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**The tone production in Cantonese profoundly
hearing impaired children and the usefulness
of residual hearing at low frequency**

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the Bachelor of Science (Speech and Hearing Sciences),
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Abstract

Sixteen hearing impaired children (fourteen profoundly, two severely to profoundly) were selected. Each produced eighteen words which were rated by three raters about the tone productions. The result shows an order of relative ease of tone productions: the most easiest tones are tone 1 (high level) and tone 6 (low level), then tone 3 (mid level), tone 2 (high rising) and tone 5 (low rising), and lastly tone 4 (low falling). This agrees with normal developmental sequence.

The children were divided into groups, namely acquired, acquiring, polar, no tone 1, monotone and severe hearing impaired, according to their production patterns which were analyzed against the children's hearing abilities. It was found that the best two groups, the severe and the acquired groups, have the lowest aided threshold at low frequency. The others had difficulty in tone production. It may arise from the difficulty in controlling the pitch due to reduction of auditory feedback.

Introduction

Children normally learn speech and language through aural-oral means. Significant hearing impairments are barriers to children learning speech and language this way. It is important to determine how hearing impairment affects speech and language development in order to find therapeutic approaches which best help. While this area has been well researched in English speaking populations (e.g. Ling, 1976; Beebe, 1978; McGarr, 1981), there is little about Cantonese and other tonal languages.

Cantonese tones

Tone languages are languages in which word meanings or grammatical categories are conveyed through pitch level. Cantonese is a tone language. Fok (1974) provided some physical data on tones of Cantonese. Fundamental frequency seems to be the main factor responsible for keeping each tone distinct. Generally the fundamental frequencies of the six Cantonese tones cover a frequency band from 100 to 400 Hz which includes the variation in male and female speakers and variations with emotions. Ching (1981) also described how Cantonese has six distinctive tones in terms of fundamental frequency: 1 high level; 2 high rising; 3 mid level; 4 low falling; 5 low rising; 6 low level. They cover the frequency band mentioned in Fok's study (1974), ranged from 100 to 500Hz (see figure 1).

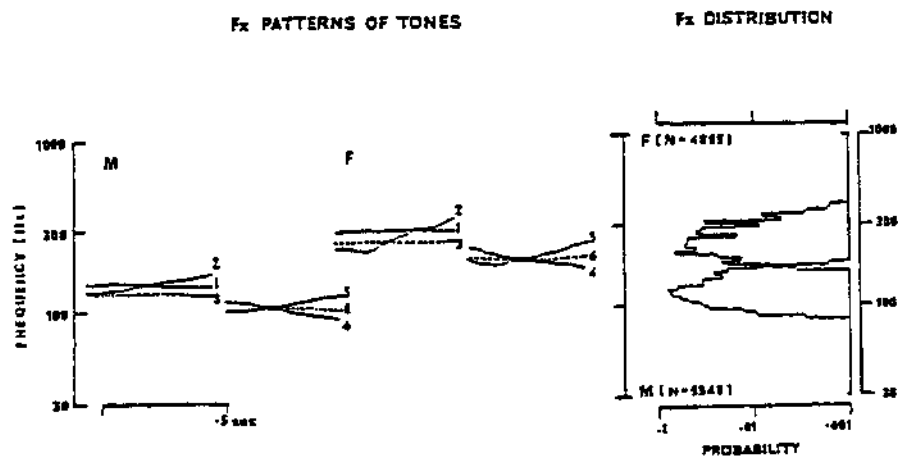


Figure 1 The larynx frequency patterns of the six contrastive tones in Cantonese in relation to the larynx frequency distribution of the two speakers. N represents the sample size in terms of number of larynx periods. (From Ching, 1981)

Tse's study (1977) on the tone acquisition of his son mentioned that tone discrimination appeared early at eight month old, and tone production appeared at 1;02 and the process was completed in eight months (1;10). Li and Thomson (1976) also found similar result in Mandarin tone acquisition (see figure 2). In both studies, the

	Stage I	Stage II	Stage III	Stage IV
Cantonese (Tse, 1977)	First 3 months of the single- word stage	The remain- ing 4 months of the single-word stage	Emergence of 2-word construction	Productive use of 2- word con- structions and emergence of longer sentences
	1; 3-1; 4 7 11 55 22	1; 5-1; 8 4 1 33 35	1; 9 1 1 23 21	1; 10-
Mandarin (Li & Thompson 1976)	Single-word stage (early)	Late single- word stage (with more words)	2-3-word stage	Longer sentences
	7 11 55 51	4 1 214 35	1+ 1- → 1+ 1- acquire the sandhi rule	

Figure 2 Stages of tone acquisition in Cantonese and Mandarin (from Tse, 1977 and Li & Thomson, 1976) process of acquisition of tone was subdivided into four stages and they were parallel. In Tse's study, at stage I, the first three month of the single word stage, the high level (55) and the low level tones (22) were produced. At stage II, the remaining four months of the single word stage, the mid-level (33) and the high rising (35) tones were produced. At stage III, the beginning of two word stages, the low rising (23) and the low falling tones (21) were produced. At stage IV, after 1;10 and at two word stage, the tone system was stable and the acquisition seemed completed. In Mandarin (Li and Thompson, 1976), at stage I level (55) and falling (51) appeared, stage II dipping tone (214) and rising tone (35) appeared. However Ching (1984) suggested tone 4, the falling tone is acquired first for it is the tone most easily perceived and has a heavy functional load in Cantonese. The low rising and the low level are acquired latest because of confusions in pitch contours. Tse (1977) suggested that there may be some kind of universal strategy in the acquisition of tones. It is interesting to investigate whether deaf children also employ such a strategy.

Tones in hearing impaired

Researches about tonal acquisition in Cantonese or other tonal languages in hearing impaired are few. However we may predict tonal acquisition from some related literature about acquiring intonation in western countries.

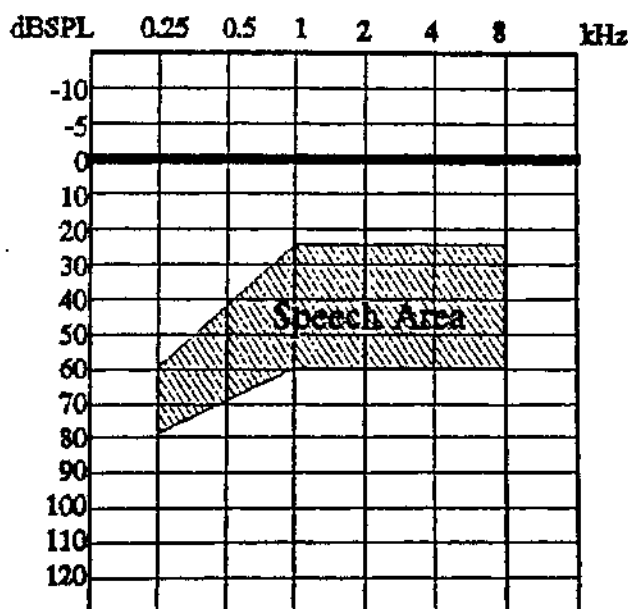


Figure 3 Speech area: All speech sounds fall in this spectrum.

On average normal speech sound loudness is 65 dB SPL as measured 1 metre from a speaker (Ross & Tomassetti, 1980). The shaded area in the audiogram shown in figure 3 is the speech area of normal speech, that is all speech sound falls in this area. If hearing threshold falls in this area or better, people can detect speech. The minimal threshold for detecting speech sound is around 30 dB HL. With the advances in technology, hearing aids can amplify an input 60 dB SPL to an output of 125 dB SPL (Schow & Nerbonne, 1988). So even profoundly deaf children, who have hearing losses on average of 90 dB HL, can have the opportunity to hear speech sounds using residual hearing.

Intonation patterns, one of the suprasegmental features patterned variation of pitch, appear early. The acquisition of intonation start as early as two to three months and becoming mature before age three (Crystal, 1986). However intonation carries a vast amount of linguistic information which is important in early communication (Crystal, 1986), so intonation is an important feature in speech communication. Parkhurst &

Levitt (1978) pointed out that suprasegmental errors, including intonation, were a major source of reducing intelligibility of deaf speech. Ling (1976) stressed that in the intervention of hearing impaired children should design with the suprasegmental features in order to have better control of voice and phonation. Children need to have hearing in a frequency range of 100 to 500 Hz (Ling, 1984)

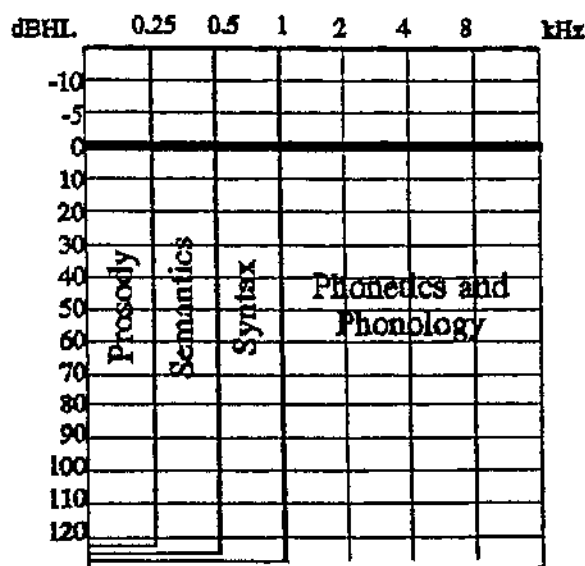


Figure 4 Relationship between residual hearing and linguistic levels (From Clezy, 1988)

Smith (1975) found that the intelligibility of hearing improved speakers is highly correlated with the residual hearing. Beebe (1978) said that even profoundly deaf can learn to hear by their residual hearing, provided they are well trained and aided. Dyrlund (1988) found that improving the aided threshold at low frequency improved the speech discrimination ability. Clezy (1988) proposed that if children have residual hearing at 250 Hz, they have the ability to acquire prosody (i.e. suprasegmental features); at 500 Hz, they have the ability to acquire semantics; at 1000 Hz, they have the ability to acquire syntax; and above 1000 Hz, they have potential to acquire phonology, depending on the extend of the frequency band. This is shown on figure 4.

However, tone is different from intonation in the following ways. Intonations are the speech melody patterns whose function is to be part of the structure of sentences, but tones are speech melody patterns whose function is to be part of the structure of words (Abercrombie, 1967). Although tones are physically patterns of variations of voice pitch, they are not the same as intonation because they carry word lexical meaning.

Whether hearing impaired children can acquire tones is an important factor which affects their intelligibility of that tone language, even more important than intonation in non-tone languages.

Extending Clezy's hypothesis, tones physically resemble to intonation and additionally have a semantic function. Hypothetically those hearing impaired children have the ability to acquire tones if they have residual hearing at 250 and 500 Hz. i.e. the low frequency band. However in the reality, e.g. in Hong Kong, can all hearing impaired children with residual hearing at low frequencies acquire tone?

The study proposed is an attempt to answer the above question. The aim is to investigate how the tone productions in Hong Kong profoundly hearing impaired children look like and how the productions relate to their residual hearing. The hypothesis is that, if the residual hearing of low frequency is a significant factor of acquisition of Cantonese tones, then the tone productions of the children with better aid at low frequency will be better. Better aid at low frequency means lower aided threshold at frequency 250, 500 and 1000Hz.

Method

Subject

Sixteen hearing impaired children were selected from the two child care centres of the Hong Kong Society for the Deaf. They were assumed to have similar quality and quantity of intervention. Their ages ranged from 3;07 to 5;07 (on 28th Feb, 1992). Fourteen of them (nine boys and five girls) were profoundly impaired and had pure tone averages equal to or over 90dBHL. The other two girls were severely to profoundly impaired and their pure tone averages were 83.3 and 85 dB HL respectively. They were separated from the profoundly impaired group in the analysis, but their results will also be discussed.

They all communicate orally. They had no indication of other significant disability which minimizes the possibility of other factors than hearing impairment hindering the development of communication. Each of them was binaurally aided, prescribed by an audiologist. This ensures that each of them is most suitably aided. The children's pure tone and aided audiograms were also obtained for later analysis of the relationship with tone productions.

Task:

Eight to ten monosyllabic words were selected in each tone as figure 5 shown. They were all drawn into pictures as stimuli. Each child was given three of the pictures for each tone. A total of eighteen pictures for six tones (3X6) were presented to each child. In addition there were five set trial plates for the children to be familiar with the task.

Trial Plates:	星	車	刀	煙	花														
	Star	Car	Knife	Cigarette	Flower														
Tone 1	咭	波	骨	燈	書	竹	屋	梯	桔										
	Card	Ball	Bone	Lamp	Book	Bamboo	House	Ladder	Luck										
Tone 2	頸	狗	手	梨	火	枱	海	碗	橙	水									
	Neck	Dog	Hand	Pear	Fire	Table	Sea	Bowl	Orange	Water									
Tone 3	腳	菜	髮	劍	鏡	尺	角	椅	鴨	血									
	Foot	Vegetable	Hair	Sword	Mirror	Ruler	Horn(of animal)	Chair	Duck	Blood									
Tone 4	頭	牛	牙	琴	鞋	雲	蛇	牀	羊	門									
	Head	Cow	Teeth	Piano	Shoe	Cloud	Snake	Bed	Sheep	Door									
Tone 5	耳	肚	米	尾	馬	蟹	雨	眼											
	Ear	Tummy	Rice	Tail	Horse	Crab	Rain	Eye											
Tone 6	額	象	飯	石	鑊	樹	木	鼻	脷										
	Forehead	Elephant	Cooked rice	Rock	Wok	Tree	Wood	Nose	Tongue										

Figure 5 Wordlist used in this study

The eighteen pictures were presented so that each picture was shown equally often. The children took part in random order. Each child was required to name each picture in a carrier sentence: "係....." (is target word). The word "係" was belongs to tone 6 (low level) in adult form. This gives more information for judging the tone production.

The task was carried out in the speech training rooms of the centres by their speech teachers, supervised by the author. The task composed of two sessions: a trial session at first, then a production session. In both sessions, the teacher asked the child a prompt question "係乜嘢" (is what?) and the child was required to answer by saying "係....." (is target word). The instruction was made as simple as possible to reduce the processing load on the children, because they are generally have different severity of speech and language delay due to the hearing impairment.

In the trial session, five trial plates were used. These were to familiarise the child with the task and to allow adaption to the respond mode. Each child was presented with the same trial plates. If the child could not produce the target sentence spontaneously, the five trial plates were repeated once. If the child still could not

produce spontaneously, he or she did the task with models provided by the teacher.

The eighteen pictures were presented to the child one by one. If the child cannot name the pictures, the examiner gave him or her models. For each picture, only two models were provided at most. Their productions were recorded in tapes (TDK SA type) by a tape recorder (Sony WMD6C) for later scoring.

Scoring:

Three raters listened to the recording. They were the author and two third year students of speech and hearing sciences. They had professional training on the judgment of tone. They listened to the last trial for each picture and determined whether the produced tone was identical to the target tone, according to their judgment, with the target words provided. If not identical, they gave a judgment about what their realizations of tone produced. A production was considered to be accurate if two or more raters score that produced tone is identical to the target tone.

Results

General Production

In the production of the fourteen profoundly hearing impaired children, the mean total score of accuracy was 8.43 from a maximum score 18 i.e. 46.83%. The accuracy scores for each tone were:

Tone 1 (high level)	1.72 (57.33%)	Tone 4 (low falling)	0.57 (19.00%)
Tone 2 (high rising)	1.07 (35.67%)	Tone 5 (low rising)	0.92 (30.67%)
Tone 3 (mid level)	1.71 (57.00%)	Tone 6 (low level)	2.42 (80.67%)

Figure 6 presents these data graphically.

The scores of accuracy of each tone

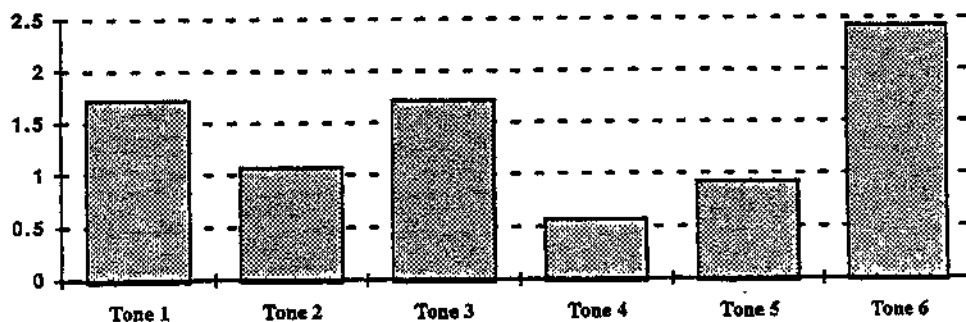


Figure 6 The scores of accuracy of each tone of the fourteen profoundly hearing impaired children. The maximum value for each tone is 3.

From the sum of the realizations of each tones of the three raters (see figure 7), most productions were realized as tone 6 (33.20% of the total number of realizations); following were the two level tones 1 (27.91%) and 3 (17.59%); the two rising tones 2 (7.80%) and 5 (7.94%) were less; the least was tone 4 (4.50%). There were also 1.06% were unclassified.

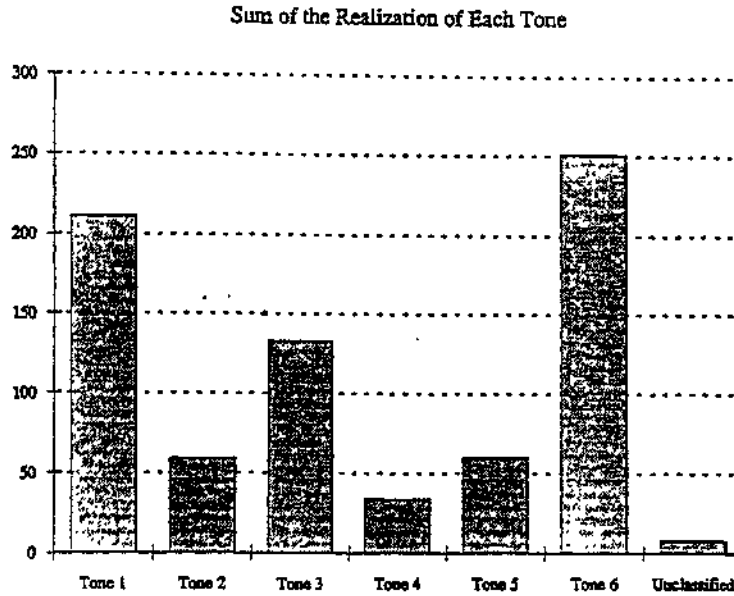


Figure 7 The sum of realizations of each tones of the fourteen profoundly hearing impaired children. The total number of realizations is 756

Table 1 and figure 8 summarize of the rater's realizations. Most of the tones were substituted by level tones, especially tones 1 and 6. Of total tone 1 realizations 62.56% (132) and 62.15% of tone 6 (156) were used for substitutions. Tone 4 is the least popular tone used for substitutions (only 8.82%).

Target	Realization						
	Tone 1	Tone 2	Tone 3	Tone 4	Tone 5	Tone 6	Unclassified
Tone 1	79	2	7	0	1	36	1
Tone 2	36	39	13	1	6	30	1
Tone 3	23	5	70	0	5	22	1
Tone 4	29	4	17	31	3	41	1
Tone 5	24	6	20	2	43	27	4
Tone 6	20	3	6	0	2	95	0
Total	211	59	133	34	60	251	8

Table 1 Summary of the raters' realizations of fourteen profoundly hearing impaired children

Inter-rater reliability

The accuracy scores of all sixteen subjects of the three raters were reliable. The Kendall's coefficient of concordance is 0.718 ($\chi^2=32.33, p<0.01$).

However, different raters have different realizations for the productions. The percentage of same realization of raters, which was calculated by dividing the number of productions that the three raters had the same realization by the total number of productions, was 31.35%.

Summary of the raters' realizations

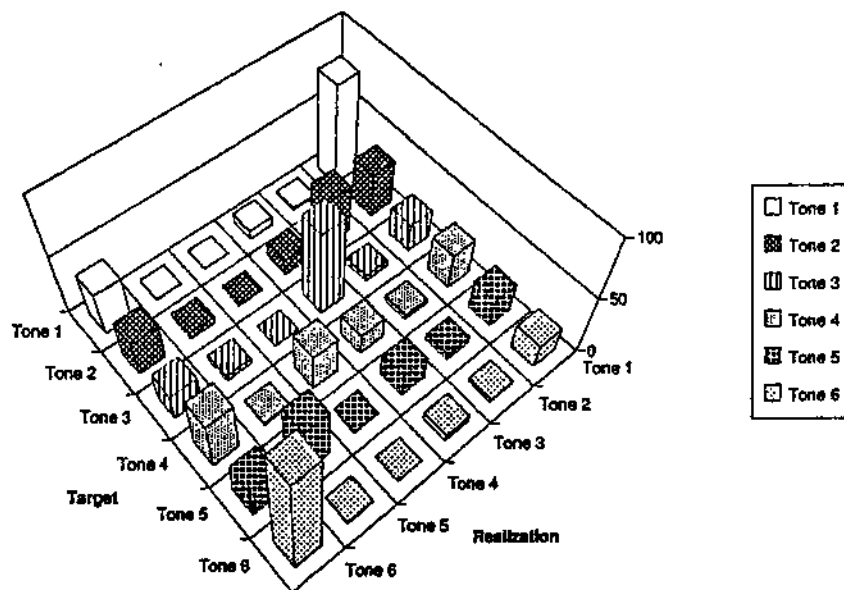


Figure 8 Graphical presentation of the raters' realizations of fourteen profoundly hearing impaired children Tone production patterns

According to the pattern of the scoring of each tones in the profoundly hearing impaired children, five distinct patterns was identified, namely acquired/nearly acquired, acquiring, polar, no tone 1 and monotone. The children were grouped according to these patterns. In addition there are one child unclassified and two severely hearing impaired children. Table 2 shows the summary of the accuracy score in each group.

Group	Total	Score of Accuracy					
		Tone 1	Tone 2	Tone 3	Tone 4	Tone 5	Tone 6
Acquired	14.67	3	2	2.33	2	2.3	3
Acquiring	6.75	2	0.25	1.5	0.25	0	2.75
Polar	8	3	1.5	2	0	0.5	1
No Tone 1	8.5	0	2.5	2.5	0	1	2.5
Monotone	4	0	0	0	0	1	3
Unclassified	6	1	0	2	1	1	1
Severe	14	3	2.5	1.5	2	2.5	2.5

Table 2 Summary of the accuracy score in each group

1. The acquired/nearly acquired group

Table 3 and figure 9 summarize this group's results. This group of children was the highest scored group which consisted of three children. The mean was 14.67 and the range was from 12 to 16. Age ranged from 4;00 to 4;06. They had a score above two in all the six tones. From the graph of the summary of realizations of the raters (figure 9), most productions were correctly realized as the targets. These children matched the Stage III of tone acquisition (Tse, 1977) that all tones appear. (This group will be called acquired group in short)

Target	Realization						Unclassified
	Tone 1	Tone 2	Tone 3	Tone 4	Tone 5	Tone 6	
Tone 1	25	0	0	0	0	2	0
Tone 2	2	16	2	0	0	6	1
Tone 3	3	1	20	0	0	3	0
Tone 4	3	0	3	15	0	6	0
Tone 5	3	3	0	0	20	1	0
Tone 6	3	0	0	0	0	24	0

Table 3 Summary of realizations of acquired/nearly acquired group (N=3)

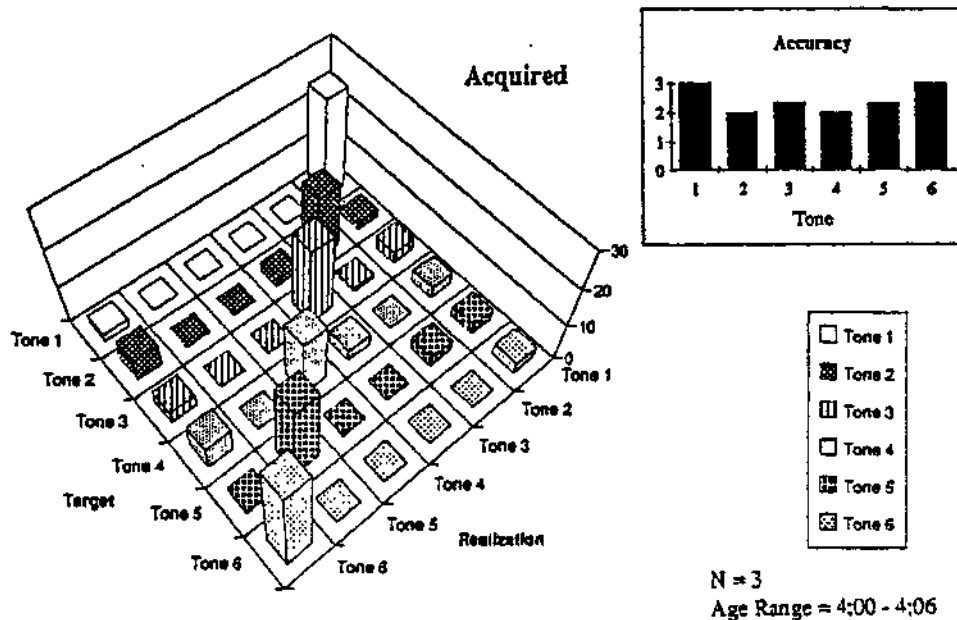


Figure 9 Graphical presentation of realizations and the accuracy rate of the acquired group

2. The acquiring group

Table 4 and figure 10 summarized this group's results. there were four children in this group. The mean score of this group of children was 6.75 and the range was from 5 to 9. Age ranged from 3;07 to 5;04. They had most of the score at the level tones but

very low score (less than one) at the rising and falling tones. From the graph of the summary of realizations of the raters (figure 10), most productions were realized as tones 1, 6, and 3. Only some were realized as tone 2, 4 and 5. These children matched the Stage II of tone acquisition (Tse, 1977), that only the level tones appeared.

Target	Realization						Unclassified
	Tone 1	Tone 2	Tone 3	Tone 4	Tone 5	Tone 6	
Tone 1	22	2	1	0	1	9	1
Tone 2	13	3	6	0	2	12	0
Tone 3	9	1	19	0	2	5	0
Tone 4	7	3	4	8	3	10	1
Tone 5	7	3	7	1	4	10	4
Tone 6	4	1	1	0	1	29	0

Table 4 Summary of realizations of acquiring group (N=3)

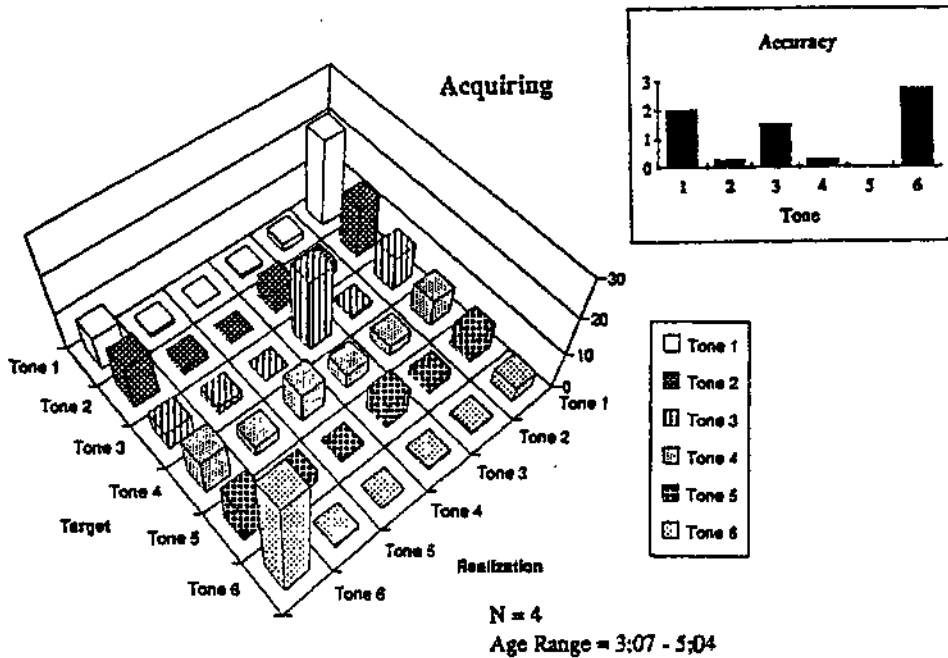


Figure 10 Graphical presentation of realizations and the accuracy rate of the acquiring group

3. The polar group

Table 5 and figure 11 summarized this group's results. There were two children in this group and both scored 8. Age ranged from 5;00 to 5;01. They had higher score in high tone, i.e. tone 1, 2, and 3. but score less in low tone. From the graph of summary of realizations, most realizations were tone 1 and tone 3. These children seemed to be at Stage II proceeding to Stage III (Tse, 1977), i.e. Tone 1, 2, 3 and 6 appeared and tone 5 and 4 is being acquired.

Target	Realization						
	Tone 1	Tone 2	Tone 3	Tone 4	Tone 5	Tone 6	Unclassified
Tone 1	18	0	0	0	0	0	0
Tone 2	10	5	3	0	0	0	0
Tone 3	6	0	10	0	0	1	1
Tone 4	10	1	4	1	0	2	0
Tone 5	6	0	7	0	2	3	0
Tone 6	5	2	3	0	0	8	0

Table 5 Summary of realizations of polar group (N=2)

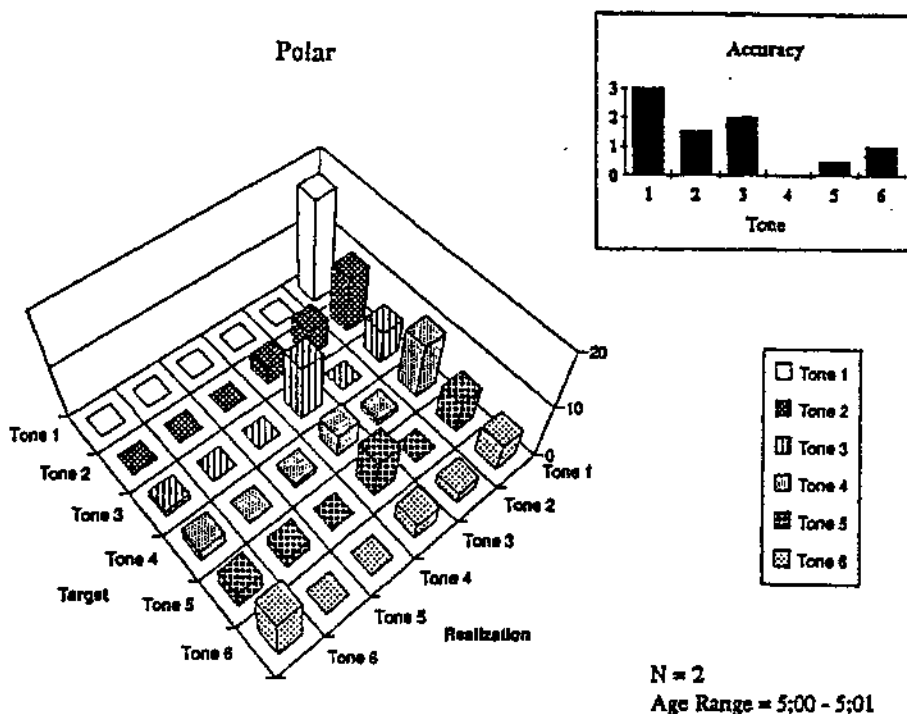


Figure 11 Graphical presentation of realizations and the accuracy rate of the polar group

4. The no tone 1 group

Table 6 and figure 12 summarized this group's results. There were two children in this group who were characterized by no score at tone 1. They did not fit into any stage of tone acquisition. The mean was 8.5 and the range was from 8 to 9. Age ranged from 3;04 to 4;04. They were the youngest group. From the graph of the summary of realizations of the raters (figure 12), most productions of tone 2, 3, and 6 were correctly realized as the targets. The productions of tone 4, 5 and 1 were unstable.

Target	Realization						
	Tone 1	Tone 2	Tone 3	Tone 4	Tone 5	Tone 6	Unclassified
Tone 1	3	0	6	0	0	9	0
Tone 2	3	14	0	0	0	1	0
Tone 3	0	2	15	0	0	1	0
Tone 4	3	0	3	4	0	8	0
Tone 5	4	0	2	0	7	5	0
Tone 6	2	0	1	0	0	15	0

Table 6 Summary of realizations of no tone 1 group (N=2)

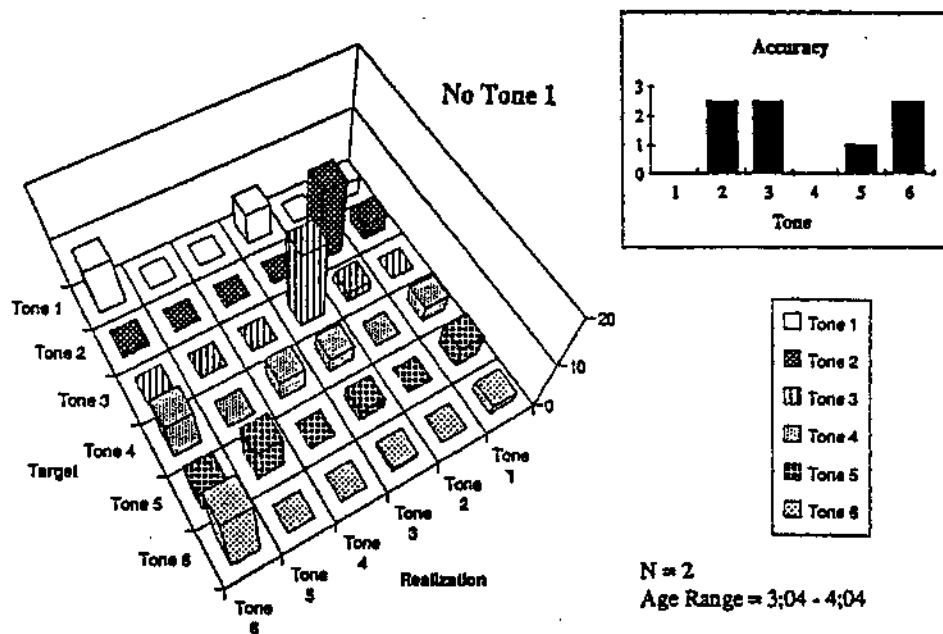


Figure 12 Graphical presentation of realizations and the accuracy rate of the no tone 1 group

5. The monotone group

This group of children was the lowest scored group. The mean was 4 ranged from 3 to 5. Age ranged from 4;03 to 5;00. They had score only at low frequency tone 5 and 6. From the graph of the summary of realizations of the raters (figure 12), most productions were realized as tone 1 and 6. If we look microscopically into each rater's scoring, one rater reported that the productions were mostly tone 1 (83.33% of the rater realizations) and the other two reported that mostly were tone 6 (77.78%). However one similar point is that, most of these children's productions were only realized as one tone only, so they were classified as monotone.

Target	Realization						Unclassified
	Tone 1	Tone 2	Tone 3	Tone 4	Tone 5	Tone 6	
Tone 1	6	0	0	0	0	12	0
Tone 2	6	0	0	0	3	9	0
Tone 3	5	1	1	0	3	8	0
Tone 4	6	0	0	0	0	12	0
Tone 5	4	0	1	1	6	6	0
Tone 6	3	0	0	0	0	15	0

Table 7 Summary of realizations of monotone group (N=2)

6. The unclassified group

There was one child who could not be grouped to either one of the above groups and table 8 and figure 14 summarized this child's result. He had score in most of the

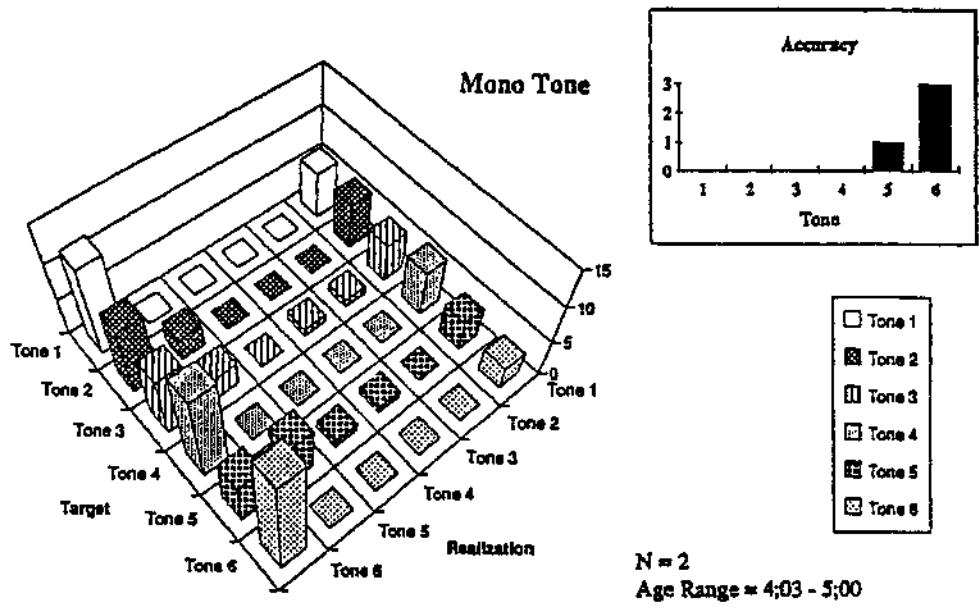


Figure 13 Graphical presentation of realizations and the accuracy rate of the monotone group tones but the scores of each tone were all low. The total score was 6. His age was 5;02. From the graph of the summary of realizations of the raters, The productions were scattered over the area that reflect the productions were unstable that caused different raters gave different realizations..

Target	Realization						Unclassified
	Tone 1	Tone 2	Tone 3	Tone 4	Tone 5	Tone 6	
Tone 1	5	0	0	0	0	4	0
Tone 2	2	1	2	1	1	2	0
Tone 3	0	0	5	0	3	4	0
Tone 4	0	0	3	3	0	3	0
Tone 5	0	0	3	0	4	2	0
Tone 6	3	0	1	0	1	4	0

Table 8 Summary of realizations of the unclassified group

7. Severely hearing impaired group

This group of children was not included in the profoundly hearing impaired group and table 9 and figure 15 summarized their results. They were found resemble to the acquired group mentioned above. Both children scored 14. Age ranged from 4;00 to 5;02. They had score in all the 6 tones. From the graph of the summary of realizations of the raters, most productions were correctly realized as the targets. There was one child who consistently elongated the last words of every utterance and raised the pitch during the phonation of these words, so there were many realizations of tone 2. However if one ignored the final rising parts, the tone productions were normal. (This group will be called severe group in short)

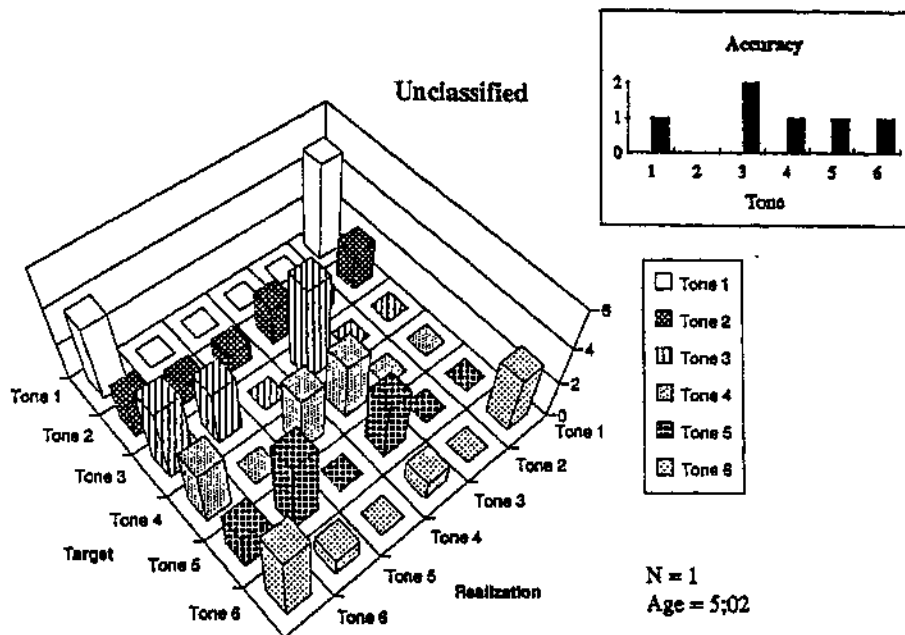


Figure 14 Graphical presentation of realizations and accuracy rate of the unclassified group

Target	Realization						Unclassified
	Tone 1	Tone 2	Tone 3	Tone 4	Tone 5	Tone 6	
Tone 1	18	0	0	0	0	0	0
Tone 2	0	15	0	3	0	0	0
Tone 3	2	4	12	0	0	0	0
Tone 4	0	5	0	13	0	0	0
Tone 5	0	4	0	0	14	0	0
Tone 6	0	3	0	0	2	13	0

Table 9 Summary of realizations of the severely hearing impaired group

The relationship with hearing

The unaided and aided threshold of the five groups of profoundly hearing impaired and the severely impaired group were plotted as figure 16 and 17 shown.

Consider the unaided threshold shown on figure 16. From a one-way analysis of variance, the severe group significantly differs from the acquired, acquiring, polar and monotone groups at 250 (table 10) and 1000 Hz (table 12), and it differs from all groups at 500 Hz (table 11). The low frequency threshold of this group falls in the speech spectrum. The profoundly impaired groups are generally homogenous, i.e. they belongs to the same homogenous group in the analysis of variance.

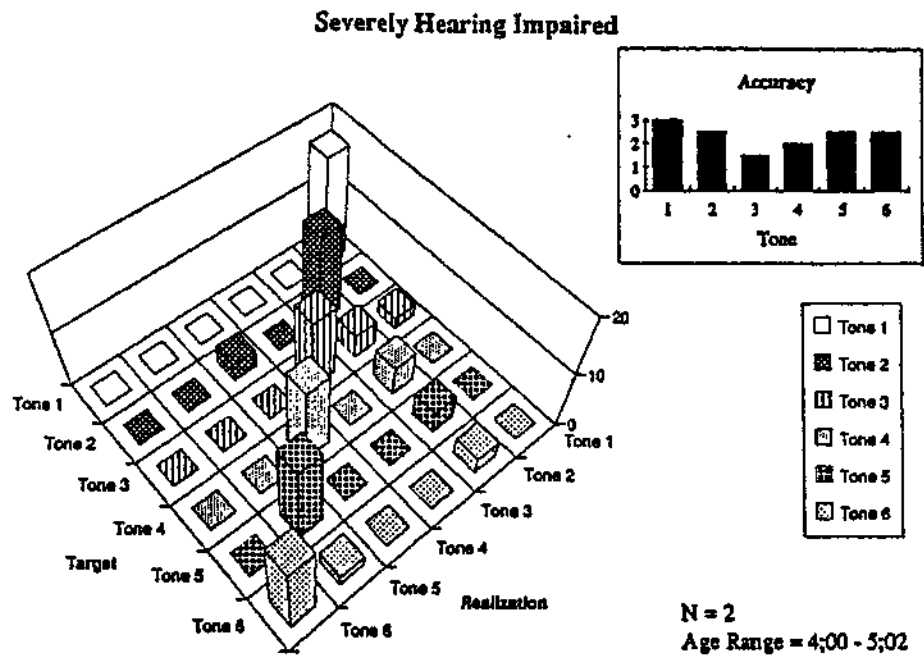


Figure 15 Graphical presentation of realizations and the accuracy rate of the severely hearing impaired group

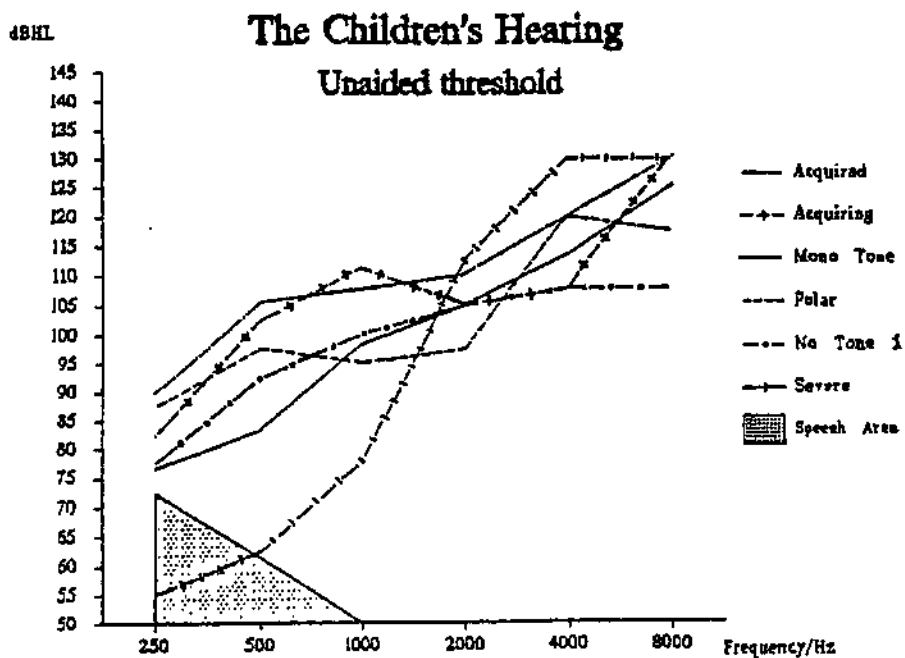


Figure 16 The unaided thresholds of the hearing impaired children

Table 10 Analysis of variance of unaided threshold at 250 Hz by groups

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	1850.5208	6	308.42014	1.901	.1856
Within groups	1460.4167	9	162.26852		
Total (corrected)	3310.9375	15			

0 missing value(s) have been excluded.

Multiple range analysis

Method: 90 Percent LSD					
Level	Count	Average	Homogeneous Groups		
			A	B	
severe	2	55.000000	X		
unclassified	1	70.000000	X	X	
acquired	3	76.666667		X	
no tone 1	2	77.500000	X	X	
acquiring	4	86.250000		X	
polar	2	87.500000		X	
monotone	2	90.000000		X	

contrast	difference	+/-	limits
acquired - no tone 1	-0.83333		21.3219
acquired - acquiring	-9.58333		17.8392
acquired - severe	21.6667		21.3219 *
acquired - polar	-10.8333		21.3219
acquired - unclassified	6.66667		26.9703
acquired - monotone	-13.3333		21.3219
no tone 1 - acquiring	-8.75000		20.2277
no tone 1 - severe	22.5000		23.3570
no tone 1 - polar	-10.0000		23.3570
no tone 1 - unclassified	7.50000		28.6063
no tone 1 - monotone	-12.5000		23.3570
acquiring - severe	31.2500		20.2277 *
acquiring - polar	-1.25000		20.2277
acquiring - unclassified	16.2500		26.1139
acquiring - monotone	-3.75000		20.2277
severe - polar	-32.5000		23.3570 *
severe - unclassified	-15.0000		28.6063
severe - monotone	-35.0000		23.3570 *
polar - unclassified	17.5000		28.6063
polar - monotone	-2.50000		23.3570
monotone - unclassified	20.0000		28.6063

* denotes a statistically significant difference.

Table 11 Analysis of variance of unaided threshold at 500Hz by groups

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	2845.8333	6	474.30556	8.067	.0033
Within groups	529.1667	9	58.79630		
Total (corrected)	3375.0000	15			

0 missing value(s) have been excluded.

Multiple range analysis

Method: 90 Percent LSD

Level	Count	Average	Homogeneous Groups			
			A	B	C	D
severe	2	62.50000	X			
acquired	3	83.33333		X		
unclassified	1	85.00000	X	X		
no tone 1	2	92.50000	X	X	X	
polar	2	97.50000		X	X	
acquiring	4	102.50000			X	
monotone	2	105.00000				X

contrast	difference	+/-	limits
acquired - no tone 1	-9.16667		12.8346
acquired - acquiring	-19.1667		10.7382 *
acquired - severe	20.8333		12.8346 *
acquired - polar	-14.1667		12.8346 *
acquired - unclassified	-1.66667		16.2347
acquired - monotone	-21.6667		12.8346 *
no tone 1 - acquiring	-10.0000		12.1760
no tone 1 - severe	30.0000		14.0596 *
no tone 1 - polar	-5.00000		14.0596
no tone 1 - unclassified	7.50000		17.2195
no tone 1 - monotone	-12.5000		14.0596
acquiring - severe	40.0000		12.1760 *
acquiring - polar	5.00000		12.1760
acquiring - unclassified	17.5000		15.7192 *
acquiring - monotone	-2.50000		12.1760
severe - polar	-35.0000		14.0596 *
severe - unclassified	-22.5000		17.2195 *
severe - monotone	-42.5000		14.0596 *
polar - unclassified	12.5000		17.2195
polar - monotone	-7.50000		14.0596
monotone - unclassified	-20.0000		17.2195 *

* denotes a statistically significant difference.

Table 12 Analysis of variance of unaided threshold at 1000Hz by groups

Means plot: Conf. Int. Confidence level: 90 Range test: LSD

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	1689.5833	6	281.59722	2.639	.0924
Within groups	960.4167	9	106.71296		
Total (corrected)	2650.0000	15			

0 missing value(s) have been excluded.

Multiple range analysis

Method: 90 Percent LSD

Level	Count	Average	Homogeneous Groups	
			A	B

severe	2	77.50000	X	
polar	2	95.00000	X	X
acquired	3	98.33333		X
no tone 1	2	100.00000		X
unclassified 1	1	100.00000	X	X
monotone	2	107.50000		X
acquiring	4	111.25000		X

contrast	difference	+/-	limits
acquired - no tone 1	-1.66667		17.2909
acquired - acquiring	-12.9167		14.4666
acquired - severe	20.8333		17.2909 *
acquired - polar	3.33333		17.2909
acquired - unclassified	-1.66667		21.8714
acquired - monotone	-9.16667		17.2909
no tone 1 - acquiring	-11.2500		16.4036
no tone 1 - severe	22.5000		18.9412 *
no tone 1 - polar	5.00000		18.9412
no tone 1 - unclassified	0.00000		23.1982
no tone 1 - monotone	-7.50000		18.9412
acquiring - severe	33.7500		16.4036 *
acquiring - polar	16.2500		16.4036
acquiring - unclassified	11.2500		21.1769
acquiring - monotone	3.75000		16.4036
severe - polar	-17.5000		18.9412
severe - unclassified	-22.5000		23.1982
severe - monotone	-30.0000		18.9412 *
polar - unclassified	-5.00000		23.1982
polar - monotone	-12.5000		18.9412
monotone - unclassified	7.50000		23.1982

* denotes a statistically significant difference.

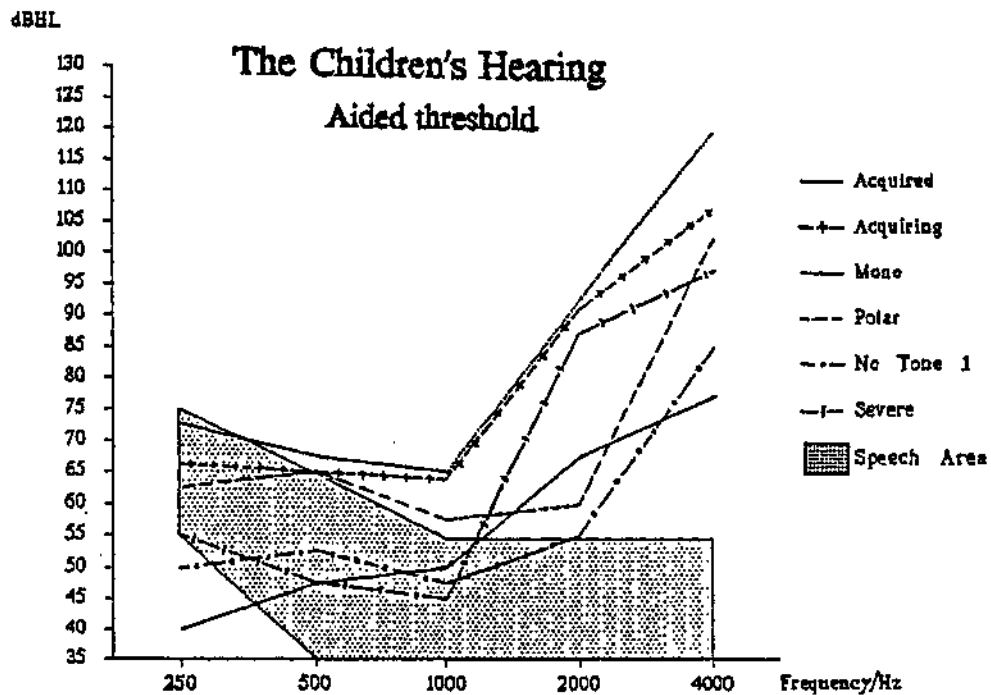


Figure 17 The aided thresholds of the hearing impaired children

However, the profoundly hearing impaired children differs from each other by aided thresholds (see figure 17). The thresholds of the severely impaired, acquired and the no tone 1 group were lower than the other three groups at low frequencies. The thresholds of 250 Hz (table 13), 500 Hz (table 14) and 1000 Hz (table 15) were in the speech spectrum. From one way analysis of variance, the acquired group is significantly differs from acquiring, polar and monotone at 250, 500 and 1000 Hz and the severely impaired, acquired and no tone 1 groups are homogeneous (homogeneous group A in the analysis of variance).

Discussion

Overall Performance

Generally speaking most of these hearing impaired children were acquiring tones at different rates. As in Tse's study (1977), tone 1 and tone 6 were the earliest tones acquired (Stage I). This matches the result that the productions and the accuracy scores here for these tones were the highest. Tone 3 is a mid level tone. It is in between tone 1 and tone 6. The number of realizations and accuracy score for it in this study was lower than for the other two level tones. Possibly the level tones were acquired first because they do not require changing of the vocal cord tensions to change the

Table 13 Analysis of variance of aided threshold at 250 Hz by groups

Means plot: Conf. Int. Confidence level: 80 Range test: LSD

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	1696.2500	6	282.70833	1.977	.1830
Within groups	1143.7500	8	142.96875		
Total (corrected)	2840.0000	14			

1 missing value(s) have been excluded.

Multiple range analysis

Method: 90 Percent LSD

Level Count Average Homogeneous Groups
A B C

acquired	2	40.000000	X		
unclassified 1	1	45.000000	X	X	
no tone 1	2	50.000000	X	X	
severe	2	55.000000	X	X	X
polar	2	62.500000		X	X
acquiring	4	66.250000		X	X
monotone	2	72.500000			X

contrast		difference	+/-	limits
acquired	- polar-low	-10.0000		22.2403
acquired	- acquiring	-26.2500		19.2606 *
acquired	- severe	-15.0000		22.2403
acquired	- polar	-22.5000		22.2403 *
acquired	- unclassified	-5.00000		27.2387
acquired	- monotone	-32.5000		22.2403 *
no tone 1	- acquiring	-16.2500		19.2606
no tone 1	- severe	-5.00000		22.2403
no tone 1	- polar-hi	-12.5000		22.2403
no tone 1	- unclass	5.00000		27.2387
no tone 1	- monotone	-22.5000		22.2403 *
acquiring	- severe	11.2500		19.2606
acquiring	- polar	3.75000		19.2606
acquiring	- unclassified	21.2500		24.8654
acquiring	- monotone	-6.25000		19.2606
severe	- polar	-7.50000		22.2403
severe	- unclassified	10.0000		27.2387
severe	- monotone	-17.5000		22.2403
polar	- unclassified	17.5000		27.2387
polar	- monotone	-10.0000		22.2403
unclassified	- monotone	-27.5000		27.2387 *

* denotes a statistically significant difference.

Table 14 Analysis of variance of aided threshold at 500Hz by groups

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	1040.0000	6	173.33333	2.133	.1586
Within groups	650.0000	8	81.25000		
Total (corrected)	1690.0000	14			

1 missing value(s) have been excluded.

Multiple range analysis

Method: 90 Percent LSD

Level Count Average Homogeneous Groups
A B

acquired	2	47.500000	X	
severe	2	47.500000	X	
unclassified	1	50.000000	X	X
no tone 1	2	52.500000	X	X
acquiring	4	65.000000		X
polar	2	65.000000		X
monotone	2	67.500000		X

contrast	difference	+/-	limits
acquired - no tone 1	-5.00000		16.7661
acquired - acquiring	-17.50000		14.5198 *
acquired - severe	0.00000		16.7661
acquired - polar	-17.50000		16.7661 *
acquired - unclassified	-2.50000		20.5342
acquired - monotone	-20.00000		16.7661 *
no tone 1 - acquiring	-12.50000		14.5198
no tone 1 - severe	5.00000		16.7661
no tone 1 - polar	-12.50000		16.7661
no tone 1 - unclassified	2.50000		20.5342
no tone 1 - monotone	-15.00000		16.7661
acquiring - severe	17.50000		14.5198 *
acquiring - polar	0.00000		14.5198
acquiring - unclassified	15.00000		18.7450
acquiring - monotone	-2.50000		14.5198
severe - polar	-17.50000		16.7661 *
severe - unclassified	-2.50000		20.5342
severe - monotone	-20.00000		16.7661 *
polar-hi - unclassified	15.00000		20.5342
polar-hi - monotone	-2.50000		16.7661
mono tone - unclassified	17.50000		20.5342

* denotes a statistically significant difference.

Table 15 Analysis of Variance of aided threshold at 1000Hz by groups
Means plot: Conf. Int. Confidence level: 90 Range test: LSD

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	899.58333	6	149.93056	8.344	.0043
Within groups	143.75000	8	17.96875		
Total (corrected)	1043.3333	14			

1 missing value(s) have been excluded.

Multiple range analysis

Method: 90 Percent LSD

Level	Count	Average	Homogeneous Groups		
			A	B	C

severe	2	45.000000	X		
no tone 1	2	47.500000	X		
acquired	2	50.000000	X	X	
unclassified	1	50.000000	X	X	
polar	2	57.500000		X	X
acquiring	4	63.750000			X
monotone	2	65.000000			X

contrast		difference	+/-	limits
acquired	- no tone 1	2.50000		7.88458
acquired	- acquiring	-13.7500		6.82825 *
acquired	- severe	5.00000		7.88458
acquired	- polar	-7.50000		7.88458
acquired	- unclassified	0.00000		9.65660
acquired	- monotone	-15.0000		7.88458 *
no tone 1	- acquiring	-16.2500		6.82825 *
no tone 1	- severe	2.50000		7.88458
no tone 1	- polar	-10.0000		7.88458 *
no tone 1	- unclassified	-2.50000		9.65660
no tone 1	- monotone	-17.5000		7.88458 *
acquiring	- severe	18.7500		6.82825 *
acquiring	- polar	6.25000		6.82825
acquiring	- unclassified	13.7500		8.81523 *
acquiring	- monotone	-1.25000		6.82825
severe	- polar	-12.5000		7.88458 *
severe	- unclass	-5.00000		9.65660
severe	- monotone	-20.0000		7.88458 *
polar	- unclass	7.50000		9.65660
polar	- monotone	-7.50000		7.88458
unclassified	- monotone	-15.0000		9.65660 *

* denotes a statistically significant difference.

fundamental frequency during the phonation. In other words, they are physiologically easy to control and produce. Tone 3 requires better control of the vocal cord tension that must not as tense as tone 1 but not as loose as tone 6. Because the skill required is finer, it is acquired later.

According to Tse (1977), the rising tones acquired later at Stage II and III. This matches with the present result that the accuracy scores and the number of realizations were lower than the level tones. Physiologically, they are harder tones than the level tones. They require changing of vocal cord tensions during phonation, not just maintain the tensions as level tones. When children had better control of their vocal cord, they can change the pitch during phonation. Then they can produce tones of changing contour, i.e. rising and falling tones, and can produce two syllables of different pitches continuously, i.e. a disyllabic word or a two word utterance. This is a possible reason why these tones appear at the end of one word stage and the beginning of two word stage.

Tone 4 was the lowest one both in accuracy score and number of realizations. This reflects that it may be the hardest tone for these children. This matched Tse's study that Tone 4 was acquired in Stage III. This result does not agree with Ching's (1984) study showing that tone 4 was acquired first. In her study, tone 4 was the least confusing tone. This may be because tone 4 is the only falling tone among the six tones. It is distinct from the other five because there is no other falling tone in the Cantonese tone system, and therefore it is less confusing with other tones. However the contour of tone 4 is 21 and the contour of tone 6 is 22. The production of tone 4 may be harder in sense that it requires the child to breakthrough the lower limit, tone 6, to an even lower pitch, that is to extend the lower limit from contour level 2 to 1.

These children often substituted level tones, especially tone 1 and 6. This may be because these two tones are acquired first and children use them skillfully. Tone 3 is the acquired after tone 1 and 6 so it is the third popular tone for substitution.

Being young and language delayed, most children not in the acquired and the severely impaired groups finished the task by modelling. This give them opportunities to imitate tones during the task and their abilities of tone production may be over estimated. However, the accuracy scores show that tones are not easy to imitate because nobody scored full marks and many of them scored low even when models were provided. The average score was 46.83%. This implies that they need more aid other than models and

more time to acquire the tones.

Relation of tone production and hearing

From the results, the acquired group have significantly lower aided thresholds from 250 Hz to 1000 Hz. In fact, this group has the lowest threshold at 250 and 500 Hz. They can hear tone sufficiently clearly in normal situation and have sufficient feedback on their own tone production. This can explain this group getting the highest score. Similar scores obtained for the severely impaired group whose aided thresholds are homogeneous with the acquired group. On the other hand, the other groups (acquiring, polar and monotone) were significantly poorer than the acquired and the severely impaired group, and their scores were lower than the best two groups. The monotone group is the poorest aided group at low frequency. The threshold of 250 Hz was barely in the speech area and the threshold of 500 Hz was out of it. They did not hear tones from others or feedback from their own clearly. This can explain why their tone productions were the poorest in this study.

A conclusion can be drawn that the hearing threshold at low frequencies is an important factor affecting the acquisition of tones. The lower the threshold, then higher the probability that the hearing impaired children can acquire tones. Therefore the amplification at low frequency is very important. In prescribing hearing aids, audiologists ought to give much amplification at low frequency as possible as it benefits tone acquisition. However, hearing at low frequency is not the only limited factor, because not all children having sufficient hearing ability can acquire tones, e.g. the no tone 1 group. Other factors such as hearing age, amount of language stimulation may affect tone acquisition. Such factors have been investigated in acquisition of English (Ling, 1976 & 1984). The effects of these factors in acquisition of Cantonese need further investigation.

Performance of each group

Some profoundly hearing impaired children can acquired tones. This can be shown from the score of the acquired group. The acquiring and the polar group match the tone acquisition Stage II and III (Tse, 1977). These children may be developing their tonal system. This indicated that the acquisition of tone in hearing impaired children may follow the same sequence as normal Cantonese children. One must bear in mind that these children's aided thresholds were not as good as the acquired group's and the

development of their tonal systems may be hindered. They may continue the development as normals do, but they may not sustain development or it may even degenerate. These children need continual monitoring and maybe other aids to help up the acquisition.

The tonal pattern of the remaining two groups , the no tone 1 and the monotone groups, may reflect difficulties that they meet in tone acquisition. One characteristic of deaf speech comes from that deaf speakers having difficulty in controlling their voice. (Parkhurst & Levitt, 1978). Their fundamental frequency can be higher or lower than normal perceptually (Subtelny, Whitehead, & Orlando, 1980; Whitehead, 1987) Their frequency range is narrower than normal (Hood & Dixon, 1969). These two phenomena are indicated in the productions of these groups of children.

For the monotone group, their frequency range had limitations, so they could not give listener a sense of different levels of starting pitch. Therefore the realizations are often at one pole: either the high pole, tone 1 or the low pole, tone 6 and some tone 5.

For the no tone 1 group, their fundamental frequency was sometimes below mean with a limited range from contour level 2 to 3. Because of this, they give listener a sense of low starting pitch. The pitch contour of tone 1, 55, is out of their range so the number of realizations realizations of tone 1 was low.

These hypotheses need confirmation by instrumental analyses of their fundamental frequency and frequency range.

Indication from inter-rater reliability

The raters were reliable in accuracy scoring, shown by the Kendell's coefficient of concordance, but they were not reliable in giving realizations that only 31.35% among the productions, the raters have the same realizations. These difficulties may arise from errors in perception among the raters or the instability of the pitch in production. In Ching's study (1984), the highest mean score of discrimination of normal speech was 89.17% made by children aged 10. Therefore we can expect the raters' perceptions in this study may not be perfect.

As we know that hearing impaired children may have difficulty in controlling phonation due to reduction of auditory stimulation and feedback, some abnormalities in their tone productions were expected. The pitch contour patterns produced may not the same as the pitch contour pattern of the six tones in Cantonese. The raters used their

linguistic competence to fit the pitch patterns produced into one of the six tones, and different raters may have different interpretations to these abnormal speech pattern. These patterns may be abnormal in fundamental frequency contour, or in higher formant frequency. In order to confirm and further investigate the abnormality of these pitch contour patterns, further analyses of their productions by instrumentation are needed.

Conclusion

This study has shown that profoundly hearing impaired children can acquire tones following the normal developmental sequence. The success is related to the aided thresholds at low frequency. At the same time, some of these children have difficulties in tone productions. These children need help from speech therapists, audiologists, teachers and other professionals in order to acquire tone properly. Some hypotheses have been made to explain the sequence and the difficulties and these hypotheses need further confirmation by further research .

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