of the energy is contained in the low-frequency region of the first formant. The lower frequency, higher-intensity first formant of vowels always remains audible to the hearing impaired (Davis & Hardick, 1986) and therefore, vowels are perceived more accurately than consonants. This result is in consistent with Bilger & Wang's (1976) findings that vowels were perceived better than consonants. The profound-hearing-loss subjects could also identify vowels to a moderate degree because they could base their judgment on the intensity, duration and perceived roughness of the vowel energy (Erber, 1979).

Clinical Implications

The demonstration that stimulus conditions can affect tone identification by the hearing-impaired provides potentially useful information for aural rehabilitative intervention. Since the moderate-to-severe-hearing-loss subjects made more correct identification and less tonal errors in carrier phrase condition, it would be better to embed the target words in a frame sentence during assessment and intervention. The profound-hearing-loss subjects, in contrast, performed better when the stimuli were presented in isolation. Perhaps shorter phrases with simplified structures and presented repeatedly may facilitate these subjects' comprehension.

The present study also shows that listeners are good at identifying tones that have the most distinctive fundamental frequency such as the HL tone. In training the hearing-impaired in tone discrimination, it would be a good idea to start with words that have the greatest fundamental frequency contrasts, such as words with the HL tone and the LF tone. When the subject is able to identify these two tones, words with less distinct frequency contrasts can be used and finally, using words with similar fundamental frequencies.

Lastly, the findings of this study do not support the concept of an exclusively auditory approach to rehabilitative intervention with the profoundly deaf listeners. Previous researches show that information perceived via the auditory and visual channels can complement one another to improve speech recognition (Erber, 1979; Osberger & Hesketh, 1988; Silverman 1971). Therefore, combined-mode (auditory and visual ones) perception of speech is recommended for the education of the profoundly hearing-impaired.

Limitations of the Present Study

The results obtained from the present study may represent only limited estimates of the tonal identification ability of the hearing-impaired population. Informal observations showed that most of the hearing-impaired subjects used sign language with no or almost no speech when communicating with others. As a result, they got less exposure to the speech sounds. Since perceptual skills improve through experience (Ching, 1984), the subjects would gradually become less competent in using the audition to perceive speech. Consequently, when they participated in some identification tasks, like the present experiment, their performance would not be as good as their aided thresholds imply.

The large intragroup variability is another limitation of the present study. Subjects in these studies came from different schools and the training they received may differ. Whilst an auditory-oral approach is claimed to be used in the education of the deaf nowadays, what the teachers actually do might differ from what they claim (Lai & Lynas, 1991). Although some schools have an official policy of natural oralism, the teachers also use sign language. The difference in the educating environment of these subjects may affect their performance in the present study. Moreover, the amount and type of speech sound information that is perceived by the hearing-impaired varies greatly among individuals. It is because the nature of the acoustic signals interacts with the configuration of hearing loss which results in various types of signal distortion. Even if two persons experience the same speech perception impairment, they may differ in the way they extract meaning from the speech signal.

Lastly, although the hearing-impaired subjects' hearing aids are issued by the Education Department with the prescription of a qualified audiologist, it remains possible that having one with the use of amplification more suitably matched to its user's auditory characteristics would result in better performance. The large difference in the subjects' hearing ages may also affect their performance. It is not surprising that subject having a longer hearing age would perform better as he/she will get more accustomed to the speech signal perceived.

Directions for Further Research

The results of this study provide evidence that the stimulus conditions do affect the perception of Cantonese tones in the hearing impaired population. This demonstration represents an important step toward obtaining more information about this aspect. As the sample size is small in the present study, it would be advantageous to collect similar data on a larger sample of subjects in order to determine the actual effect of the stimulus conditions in the identification of Cantonese tones. The relationship between the configuration of hearing loss and tonal perception also awaits further investigation. As shown in the present experiment, the subjects made errors in the segmental features of words in addition to tones. As little researches have been done on the patterns of consonant confusions in the hearing-impaired in Cantonese, further investigation may focus on this area. Furthermore, perception and production are closely related (Ching, 1984). The production of different Cantonese tones by the hard-of-hearing will also be an interesting area to explore. The intent of these proposals is to provide new insights into the assessment and intervention of the hearing-impaired listeners.

CONCLUSION

The present study reveals that (a) the presence of sensorineural hearing impairment does affect the perception of Cantonese tones, (b) the stimulus conditions can affect tonal identification, (c) carrier phrases facilitate tonal identification in the moderate-to-severe-hearing-loss listeners and (d) the profoundly deaf listeners show better performance when the stimuli are presented in isolation. Individuals involved in the assessment and education of the deaf may find the data reported here useful as a basis for developing more appropriate assessment and intervention materials for the hearing-impaired population.

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