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Lexical tone in non-fluent Chinese-speaking aphasics

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Lexical Tone in Non-Fluent Chinese-Speaking Aphasics

by

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Abstract

LEXICAL TONE IN NON-FLUENT CHINESE-SPEAKING APHASICS

by

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Studies of Western languages have suggested that language abilities are functions of the left hemisphere while non-linguistic abilities such as tone appreciation are functions of the right hemisphere. However, in tone languages, tone is a phoneme can distinguishes among lexemes. Thus this "melodic" element plays a linguistic role. Aphasia studies with speakers of tonal languages have suggested that like segmental language phenomena, tone is also subject to deficit following damage to the left hemisphere. The purpose of this study was to assess the ability of aphasic speakers of Toisanese Chinese to perceive and produce lexical tone. Normal native speakers and non-fluent aphasic speakers of Toisanese participated in single syllable word production and perception tasks. Word productions from both speaker groups were subjected to acoustical measurements of various

parameters of pitch contour and to a native listener word identification task. Values for F0 height and tone duration were obtained from the acoustical measurements. Accuracy scores from native listeners' responses to single word productions were derived; these scores indicated the success of speakers' attempts to signal lexical tone. Confusion matrices were constructed to observe possible patterns of tone confusion. While no statistically significant effects or variables were noted, a closer analysis of individual speakers' data revealed that although aphasic speakers attempted to distinguish among the five tones of Toisanese, these attempts were not readily perceived by native listeners. Moreover, these is a pattern of confusion among the tones of Toisanese in addition to uneven levels of perceptibility among these tones. Findings also revealed that there is difficulty in the perception of lexical tones among aphasic speakers and to a lesser degree, among normal, native listeners.

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INTRODUCTION

Research on language production of aphasic speakers clearly describes the types of deficits typically encountered - including syntactical, morphological, phonological and lexical losses as well as disturbances in the articulation of speech. However, for the most part, these investigations have dealt primarily with speakers of English - a non-tone language, so that information gathered from these studies cannot necessarily be generalized to speakers of other languages - such as tone languages.

From a theoretical perspective, the notion that melody, typically considered a right hemisphere function, is used in tone languages as a linguistic elements, serves as a basis for experimental study. Earlier neurolinguistic studies of tone production following brain damage to speakers of Thai and in speakers of Mandarin Chinese describe some tone disintegration but without acoustical information on aphasic productions to substantiate perceptual judgments. Only recently did researchers begin to use objective acoustical measurements in attempts to explain listener's judgment of lexical tone productions (Gandour, Petty and Dardarananda, 1988 and Gandour, Ponglorpisit, Khunadorn, Dechongkit, Boongird, Boonlam and Potisuk, 1992). Clinical observations and practical experience also suggest that there are aphasic speakers of Toisanese Chinese who demonstrate some type of lexical tone disruption in both production and perception.

The purpose of this study was to observe the effect of left hemisphere damage on the production and perception of lexical tone. Specifically, there was interest in observing distortions of tone production from an acoustic perspective and studying the extent to which these differences can lead to misperceptions of tone in native listeners. In addition, there was interest in observing whether or not difficulties in lexical tone perception existed and whether or not these difficulties were predictable. As these issues are resolved, this information should serve both diagnostic and therapeutic purposes in work with aphasic speakers of tonal languages. Realizing the presence of tonal deficits would lead to the development of intervention approaches to address them. This study has focused specifically on Toisanese Chinese since it is the dialect of the elder Chinese population in the established Chinatown communities in the United States.

To set the context of this study, I have provided a review of the literature with respect to the Toisanese dialect and its tone system; tone perception; and neurolinguistic studies of tone production. This review is followed by a description of the present study, its findings and results and a discussion of these findings.

REVIEW OF THE LITERATURE

Historical Context: T'ai Chan and the Toisanese

At the end of the last century, Toisanese men, in search of better living standards, turned to America, the land of opportunity. Having heard of the riches mined from the land, young men made long and treacherous journeys to America. These pioneers arrived on the shores of the United States, dubbed as the "Golden Mountain," to mine for gold. The first immigrants worked diligently - making sure to save and send their earnings home to loved ones. Unfortunately, many of these men were quite young - often leaving behind them recent wives and young children. The hope of someday returning and being reunited with their loved ones kept morale high. However, many of these workers never got to see their families again. Since they had spent most of their adult lives in this country, their familial ties were long severed. Even for those who did have the opportunity to reunite with family members, there was little sense of "family."

To make the best of the situation, the Toisanese banded together for social, cultural, linguistic, economic and emotional purposes. The natural gathering of these Toisanese speakers laid the foundation for those long standing Chinatown communities across the country, i.e., New York, San Francisco, Washington, Boston and Philadelphia. Since the arrival of the first immigrants from the Toisan region at the end of the last century, there has been a steady influx of Chinese from that region. At that time, only Chinese persons with relatives in the United States were allowed to enter and settle in this country, so that prior to dramatic changes in the US immigration laws in 1965, approximately 75% of the Chinese American population in New York City were Toisanese speakers. In 1965, the immigration laws were changed so that any Chinese person would be allowed to immigrate to this country. Presently, approximately 40% of the Chinese American population of New york City speak Toisanese, (V. Lee, personal communication, June, 1991). Today, Toisanese is still spoken among the "elders" in all of these Chinatown communities. Yet, despite the fact that Toisanese has been the "lingua franca" of the early immigrants, there are few studies of this Cantonese dialect.

The SyeYap (四邑) region of China is located in the South, approximately 120 miles southwest of Canton. Measuring approximately 50 miles from North to South and 70 miles from Eat to West, this mountainous area is divided into four districts: they are T'ai Shan (台山), Hoi Ping (開平), Yin Ping (恩平) and Sun Wei (新會). Within each district, there are a number of villages. Toisanese, a dialect of Cantonese, is spoken throughout the SyeYap Region. Among the villages, there is a great deal of variation among the Toisanese subdialects spoken. For example, the Nam Chuen community and the Bak Shek community are approximately 2 miles apart, but one group uses /tɬ/ (a lateral affricate initial) in some contexts whereas the other uses /k/ (a velar stop initial). McCoy (1966) recognized many such communities within each of the four SyeYap districts where each community has a speech pattern which is slightly different from the next. Realizing subtle speech/language differences among these communities is important in a systematic study of Toisanese. Variations in the pronunciation of words distinguish among the dialects of Toisanese. Though there may also be differences in tonal patterns, this issue has not been addressed by any writer to date. In this study, the issue has been addressed by pairing each aphasic subject with a normal control subject who has had similar linguistic and cultural experiences. Table 1 is a listing of the communities in the SyeYap region and Figure 1 is a map of the four regions of SyeYap.

The Chinese Language

In Cheng's (1973) survey of the Chinese language and its dialect families and dialects, she reported that there are eleven dialect families in the language: Northern Mandarin, Xiang, Southwestern Mandarin, Easter Mandarin, HuiZhou, Wu, Gan, Hakka, Cantonese (Yue), Northern Min and Southern Min. Under each of these families are a number of different dialects which are classified based on the sound systems of the dialect and the dialect families.

Bodman (1967) observed the rather causal usage of the term "dialect" in referring to variations in the Chinese language and pointed out that "Chinese usage commonly has 'dialect' in a loose as well as in a more precise sense. Loosely used, it refers to regional speech which should properly be called 'language', such as Mandarin, Wu, Hakka, etc. Stricter usage refers to Mandarin dialects, the Peking

Table 1. Major communities in the SyeYap Region.

T'ai Shan:	Kung Yik	Chung Lau	Kwong Hoi
	Tik Hoi	Chung Won	Hoi An
	Tai Ling	Na Tai	Nam Chuen
	Pak Shek		
Hoi Ping:	Hoi Sum	Wu Chung	Chek Ham
	Hin Kong	Pak Sha	Chek Shui
Yun Ping:	Shuen Kok		
Sun Wei			


開平
新會
恩平
台山
N

dialect, etc." DeFrancis (1984) provided clarification and simplification of this system by referring to the outcome of the Technical Conference on the Standardization of Modern Chinese in Peking in 1955 and using a more concise distinction between dialect family and dialect. Simply stated, DeFrancis used the terms regional speech or regiolect to refer to the speech pattern of a specific region of China; these are, as a rule, mutually unintelligible. The term dialect is then reserved to use in referring to subvarieties of regiolects which are more or less mutually intelligible.

Lexical Tone

The Phonology Archives Project (PAP) at Stanford University reported that approximately 30% of the world's languages are considered to be tonal (Hombert, 1977). More specifically, if languages within language families are considered - such as Cantonese, for example, - then this figure is closer to 50%. In this article, Hombert provided an approximate count of the distribution of tone systems as a function of the number of tones in each system. Approximately 30% of tone languages have 2 tones; another 30% have 3 tones. There are approximately 15% of tone languages that have 4 tones and 10% of tone languages have 5 tones. Languages that world's tonal languages. As for specific types of tones within languages, a high tone and a low tone constitute 90% of all two-tone systems. Sixty five percent of the three-tone systems consist of a high tone, a mid tone and a low tone. In the four-tone systems, 40% of these systems consist of a high tone, a low tone, a rising tone and a falling tone while 30% of these systems have a high tone, a mid tone, a low tone and a falling tone. Sixty percent of the five-tone systems consist of a high tone, a mid tone, a low tone, a falling tone and a rising tone and 60% of the six-tone systems consist of two level tones (low tone and mid tone); two falling tones (mid-low tone and high-mid tone); two rising tones (mid-high tone and low-mid tone).

Across dialects, tone is an integral part of Chinese words; it is as phonologically relevant as consonants and vowels. Tone is the pitch level and pitch contour at which individual syllables are uttered. It is used to make lexical distinctions in tonal languages such as Chinese. Chao (1970)'s graphic system incorporates the dimensions of time and pitch within a set of relative numbers, 1-5, to describe tone. Numbers are used to describe relative height. In any tonal language or dialect (as in the case of Chinese) where the tone system has been identified, tone graphs can be sued to describe the system. Of importance to bear in mind is that lexical tone is relative to a particular dialect. That is to say, a high level tone in one dialect is not necessarily the same, acoustically speaking, in a different dialect. Chao (1970) offers examples from mandarin; Cheng (1973) offers examples from Toisanese and Ramsey (1987) offers examples from Cantonese.

MANDARIN Tone:Graph:Level:Description:Example:Gloss:Referent

Tone	Graph	Level	Description	Example	Gloss	Referent
1	˥	55	high level	媽	/ma/	mother
2	˧˥	35	rising	麻	/ma/	hemp
3	˨˩˥	315	dipping	馬	/ma/	horse
4	˥˩	51	falling	罵	/ma/	scold

TOISANESE Tone:Graph:Level:Description:Example:Gloss:Referent

Tone	Graph	Level	Description	Example	Gloss	Referent
1	˥	55	high level	口	/hau/	mouth
2	˧	33	mid level	孝	/hau/	filial piety
3	˩	11	low level	頭	/hau/	head
4	˧˩	31	mid falling	後	/hau/	behind
5	˩	10	low falling	厚	/hau/	thick

CANTONESE

Tone	Graph	Level	Description	Example	Gloss	Referent
1	˥˧	53	high high	詩	/si/	poem
2	˨˩	21	low low	時	/si/	time
3	˧	33	mid high	試	/si/	exam
4	˨	22	mid low	事	/si/	matter
5	˧˥	35	high rise	史	/si/	history
6	˨˧	23	low rise	市	/si/	city

As illustrated, lexical differentiation can be signaled by the pitch contour on which a syllable is uttered. That is, different pitch contours signal lexical differences among the members of a minimal set. This suprasegmental feature of syllables allows the same segmental string to have different referents, depending on the tone that is used. In this study, I took advantage of this phenomenon by selecting stimuli that share the same segmental string but are distinguished by lexical tone.

Tones in Toisanese

Four methodical studies have been conducted to describe the tonal system of Toisanese; each offered a slightly different analysis though the individual tones identified are virtually the same. Table 2 summaries the information from these analyses. Wong accounted for the use of the "0" level as an extension of Chao's basic levels by pointing out that in Toisanese, unlike Mandarin (which is the dialect Chao's system was initially based upon), these exists a level that is lower than the low tone in Mandarin. Wong provided these contrasting examples in Toisanese:

麻 /ma/ 11 hemp and 馬 /ma/ 10 horse

頭 /hau/ 11 head and 厚 /hau/ 10 thick

Cheng (1973) identified the same tones but instead of accounting for the extra low tone on the bottom of the scale, she proposed that an extra level is added to the tope of the scale.

Additionally, Cheng reported that not all tones have the same duration. By extracting fundamental frequency contours on a LINC-8 computer system in the Phonology Laboratory at the University of California at Berkeley, Cheng observed that the longest tone was Tone 2, followed by Tone 1, Tone 3, Tone 5 and then Tone 4. Level tones do not overlap in terms of pitch range. Similarly, falling tones do not overlap nor do the falls have identical slopes.

Table 2. Variations on the tonal system of Toisanese.

	Tone	Graph	Level	Description
Yiu (1946)	1	˥	55	high even
	2	˧˥	35	high rising
	3	˧	33	mid even
	4	˨	22	mid low even
	5	˩	11	low even
McCoy (1968)	1	˥	55	high level
	2	˧	33	mid level
	3	˩	11	low level
	4	˧˨	32	mid falling
	5	˨˩	21	low falling
Wong (1970)	1	˥	55	high level
	2	˧	33	mid level
	3	˩	11	low level
	4	˧˩	31	mid falling
	5	˩	10	low falling
Cheng (1973)	1	˥	66	high even
	2	˧	44	mid even
	3	˨	22	low even
	4	˥˨	52	mid falling
	5	˧˩	31	low falling

The Perception of Tone

The early work with tonal languages focused on the perception of tone by normal listeners. Many of these works were conducted in Thai, a tonal language with five different tones. Abramson (1962) described the tones of this language as consisting of three static tones (high, mid and low) and two dynamic tones (falling and rising). Specifically, static tones were those which did not have a perceptible change in fundamental frequency over time while dynamic tones have a discernible, abrupt change in fundamental frequency.

With regard to the accuracy of this dichotomy, Abramson (1978) created tone variants of the Central Thai tones using a formant synthesizer. Fundamental frequency (F0) levels and amount of F0 movement over time were manipulated and imposed on the syllable [kha:]. Recording of these syllables were made and presented to native listeners in a tone identification task. Results indicate that F0 level does carry sufficient information for identification of static tones and that accuracy of identification improved with F0 movements. In addition, listeners were also observed to be sensitive to abrupt movement of the F0 as these tokens were identified as dynamic tones. This work suggested that static tones are not truly static in that there is some movement of F0 over time in tones which were traditionally considered static; the amount of movement serves as a cue to distinguishing between static and dynamic tones.

Lin and Repp (1989) manipulated two features of tone, namely, F0 height and F0 movement, in order to assess the relative saliency of these features to native speakers. In this recent study, the researchers worked on Taiwanese Chinese, a dialect which has a five-tone system: high level (Tone 1), mid level (Tone 5), high falling (Tone 2), mid falling (Tone 3) and low rising (Tone 4) (Zee, 1978; Lin and Repp, 1989). Results indicate that F0 height is used to distinguish among tones with similar contours but different pitch levels, while F0 movement is used to distinguish among tones with different contours. Lin and Repp reasoned that since there are more dynamic tones in Taiwanese, awareness of F0 movement is heightened. The work of Gandour (1981) is cited in support of this notion as his work focused on Cantonese speakers and found that in this Chinese dialect where four of the six lexical tones are dynamic, native listeners rely relatively more on F0 contour than on F0 height as compared to speakers of Mandarin or Taiwanese Chinese.

In natural context, tones rarely appear in citation form. That is, syllables usually occur in context where listeners have the opportunity to utilize available context cues to facilitate comprehension. Working with native Thai speakers and listeners, Abramson (1976) investigated the role of knowledge of a speaker's tonal space in identifying tones of Central Thai. Five men and five women recorded a set of words differing only in lexical tone. These recordings were then presented to native listeners under two conditions: a composite task and an individual task. In the composite task, all utterances from all speakers were randomized; in the individual task, the randomized utterances of each speaker were presented in succession. Native listeners were asked to identify each token. Results indicate that accuracy of response increased when listeners had access to each speaker's tone space. Also, results indicated difficulty in differentiating between the mid level tone and the low level tone in the composite task. Abramson speculated that errors were due to relatively small changes in fundamental frequency over time so that the other Thai tones - the high, falling and rising tones with more distinctive contours - were less likely to be confused than were the mid and low level tones. In addition, without the benefits of linguistic context, native listeners do not have access to the speakers' tone space, i.e., the range within which one speaks, which might contribute to the difficulty in distinguishing between two similar tones.

The tendency to confuse tones of a given system is not specific to Thai. In Mandarin, Gandour (1978) reported that the two tones confused by native speakers are Tone 2 (a rising tone with a 35 contour) and Tone 3 (a dipping tone with a 315 contour). Some researchers note that both targets start at the same pitch level and that both have similar directions - which might lead to confusion. Even among normal speakers, there is considerable variation with respect to initial and end points so that neither falling nor rising contour or position of the "dip," i.e., sudden change of fundamental frequency as in Tone 3, serves as a salient cue. Shen and Lin (1991) concluded from their study that in Mandarin, Tones 2 and 3 are cued by the timing of the turning point.

Li and Thompson (1977) note that most errors in the speech of Mandarin speaking children are in the direction of substituting a dipping for a rising tone. Other perceptual studies conducted in Mandarin also indicate confusion among tones of this Chinese dialect. Kiriloff (1969) found that adult learners of Mandarin made more errors perceiving rising and dipping tones (Tones 2 and 3) than high and falling tones (Tones 1 and 4). There was a marked tendency to confuse rising and dipping tones in identification tasks. Ohala and Ewan (1973) reported that one can execute a falling pitch faster than a rising one due to the physiological effort needed to raise pitch. They found that speakers of Mandarin Chinese can produce falling pitch over a given pitch interval faster than a rising pitch over the same interval. Also, they noted that when tone is produced faster, speech becomes a better contrast among tones and so this variable becomes a perceptual cue. However, native listeners do not appear to be using rate of production as a salient perceptual cue as indicated by their confusion of Tones 2 and 3.

In sum, there is a degree of confusion between certain tones on certain tasks among speakers of tonal languages and dialects. Linguistic environment, speakers' tone range, manner of presentation, etc. may serve to influence the perception of tone. That is to say, there is a relatively stable and observable tone system in different tone languages but under certain conditions, tonal confusions might be observed.

Neurolinguistic Considerations

Production of Suprasegmental Features in Aphasia

Speculative notions regarding the influence of the left hemisphere over such features as intonation contours and lexical tones have led to two extensive investigations with English speaking aphasics. Danly and Shapiro (1982) found that their non-fluent aphasic subjects had a very narrow range in linguistic planning. That is to say, these aphasics seemed unable to plan suprasegmental productions over longer utterances. The investigators reasoned that awareness of sentence length and sentence contour was prerequisite to planning sentence contour. For example, there were "peak-to-valley" changes in fundamental frequency on the final word of lengthier sentences in normal speakers. However, the aphasic speakers failed to execute such changes. Danly and Shapiro attributed the lack of "peak-to-valley" changes to the speaker's inability to appreciate the length of his utterance prior to production. Curiously, when the subjects' productions were carefully examined on a word level (where words were extracted from context), there was more fluctuation of fundamental frequency as compared to productions made by non-brain damaged speakers. This discrepancy supports the notion that size of the linguistic unit has influence on the production of fundamental frequency. This finding was later supported by the work of Gandour et al. (1989), in their case study. Using a point-to-point measurement of F0 contour to observe the productions of a native Thai speaker with Broca's aphasia was found to produce slightly higher variability of the F0 contour for the mid and falling tones and slightly lower variability of the F0 contour for the high, low and rising tones when compared to normal speakers.

In a follow-up study, Danly, Cooper and Shapiro (1983) reported that English-speaking Wernicke's aphasics also exhibited difficulty incorporating syntactic limits and speech planning. These subjects were observed to use more continuation rises at minor boundaries; they also had more F0 variability but at the same time failed to use F0 variability to differentiate among different constituent structures. Thus far, these papers suggest that there might be a disturbance in the timing and possibly in the duration of intonation contour that could be probable sources for prosodic disturbance in a non-tonal language following cerebral insult. Ryalls (1982) submitted recordings of sentence productions from eight non-fluent English-speaking aphasics to a spectrographic analysis and reported that for this group, intonation contours were restricted in range and longer in duration as compared to those of the normal control subjects. Using CVC syllables and then measuring the period-to-period variation of the F0 contour, Ryalls (1984) described aphasic productions of the F0 contours as being wider in range than the productions of normal speakers. More interestingly, it was the Wernicke's aphasics who exhibited more period-to-period variability than the Broca's aphasics. More recently, Van Lancker and Sidtis (1992), following their study of the performance of right and left brain-damaged subjects on identification of affective-prosodic stimuli, reported that their two subject groups were responding differently to the acoustic cues that comprise affective-prosodic signals. The researchers suggest that perhaps different properties of these signals are handled by different cerebral systems.

Production of Lexical Tone in Aphasia

Some disturbances in prosody are manifested in the syllable and sentence contours of English-speaking aphasics. Current research seems to suggest that these disturbances are linguistically based. That is to say, none of the aforementioned papers referred to intonation contours as serving an affective, i.e., right hemisphere function. Instead, the disturbances of intonation that have been observed and reported were noted in linguistic environments.

What then, can be observed in lexical tone production by aphasic speakers of tonal languages? In Chinese and other tone languages, the demand on fundamental frequency control is over a very short unit of speech, namely a syllable. Danly and Shapiro and others have demonstrated that various prosodic features of sentence intonation contours are affected following aphasia. Moreover, there is a general consensus that aphasics have difficulty in planning over long linguistic units such as phrases and sentences. Presumably then, when the unit over which fundamental frequency must be controlled is shortened, then the prosodic features of such a unit could be expected to remain intact.

In studies that look at the production of tone in speakers of tonal languages, researchers indeed report deficits in the production of tone. Gandour (1988) reported that in Thai-speaking aphasics, only more severe aphasics demonstrated some type of tone dissolution following cerebral insult. In his case study of a subcortical aphasic Thai-speaker, Gandour (1990) found that the five tones of Thai were unequally spared. Specifically, the falling and rising tones were relatively spared; the high tone was mildly impaired; the mid and low tones were severely impaired. Gandour suggested that F0 contour itself may contribute to a tone's resilience; falling, rising and high tones have more F0 range than the mid and low tones of Thai. That is, perhaps it is the dynamic feature of certain tones that contributes to their resistance to breakdown in aphasia.

A recent study conducted by Gandour et al. (1992) furthered current understanding of tone deficits. In their paper, a comprehensive analysis of lexical tone disruptions following brain damage in Thai-speakers. Their results indicated that left brain damaged speakers' productions of tone were less recognizable by native listeners (as compared to productions of normal, non-brain damaged speakers) and that this level of recognition was related to the severity of aphasia. Additionally, the lexical tones of this language were not equally distorted in aphasics' productions, as some tones were more easily recognized than others. The researchers proposed that the turning point of dynamic tones is a salient cue for tone identification.

This type of a "selective" impairment of tone has also been reported in the literature on Mandarin Chinese speaking aphasics. Naeser and Chan (1981) described a 56 year old tridialectal (Cantonese, Mandarin and FuChowese) woman who presented as a severe Broca's aphasic. On examination, the subject was reported to have difficulty on Mandarin word repetition tasks, particularly with lexical items with Tones 2 or 3 (rising and dipping tone, respectively). Interestingly, these tones are related by tone sandhi - the changing of certain tones in certain tonal contexts - so that lexical tones are not as tightly bound to phonetic strings as, say, those morphemes with tones that are not subject to tone sandhi changes.

Packard (1986), also working with Mandarin speaking aphasics, analyzed responses on a word repetition task and found that Mandarin-speaking Broca's aphasics made both tone and segment errors. Specifically, Packard analyzed the tone errors using a distinctive feature approach and reported that like segmental errors, most tone errors were approximately one "feature" away from the intended target. In his work, Packard viewed tones as being composed of clusters of distinctive features and tone substitution errors could be defined by the distance the production is from the target.

In summary, dissolution of lexical tone in tonal languages following damage to the left hemisphere has been reported for Thai-speakers as well as Mandarin-speakers. Specifically, this disturbance is not uniform across all tones but instead, some tones seem to be less resistant to break-down than others. For example, Tone 2 (rising tone) and Tone 3 (dipping tone) of Mandarin Chinese and the static mid tone and low tone of Thai are more likely to break down as compared to other tones in their respective systems. In addition, Packard's use of a distinctive feature approach offers a systematic process for quantifying these disturbances. His analysis suggests that tonal errors are not randomly committed but rather these errors can be viewed as being "one distinctive feature away" from the target tone.

HYPOTHESIS AND RATIONALE FOR THE STUDY

Existing studies on the dissolution of lexical tone in aphasic speakers of tonal languages have investigated the ability to produce tone, e.g., Gandour, 1990; Gandour and Dardarananda, 1984; Packard, 1986. These researchers reported that productions of lexical tone by non-fluent aphasic speakers deviated from lexical tone productions of normal native speakers. Moreover, not all tones are equally affected as it has been reported that it is dynamic tones that are more affected by aphasia than static tones. This was observed for Mandarin Chinese but vice versa for Thai.

Acoustic studies have demonstrated that F0 contours can deviate from the norm in the speech of non-fluent aphasic English-speakers. Such an analytical and objective approach would be useful in determining whether differences in pitch contours existed between normal speakers and brain-damaged speakers of Toisanese. Pilot data demonstrated that Toisanese-speaking non-fluent aphasics committed errors in tone production as well as in tone perception. This dissertation describes the particular forms of errors and proposes patterns of impairment in this population.

The primary purpose of this study was to investigate the ability of Toisanese Chinese aphasic speakers to make distinctions among lexical tones of their dialect. Secondly, I was interested in whether aphasic speakers are able to perceive lexical/semantic differences signaled by tone differences as compared to their normal counterparts. Thirdly, I was interested in whether acoustic analyses of tone productions correlate with native listeners' perceptions of tone impairment. Lastly, I was interested in presenting more detailed information regarding the nature of Toisanese tones. In particular, I wanted to determine if acoustic evidence gathered could be used to verify any of the various linguists' descriptions of the tones and to learn if there were patterns of confusibility among tones.

Based on the previous research and my own pilot testing, it was hypothesized that non-fluent aphasics would have difficulty in producing lexical tones which would be distinctive enough to be perceived by native listeners. It was also hypothesized that non-fluent aphasics would have difficulty with the perception of tone. Though this has only been anecdotally reported, the author's clinical experiences indicate that there are difficulties in tone perception for the brain-damaged population. As for the acoustic analysis, it was hypothesized that this objective measure would demonstrate aphasics' deficits in tone perception and that these, in turn, would impede normal, native listeners' ability to distinguish among the different tones of this dialect.

METHODOLOGY

Subjects

Ten subjects participated in this study. These subjects were divided into two equal groups: five normal speakers as controls and five aphasic speakers. In each group, there were two male subjects and three female subjects. All subjects were right-handed, native speakers of the Toisanese dialect. The subjects spoke Toisanese in the homes as well as in their job settings. A survey of each aphasic speaker's premorbid language skills was conducted. See Appendix A.

In order to control for dialectal differences among the different regions of the SyeYap Region, each aphasic subject was matched with a relative of the same sex who was fluent in Toisanese; this person served as the control subject from the same region. If such a relative was not available (as in the case of one nursing home resident who participated in this study), a native speaker of the same sex from the same region in Toisan was used. In order to account for possible changes in fundamental frequency over time as a function of the aging process, a native speaker who was as close to the aphasic subject's age was selected whenever possible.

Severity of aphasia for subjects ranged from mild to severe. Each aphasic subject was non-fluent following a single episode of cerebral injury circumscribed to the left hemisphere. Radiology reports for each subject were reviewed to verify site of lesion. Severity of aphasia was determined by each subject's performance on my Toisanese version of parts of the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1983). See Appendix B. The translation of this examination was not standardized; it was administered to identify problem area(s), not for comparative purposes. See Table 3 for the demographic information on subjects.

Each normal control had no neurological impairment or sensory deficits that would preclude his/her participation in this study. Motor speech disorders were screened for by the examiner. No subject presented any evidence of apraxia of speech or dysarthria. Language deficits observed in the aphasic subjects were not in any way the result of a form of dementia; for all aphasic subjects, dementia was ruled out using the Mini-Mental State (Folstein, Folstein and McHugh, 1975) translated to Toisanese for the purposes of this study. See Appendix C. All subjects achieved a score of 27 or better in order to be included in this study. In addition, subjects

Table 3. Demographic Information of Subjects

Subject	Sex	Age	Site of Lesion	Time[1]	Aphasia	Time[2]	MMS[3]
A-1	M	71	L Subinsular hypodensity	13mos	mild	40yrs	30
N-1	M	74	----	---	---	48yrs	-
A-2	F	79	L cerebral infarct	35mos	mod	36yrs	27
N-2	F	35	----	---	---	20yrs	-
A-3	F	62	L basoganglia infarct	6mos	mild	8yrs	28
N-3	F	60	----	---	---	8yrs	-
A-4	F	78	L cerebral hemorrhage	22mos	severe	45yrs	28
N-4	F	74	----	---	---	30yrs	-
A-5	M	59	L basoganglia hemorrhage	8mos	mod	5yrs	29
N-5	M	52	----	---	---	2yrs	-

1-Time Post Stroke
2-Time in USA (that is, amount of time the subject has been away from his/her native land)
3-Mini-Mental State Score (out of 30)

involved in this study were subject to a hearing screening conducted at 40dB from .5K thru 2KHz to rule out severe hearing loss.

A consent form for participation this this study was presented to each aphasic speaker. This form was explained to each speaker in the native language. See Appendix D.

The first aphasic speaker was a 71-year-old, right-handed Toisanese-speaking male whose C-T scan revealed a left subinsular hypodensity. Administration of portions of the Boston Diagnostic Aphasic Examination (BDAE) in Toisanese, revealed mild receptive deficits and mild expressive deficits. Results indicated difficulties in auditory comprehension of complex ideational materials, confrontational naming and overall reduction in sentence length; occasional articulation errors observed in the form of distortions. Since his discharge from the hospital, this subject had received speech/language therapy biweekly, for fourteen months. Intervention had been provided in the native dialect. Because this subject had no surviving siblings, an 74-year-old male who was from the same SyeYap region served as his control speaker. Throughout this study, this pair has been referred to as A-1 (aphasic speaker) and N-1 (normal speaker).

The second aphasic speaker was a 79-year-old, right-handed Toisanese-speaking female whose C-T scan revealed a left sided infarct in Broca's area in June, 1988. She demonstrated adequate receptive language skills and moderate expressive language deficits as assessed on portions of the BDAE. Specifically, she had significant word retrieval problems with occasional articulation errors. Overall length of utterances was reduced. While therapy had been provided for over a two-year period in her native language, progress had been poor, primarily due to her lack of motivation. She is a nursing home resident without any family members except for two granddaughters. One of her granddaughters, age 35, served as her control speaker. This woman was fluent in Toisanese and English. Throughout this study, this pair has been referred to A-2 (aphasic speaker) and N-2 (normal speaker).

The third aphasic speaker was 62-year-old, right-handed Toisanese-speaking female whose C-T scan revealed a left basoganglia infarct. She demonstrated mild expressive language deficits following her stroke, as assessed on the BDAE. Deficits were found in confrontational naming and there was an overall reduction in sentence length. Occasional literal paraphasia was observed in addition to sound distortions. This subject was quite resourceful in using non-verbal gestures to facilitate communication attempts. Although she had not had any speech/language therapy since her stroke, family members reported of a notable level of spontaneous recovery. Her sister, age 56, served as her control speaker. Throughout this study, this pair has been referred to as A-3 (aphasic speaker) and N-3 (normal speaker).

The fourth aphasic was a 78-year-old, right-handed Toisanese-speaking female whose C-T scan revealed a left frontal lobe infarct. She presented with mild receptive deficits and severe expressive deficits as observed on her performance on the BDAE. Testing revealed difficulties in auditory comprehension of commands and complex ideational materials; in addition, output was reduced to single word productions. Difficulties repeating low probability words was noted; automatic speech productions were essentially intact. Despite the availability of speech/language therapy, this subject made minimal progress in therapy. Her control speaker was her sister, a 74-year-old woman. Throughout this session, this pair has been referred to as A-4 (aphasic speaker) and N-4 (normal speaker).

The fifth aphasic was a 59-year-old, right-handed, Toisanese-speaking male whose C-T scan revealed a deep left cerebral hemorrhage. He presented with adequate receptive language skills but moderate expressive language deficits. He had made some progress in therapy and at the time of this data collection, he was still involved in rehabilitation. His control speaker was his brother, a 52-year-old male. Throughout this study, this pair has been referred to as A-5 (aphasic speaker) and N-5 (normal speaker).

Stimuli

The stimulus material for this study consisted of four minimal sets. In each set, all items shared the same string of segmental elements and were differentiated only by lexical tone. A total of 20 words was used. Although word frequency is often a variable that is controlled for in neurolinguistic studies, considering this variable in the development of the stimulus material would have severely limited the number of minimal sets that could have been identified. Therefore, word frequency was not taken into account. See Appendix E.

<u>Tasks</u>

Subjects' Tasks

Each subject was engaged in two different tasks: a Picture Pointing Task (PPT) and a Word Repetition Task (WRT).

Subjects were seen in two separate sessions; sessions were scheduled at least one week apart from each other. The first session consisted of the intake interview, administration of the Mini-Mental State and the PPT. The second session consisted of the WRT.

To assess the subject's ability to focus on tone, each subject participated in the PPT. This task required the subject to point to a picture (photograph) named by the examiner. The words that comprise the twenty items of the four minimal sets described above were depicted in individual photographs. On each trial, the subject was presented with a set of photographs that corresponded to one of the minimal sets. He/she was then asked to point to a specific item. All subjects' responses were manually recorded by the examiner.

For the WRT, all subjects were asked to repeat monosyllabic words spoken by the examiner. The twenty words that comprise the four minimal sets were presented at random. Although only two samples of each utterance were subjected to acoustic and perceptual analyses, each word was presented three times for a total of 60 utterances to assure that there would be at least two samples which could be used for both analyses. All responses were recorded using a Marantz Dolby

System recorder. All recordings were made in a relatively quiet area of the subject's home or hospital room.

Native Listeners' Task

All responses of control and aphasic subjects were audiotaped for a native listener Word Identification Task (WIT). A single tape of each participant's responses was constructed. Each tape was edited using a waveform editing program whereby each utterance was digitized and then stored. After each tape was edited, all utterances were then randomized, resulting in a single tape of all the utterances of all subjects were presented in random order.

The tape was played for five native listeners from the SyeYap Region for the WIT. Native listeners were adult, native speakers of Toisanese who report themselves as having normal hearing. Because this task involved some reading ability, only listeners who had had at least three years of formal education in Chinese (or were able to read the Chinese daily newspaper) were included in this study. Each native listener was given a score sheet on which he/she was instructed to circle the word that she/he thought was spoken. The score sheet itself consisted of 400 lines (10 subjects times 40 utterances per subject). Each line included the word presented on the tape along with the corresponding minimal set for that particular word.

Analysis

All of the subjects' verbal responses were subjected to a perceptual rating by native listeners via the WIT. These responses were also analyzed acoustically with MacSpeech Lab (MSL), a speech analysis program for the Macintosh computer. This program allowed for the recording, viewing, analyzing, editing and printing of speech data. Utterances put into memory were digitized and displayed as waveforms.

For acoustical analysis of tone contour, the F0 contour of each response was extracted for several measurements. First, the duration of the contour was defined and measured as the time of the vocalic portion of each response. With respect to syllable final nasals, only a continuous trace was considered representational of tone. The time between the onset and offset of each pitch contour was recorded in milliseconds. Secondly, a total of five points: onset, 25%-, 50%-, 75%- of the contour and offset, was identified. Finally, the frequency at each of these points along the pitch contour of each utterance was measured to describe the contour of each tone.

Statistical Treatment of the Data

Using the SPSSX Information Analysis System, different analyses of variance (ANOVA) were performed for each speaker's productions of lexical tone.

RESULTS

While most of the literature has described the five lexical tones of Toisanese by using auditory information, this study provided the acoustical information to complement previous reports. Recall that five distinctive tonal patterns have been reported in this dialect: three static tones, namely, Tones 1, 2 and 3, and two dynamic tones, namely, Tones 4 and 5. Though acoustic analysis confirms these descriptions for Tones 2, 3, 4 and 5, these analyses demonstrate that the High Level Tone (Tone 1), is better described as a "high rising" tone because in both groups of speakers the frequency at the onset of the tone is consistently lower than at the end of the tone; the normal speakers, on average, start at 172Hz and end at 193Hz. The aphasic speakers, on average, start at 180Hz and end at 193Hz; see Figures 2 and 3, respectively. A previously reported phenomenon - that the durations of the tones are different - is substantiated by both groups of speakers. See Table 4.

Native Listeners' Data

The responses of native listeners on the Word Identification Task (WIT) to both the normal and aphasic speaker groups were recorded and analyzed to determine whether or not there are intelligibility differences in the production

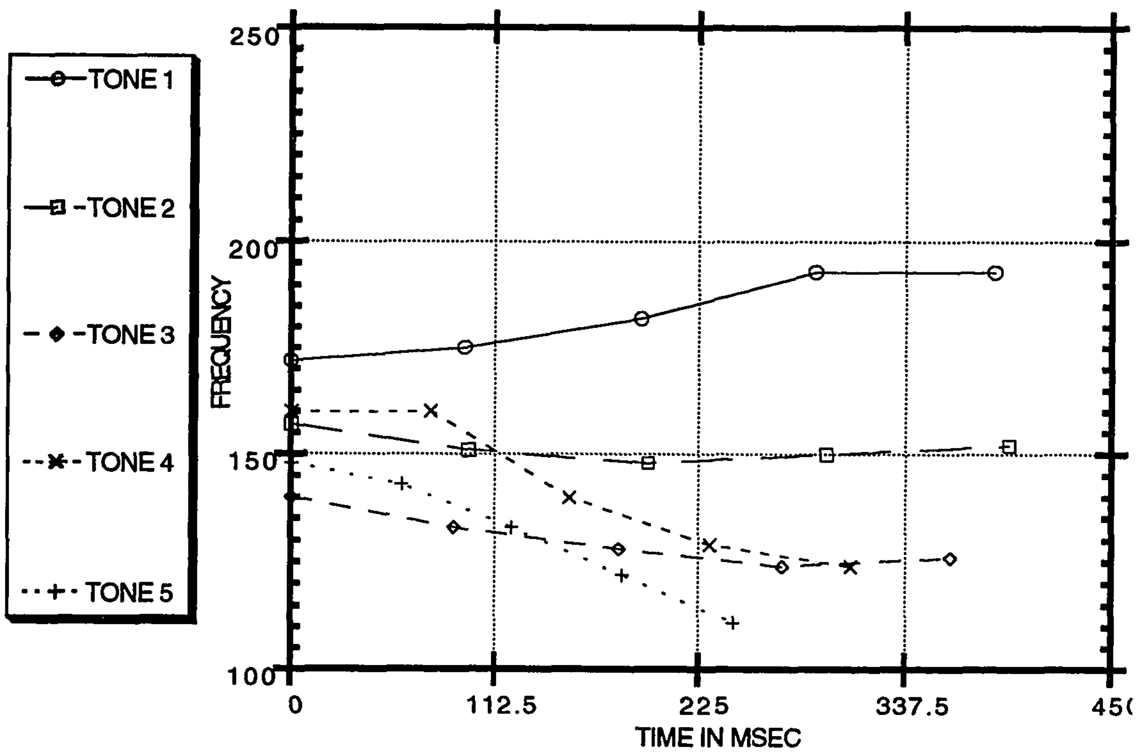

Figure 2. Average tone contours of the five tones of Toisanese as produced by the normal speakers.

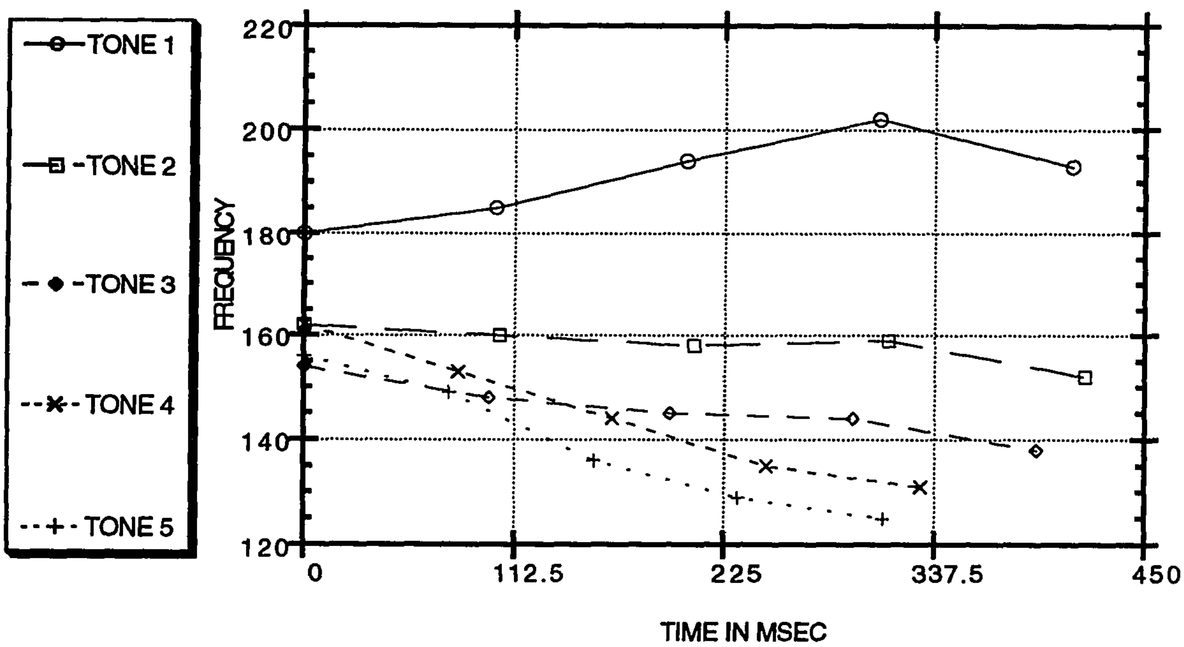

Figure 3. Average tone contours for the five tones of Toisanese as produced by the aphasic speakers group.

Table 4. Average tone durations presented in milliseconds for the two speaker groups.

Tone	Normal Speakers	Aphasic Speakers
1	386 msec	411 msec
2	398 msec	418 msec
3	364 msec	393 msec
4	308 msec	330 msec
5	245 msec	310 msec

of lexical tone between the two groups. Findings indicate that native listeners have more difficulty correctly perceiving tones produced by the aphasic speakers as compared to normal speakers. An Intelligibility Score was computed for each speaker group using the following formula:

$$\frac{\text{Number of correctly identified tones}}{\text{Total number of tones produced}}$$

On average, the aphasic speakers as a group attained an Intelligibility Score of 43%. On average, the normal speakers as a group attained an Intelligibility Score of 72%. Table 5 represents the percentage of correctly identified tones for each subject and for each tone. Figure 4 summarizes the differences in the native listeners' decisions about tones produced by the control group and the experimental group.

Further analysis demonstrated a correlation between the severity of aphasia and the level of intelligibility as expressed by native listeners. The most severe aphasic was the least intelligible and all of the normal speakers were rated as being more intelligible than even the least severe aphasic, suggesting that there is a certain level of tone dissolution even with a mild aphasia. The mildest aphasic attained an intelligibility score of 52%; the lowest intelligibility score in the control group was 63%. Figure 5

Table 5. Percentage of correct tone identification by native listeners for each speaker.

Aphasic Speaker	T1	T2	T3	T4	T5	(average)
A-1	55%	53%	58%	48%	48%	52%
A-2	45%	50%	50%	48%	20%	43%
A-3	93%	53%	23%	30%	33%	46%
A-4	85%	43%	10%	20%	0%	32%
A-5	85%	43%	25%	65%	3%	44%
	===	===	===	===	===	
(avg)	73%	48%	33%	42%	21%	

Normal Speaker	T1	T2	T3	T4	T5	(average)
N-1	95%	68%	50%	50%	68%	66%
N-2	95%	93%	58%	60%	93%	80%
N-3	88%	88%	50%	45%	55%	65%
N-4	100%	88%	75%	95%	73%	86%
N-5	85%	68%	70%	50%	40%	63%
	===	===	===	===	===	
(avg)	93%	81%	61%	60%	66%	

T1=Tone 1 T2=Tone 2 T3=Tone 3 T4=Tone 4 T5=Tone 5

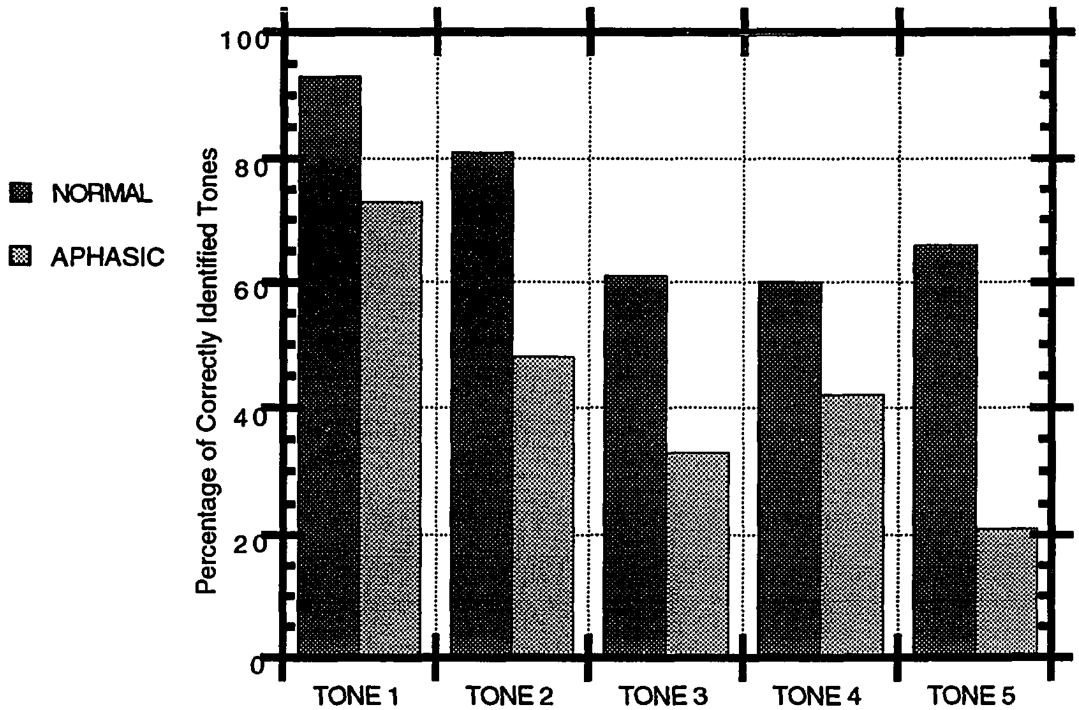

Figure 4. Average WIT scores of the two speaker groups across the five lexical tones.

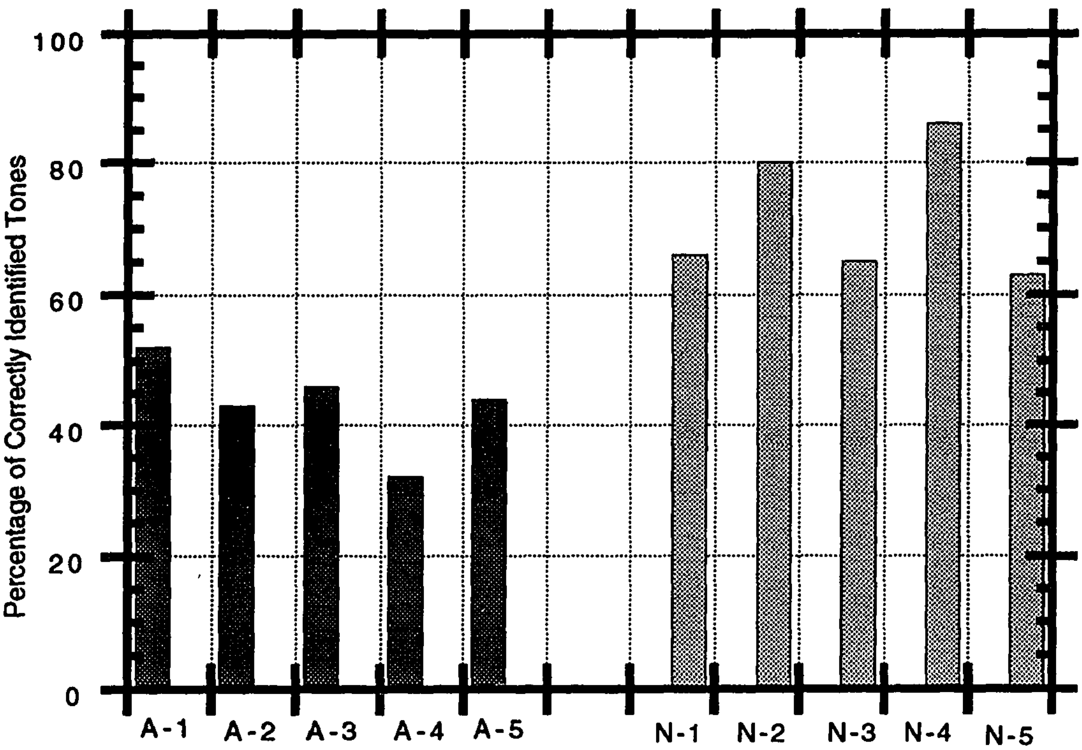

Figure 5. Intelligibility Scores of Individual Subjects.

compares the average intelligibility of each speaker. Figure 6 compares aphasia severity to intelligibility of tone productions.

Acoustic Analysis of Tone Contours

An ANOVA was performed on the acoustical data extracted from the recordings of the single word utterances produced by the two speaker groups. See Table 6. Specifically, frequency measurements were taken at quarter intervals for each token from each speaker of both speaker groups. Within and between group comparisons were made and findings revealed that both speaker groups made statistically significant distinctions among the five tones of Toisanese, with all F's significant at $p<.001$. Furthermore, when tones were compared between the groups, there was no significant difference. That is, aphasics' productions of Tones 1, 2, 3, 4 and 5 did not differ respectively from the normals' productions of Tones 1, 2, 3, 4 and 5, $F(16,16)=1.26$, $p=.233$. Table 7 presents the average frequency of each speaker group's production of each tone at specified intervals time on the tone contour. Figures 7, 8, 9, 10, and 11 are graphs of the normalized pitch contours for each of the five tones for each of the aphasic speakers. Figures 12, 13, 14, 15 and 16 are graphs of the normalized

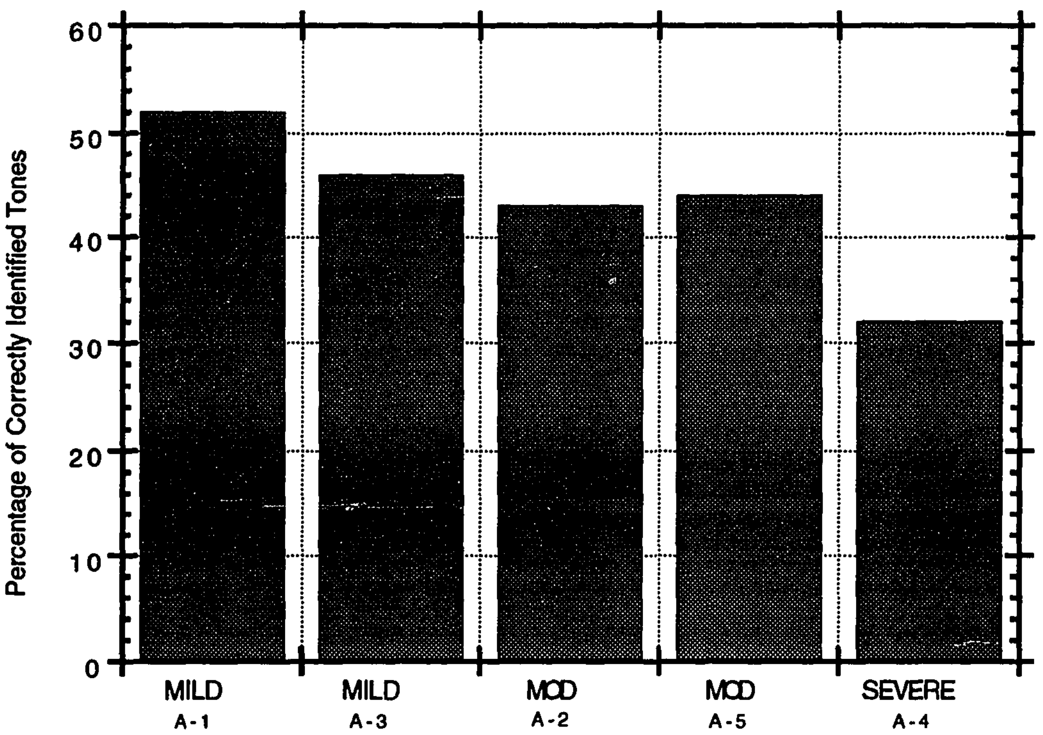

Figure 6. Comparison of aphasia severity and performance on the WIT.

Table 6. ANOVA Summary Table for the Effects of Group, Tone and Interval.

SOURCE	SS	df	MS	F	Sig. of F
Group (G)	4361.83	1	4361.83	.14	.722
S/G	257198.9	8	32149.86		
Tone (T)	89766.34	4	22441.58	61.03	.0
T x G	939.3	4	234.82	.64	.639
T x S/G	11767.22	32	367.73		
Interval (I)	6248.61	4	1562.15	16.9	.0
I x G	90.92	4	22.73	.25	.910
I x S/G	2958.32	32	92.45		
T x I	14422.56	16	902.66	29.11	.0
T x I x G	625.2	16	39.07	1.26	.233
T x I x S/G	3968.77	128	31.01		

p<.001

Table 7. Average frequency of each speaker group across the five Toisanese tones. Measurements of frequency were taken at quarter intervals (starting with the onset) of the pitch contour for a total of five points of measurement for each tone.

Aphasic Speakers Group

Tone	Time 1	Time 2	Time 3	Time 4	Time 5	(avg)
1	180Hz	185Hz	194Hz	202Hz	193Hz	191Hz
2	162Hz	160Hz	158Hz	159Hz	152Hz	158Hz
3	154Hz	148Hz	145Hz	144Hz	138Hz	146Hz
4	162Hz	153Hz	144Hz	135Hz	131Hz	145Hz
5	156Hz	149Hz	136Hz	129Hz	125Hz	139Hz
	=====	=====	=====	=====	=====	
(avg)	163Hz	159Hz	155Hz	154Hz	148Hz	

Normal Speakers Group

Tone	Time 1	Time 2	Time 3	Time 4	Time 5	(avg)
1	172Hz	175Hz	182Hz	193Hz	193Hz	183Hz
2	157Hz	151Hz	148Hz	150Hz	152Hz	152Hz
3	140Hz	133Hz	128Hz	124Hz	126Hz	130Hz
4	160Hz	160Hz	140Hz	129Hz	124Hz	143Hz
5	148Hz	143Hz	133Hz	122Hz	111Hz	131Hz
	=====	=====	=====	=====	=====	
(avg)	155Hz	152Hz	146Hz	144Hz	141Hz	

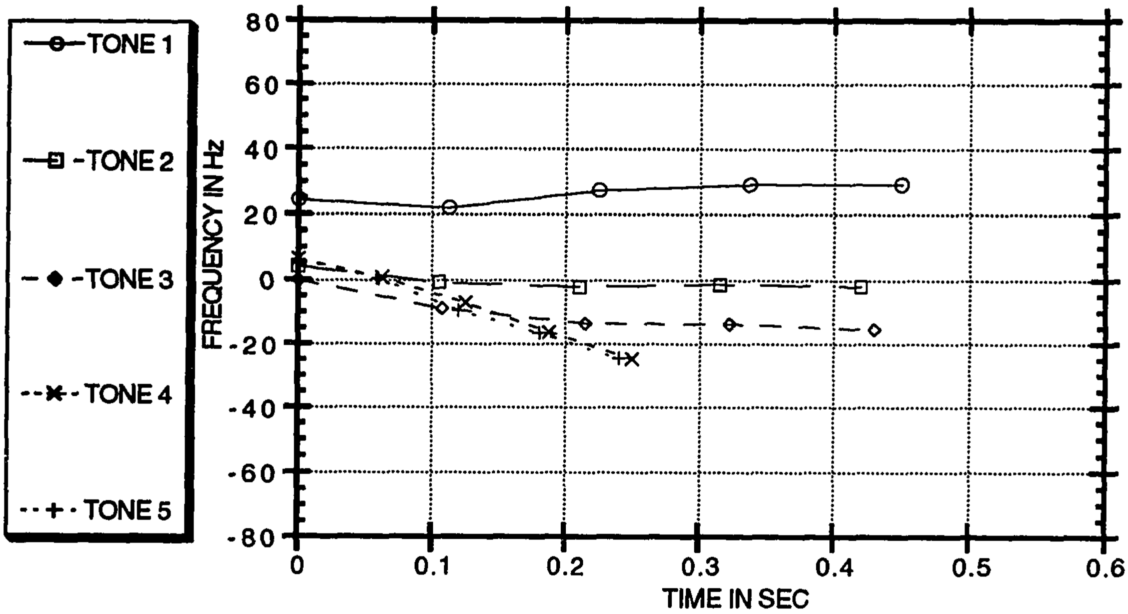

Figure 7. Normalized tone contours for Subject A-1.

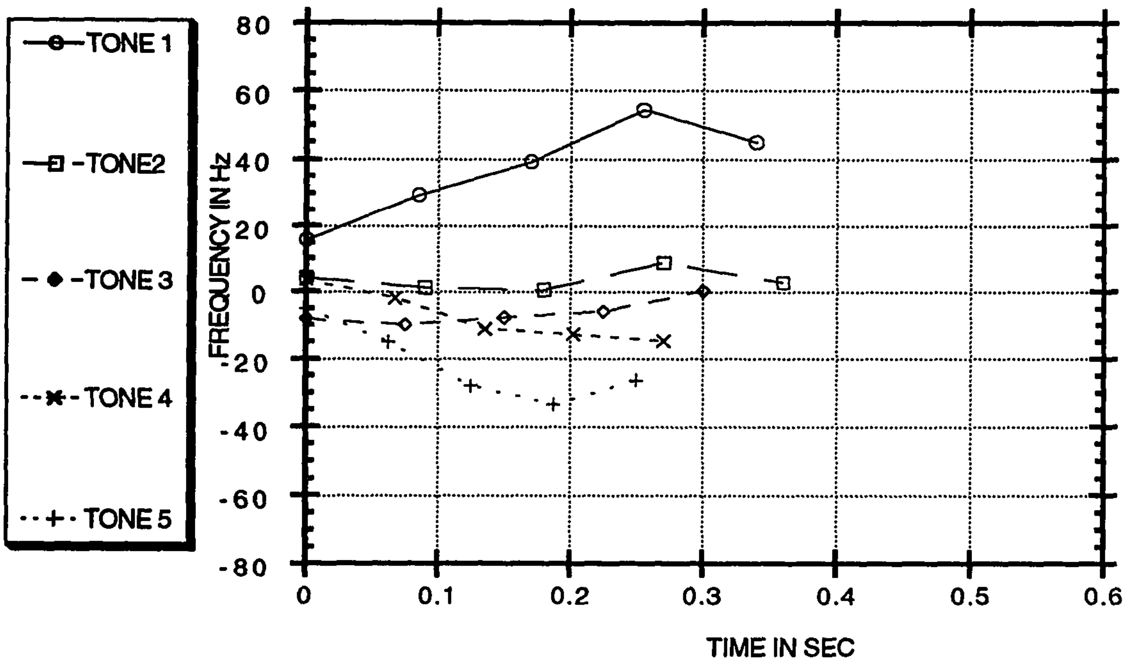

Figure 8. Normalized tone contours for Subject A-3.

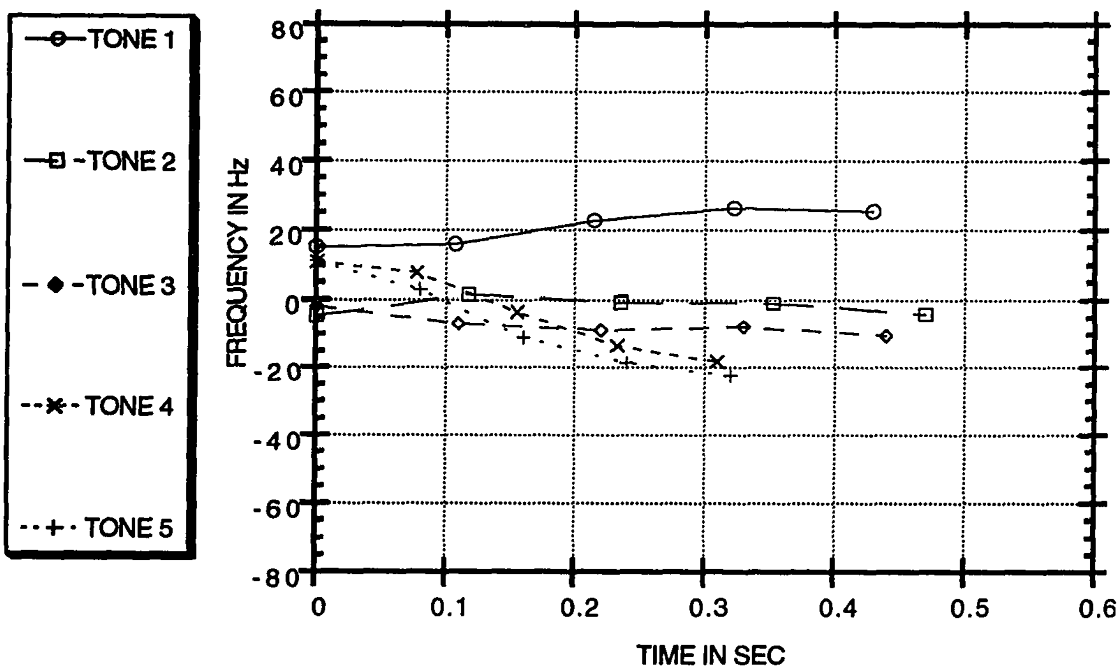

Figure 9. Normalized tone contours for Subject A-2.

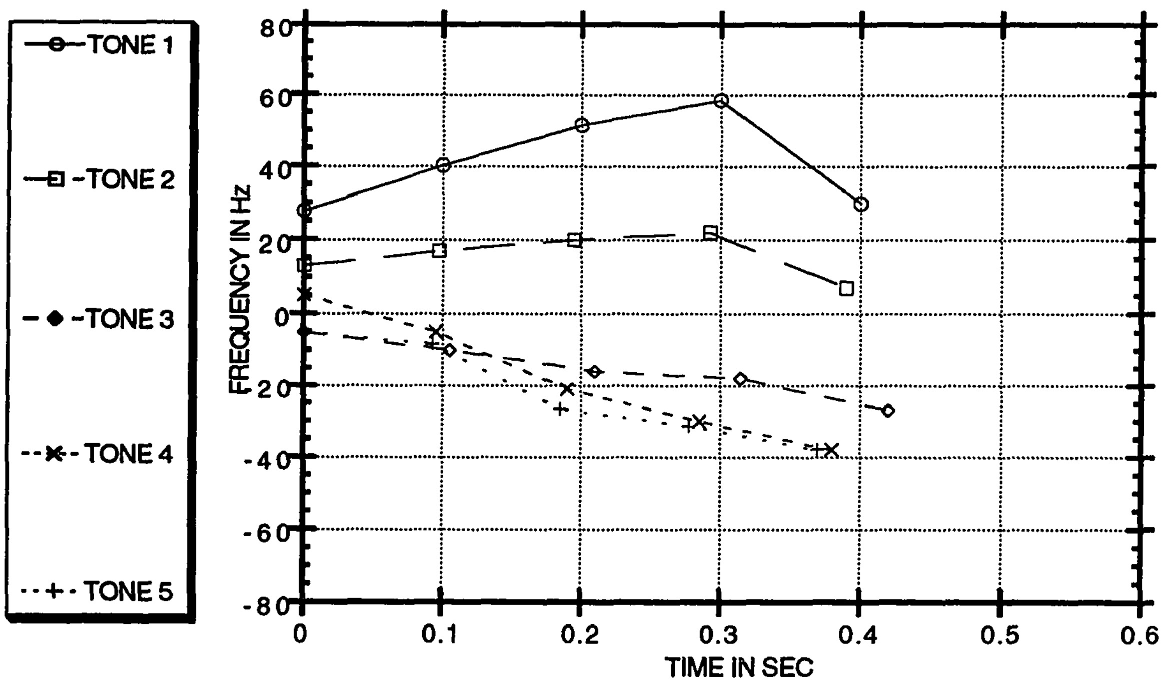

Figure 10. Normalized tone contours for Subject A-5.

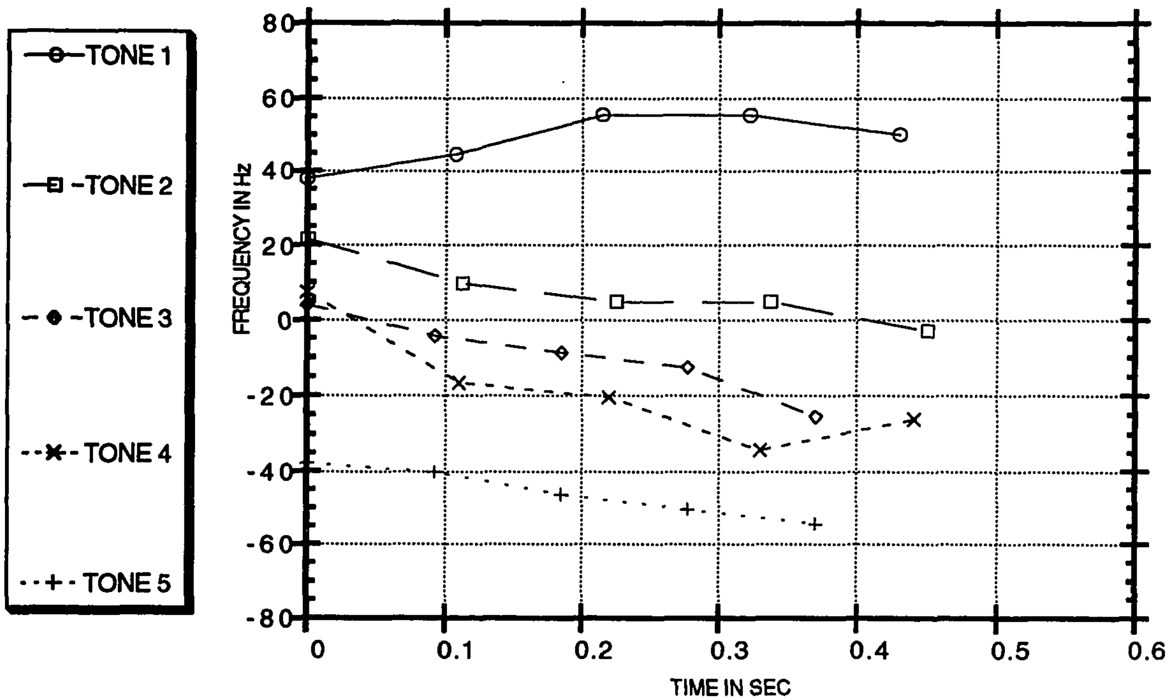

Figure 11. Normalized tone contours for Subject A-4.

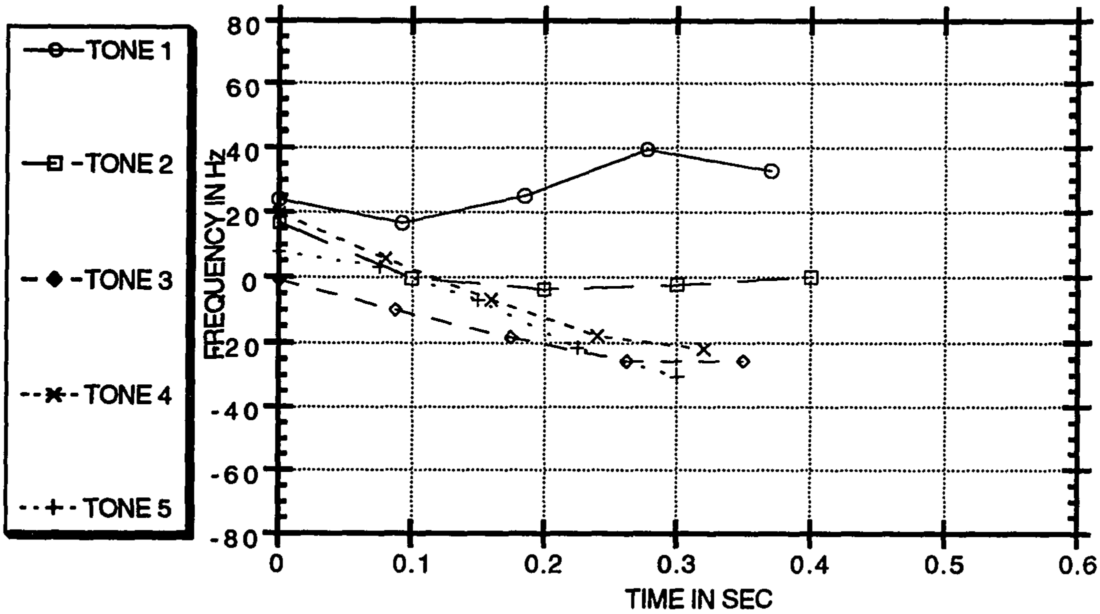

Figure 12. Normalized tone contours for Subject N-1.

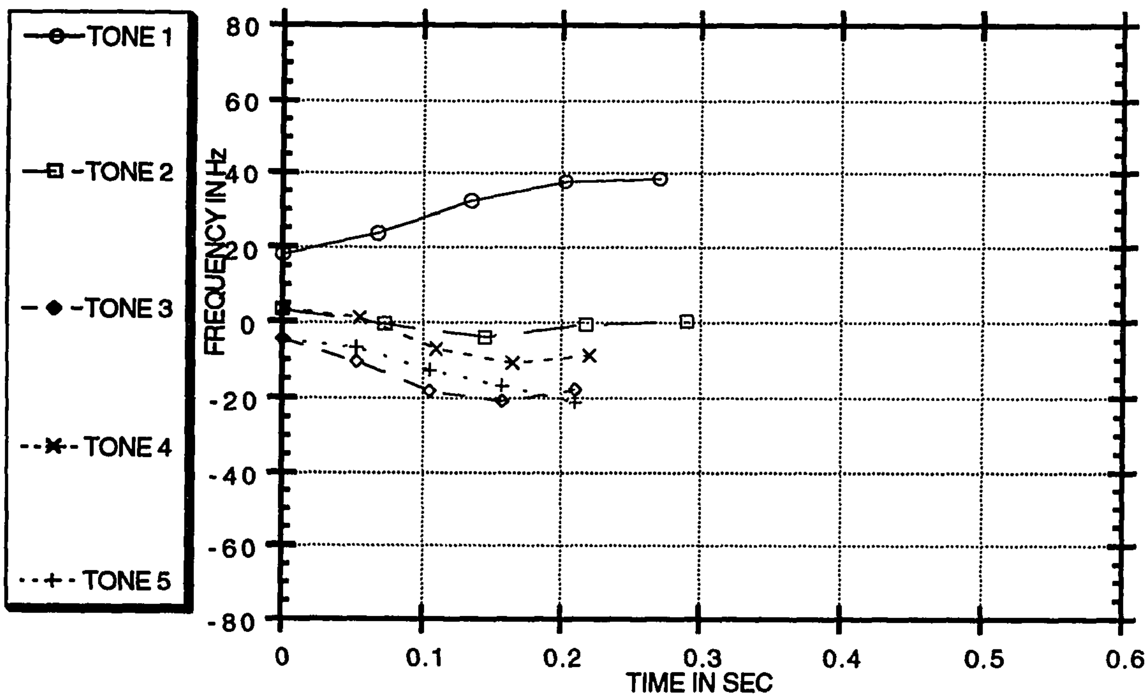

Figure 13. Normalized tone contours for Subject N-3.

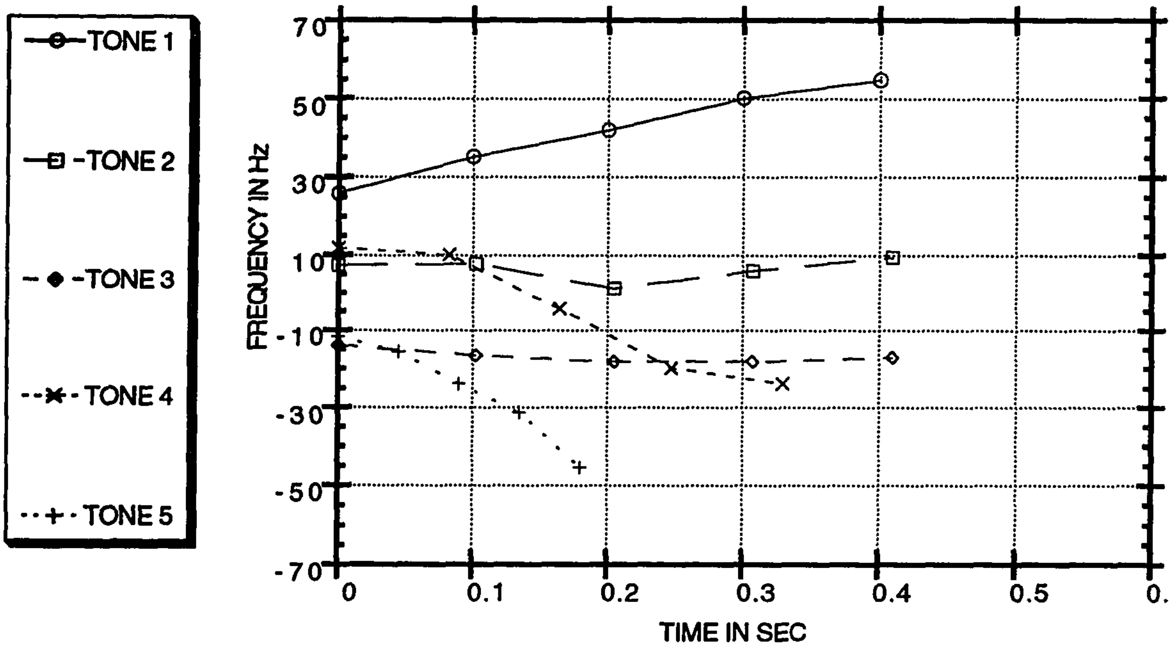

Figure 14. Normalized tone contours for Subject N-2.

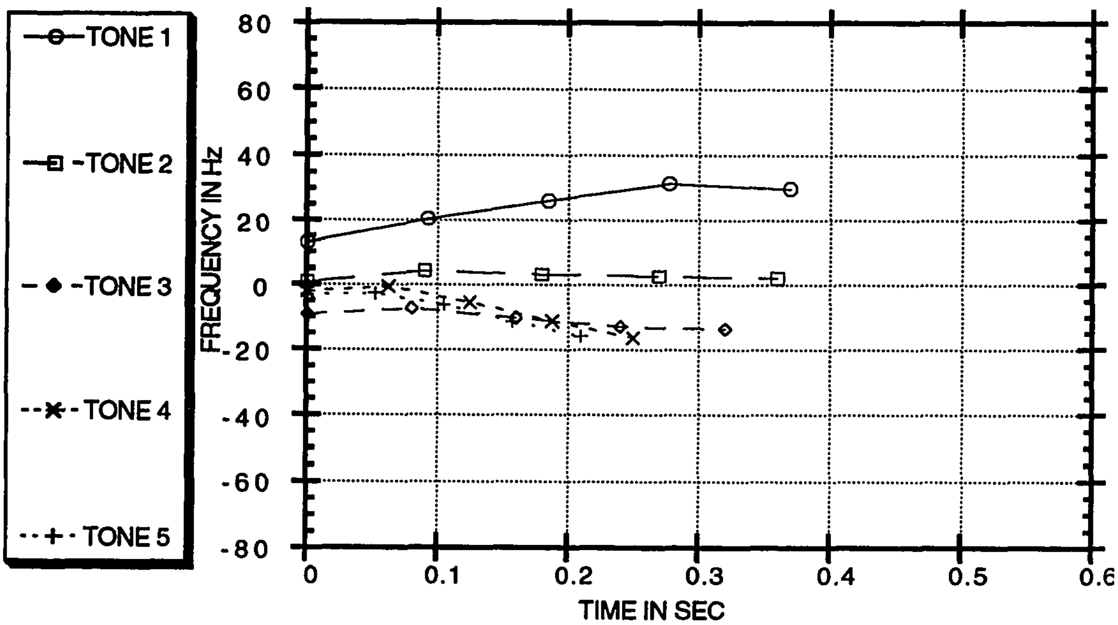

Figure 15. Normalized tone contours for Subject N-5.

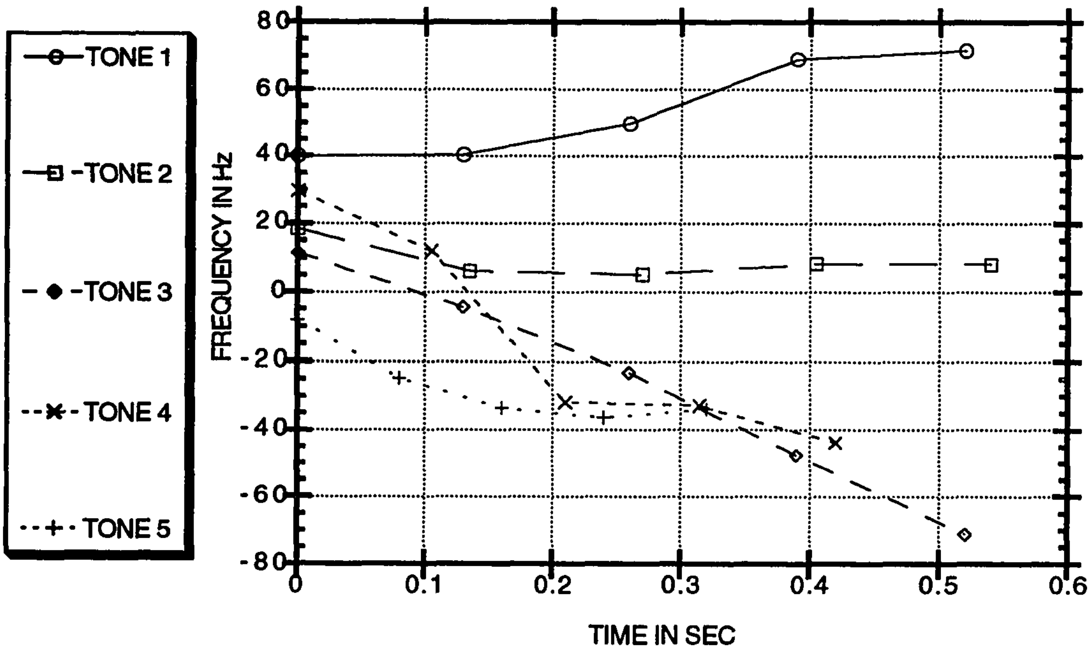

Figure 16. Normalized tone contours for Subject N-4.

pitch contours for each of the five tones for each of the normal speakers. The tone contours of each tone for each speaker were normalized by determining each speaker's average pitch over the five tones and then determining how close to this frequency each measurement at each interval of each tone was.

Between and within group measurements for pitch height at each interval of measurement (I) were made and findings revealed that both speaker groups made frequency changes over time, with all F's significant at $p<.001$. Moreover, when interval frequency measurements were compared between the groups, there was no significant difference. That is, the aphasics' tone contours did not differ from the normals' respective tone contours.

The acoustic data on tone production of the two groups of speakers revealed that there are durational differences for the tones of Toisanese. An ANOVA was performed on the duration data collected from each token of each speaker. See Table 8. Measurements of tone durations demonstrated that both the normal speakers and the aphasic speakers maintained these differences at the $p<.001$ level, and more importantly, the durations of the aphasic group agreed with the relative

Table 8. ANOVA Summary for the Effect of Duration.

Source	SS	df	MS	F	Sig of F
Group (G)	.01	1	.01	.61	.459
S/G	.17	8	.02		
Tone (T)	.13	4	.03	18.4	.0
G x T	.0	4	.0	.53	.715
T x S/G	.05	32	.0		

p<.001

differences in tonal durations of the normal group, $F(4,4)=.53$, $p=.715$. For both groups, Tone 2 was the longest, followed by Tone 1, Tone 3, Tone 4 and then Tone 5. Table 9 illustrates the similarities of durational differences for Toisanese tones between the two speaker groups. The fact that aphasic tones were slightly longer than their normal counterparts was consistent across all tones of Toisanese. See Figure 17.

Patterns of Tone Production and Perception

Comparison of WIT scores obtained by the two speaker groups revealed a difference in terms of perceptibility which was observed across the five tones of Toisanese; this is substantiated by the examination of individual speakers and individual confusion matrices. That is, the level of perceptibility was different for each tone of Toisanese. Moreover, this pattern of perceptibility was maintained for both groups. Tones 1 and 2 were more likely to be correctly identified as such, as demonstrated by higher intelligibility scores when compared to intelligibility scores derived for Tones 3, 4 and 5. Refer back to Figure 4.

Table 9. Average tone durations presented in milliseconds for individual speakers.

APHASIC SPEAKERS

SPEAKER	TONE	DURATION
A-1	1	45msec
	2	42msec
	3	43msec
	4	25msec
	5	24msec
A-2	1	43msec
	2	47msec
	3	44msec
	4	31msec
	5	32msec
A-3	1	34msec
	2	36msec
	3	30msec
	4	27msec
	5	25msec
A-4	1	43msec
	2	45msec
	3	37msec
	4	44msec
	5	37msec
A-5	1	40msec
	2	39msec
	3	42msec
	4	38msec
	5	37msec

NORMAL SPEAKERS

SPEAKER	TONE	DURATION
N-1	1	37msec
	2	40msec
	3	35msec
	4	32msec
	5	30msec
N-2	1	40msec
	2	41msec
	3	41msec
	4	33msec
	5	18msec
N-3	1	27msec
	2	29msec
	3	21msec
	4	22msec
	5	21msec
N-4	1	52msec
	2	54msec
	3	52msec
	4	42msec
	5	32msec
N-5	1	37msec
	2	36msec
	3	32msec
	4	25msec
	5	21msec

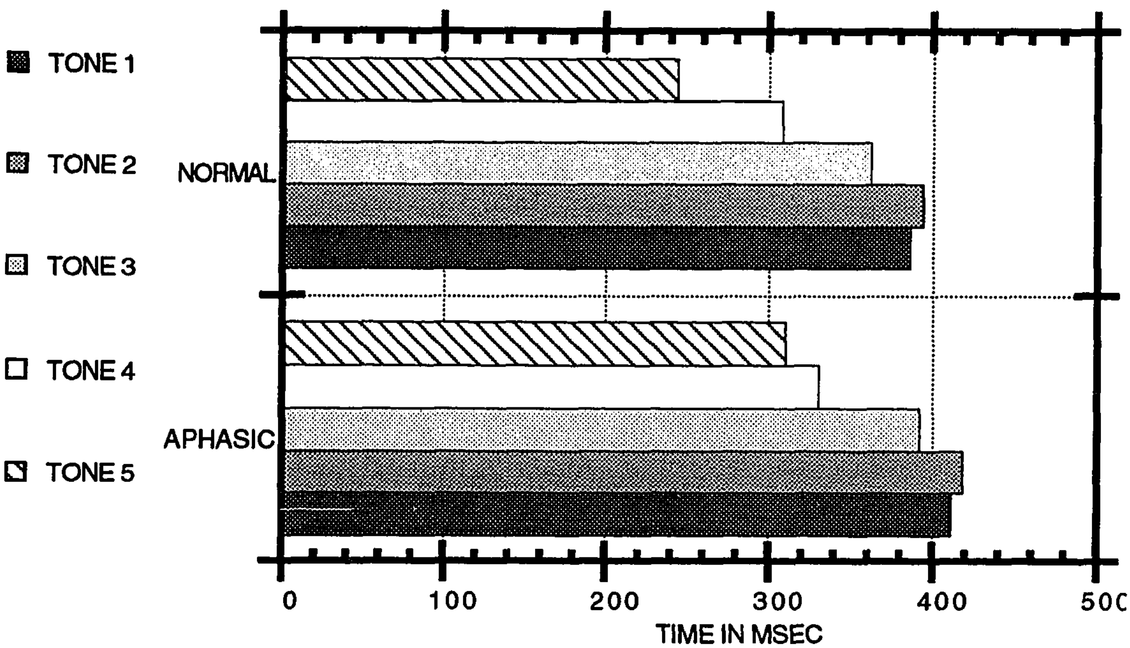

Figure 17. Comparison of tone durations between the two speaker groups.

Further evidence of a tone-specific perceptual difference was found when confusion matrices were constructed for the responses of the native listeners' data. These matrices reveal a subtle pattern of tone confusion that was present in both groups. Results indicated that for both groups, Tone 1 was most easily identified as such and if there were errors, the tone was most likely perceived as Tone 2. Additionally, Tone 2 was also readily identified as such though not as predictably as Tone 1. When errors occurred, Tone 2 was most likely perceived as Tone 3. For Tones 3, 4 and 5, there was an overall lower level of perceptibility as compared to Tones 1 and 2. There was a slight tendency for Tone 3 to be confused with Tone 2 while a less defined pattern of substitution was observed for Tones 4 and 5. These tones tended to be confused with each other with some scattering into Tones 2 and 3. There was only 3 responses among all responses from all listeners where either Tone 4 or Tone 5 was confused with Tone 1. The percentage correct for each tone and the percentage to which the target tone is mistaken for other tones were recorded for each speaker group in Table 10, illustrating a possible pattern of tone confusion.

This proposed pattern is substantiated by an analysis of the responses of the two speaker groups on the Picture

Table 10. Confusion matrix of the average percentage of responses of native listeners to the two speaker groups. Information is given on how well target tones were perceived and the nature of the errors committed.

Aphasic Group

Target Tone (TTx)	Target Tone Judged As (JTx)				
	JT1	JT2	JT3	JT4	JT5
TT1	73%	21%	3%	3%	2%
TT2	21%	48%	21%	9%	2%
TT3	10%	37%	33%	14%	6%
TT4	1%	14%	22%	42%	21%
TT5	2%	13%	31%	35%	21%

Normal Group

Target Tone (TTx)	Target Tone Judged As (JTx)				
	JT1	JT2	JT3	JT4	JT5
TT1	93%	6%	1%	0%	1%
TT2	5%	81%	13%	0%	2%
TT3	0%	23%	61%	10%	4%
TT4	0%	9%	16%	60%	15%
TT5	0%	9%	11%	15%	66%

Pointing Task (see section below for complete discussion) to assess tone perception abilities. The confusion matrixes constructed from this set of data represented the percentage of correct tone identification along with the percentage to which target ones are mistaken for other tones. Review of the error data suggests a close parallel to a pattern observed with the data on intelligibility levels whereby Tones 1 and 2 are more easily identified as compared to the perceptibility of Tones 3, 4 or 5, these tones were most likely confused among each other; this information is presented in Table 11.

Confusability of Tones among Individual Speakers

The analysis of the ease with which native listeners can perceive lexical tones was measured by the intelligibility scores from the WIT obtained from the normal speakers group as compared to the aphasic speakers group. However, it was realized that one of the limitations of this study is the fact that a small number of aphasic speakers with varying degrees of severity (of aphasia) was used and that this group has been viewed as a homogeneous group, therefore, a subject by subject review of the data was initiated. This approach revealed information with respect to tone height and duration. This

Table 11. Comparison of the responses of the two speaker groups on the Picture Pointing Task. The average percentage of correct identifications of the target tones as well as the average percentage of mistaken identifications are presented for each group.

Aphasic Group

Target Tone (TTx)	Target tone judged as (JTx) JT1	JT2	JT3	JT4	JT5
TT1	95%	5%	0%	0%	0%
TT2	30%	70%	0%	0%	0%
TT3	5%	0%	45%	30%	20%
TT4	10%	0%	5%	55%	30%
TT5	0%	0%	25%	35%	40%

Normal Group

Target Tone (TTx)	Target tone judged as (JTx) JT1	JT2	JT3	JT4	JT5
TT1	100%	0%	0%	0%	0%
TT2	0%	100%	0%	0%	0%
TT3	5%	0%	75%	20%	0%
TT4	0%	10%	0%	80%	10%
TT5	0%	0%	5%	10%	85%

section has been devoted to discussing native listeners' responses to individual speakers so that each speaker's productions will be discussed in detail. Throughout the section, use of the term "contour" refers to the line which was drawn from one interval point to the next. I will start with the mildest aphasic and end with the most severely impaired aphasic. The control subjects will be discussed in the same order as the matched experimental subject. This will be followed with discussion on possible correlations between the WIT group scores and the acoustical data.

Speaker A-1 is a mild aphasic speaker. Figure 7 shows his normalized pitch contours across the five tones; Table 12 presents the confusion matrix for this speaker where native listeners' responses to A-1's utterances are reported. The reader will note that Tone 1, found to be a high-rising tone, is essentially static in A-1's production. When errors were made in identifying his responses as Tone 1 targets, listeners tended to identify these items as Tone 2 items 89% of the time. On Tone 2 errors, listeners tended to identify these as either Tone 3, in 42% of errors observed or Tone 4, in 53% of the errors observed. This was most likely due to the close proximity (in terms of F0 height) Tone 2 maintains to Tone 3 and the amount of tone space Tone 2 shares with Tone 4. A-1's production of Tone 3 is occasionally confused for Tones 2, 4 and 5; this type of confusion might be attributable to the close proximity that these tones have to each other. However, A-1's production of Tone 3 starts in the low frequency range but has a slight drop in execution, thus lending itself to possible confusion with the two falling tones. In reviewing A-1's productions of Tones 4 and Tones 5, the confusion made between the two is plausibly attributable to the marked similarity between these productions so that Tone 4 and Tone 5 are confused with each other in 48% of the errors committed. Interestingly, the same number of errors of mis-identification of Tone 4 for Tone 5 and vice versa was exactly the same.

Speaker A-3 is a mild aphasic speaker. Figure 8 shows her normalized pitch contours across the five tones; Table 13 presents the confusion matrix for this speaker where listeners' responses to A-3's utterances are reported. At first glance, one notes that Tone 1 is easily identified and indeed listeners had virtually no difficulty recognizing A-3's Tone 1 as such; accuracy was observed at 93%. Her Tone 2 is produced with a slight rise in the contour which might lead listeners into identifying these productions as Tone 1; in fact, 53% of the errors noted on Tone 2 targets were identified as Tone 1. The Tone 3 contour was produced much like Tone 2 in terms of F0 height; there was also a slight rise in its production. Listeners responded to these productions by identifying these as Tone 2 in 45% of the errors and as Tone 1 in 26% of the errors. For this speaker Tone 4 was produced with only a slight drop in pitch level over time. This was reflected in listeners' responses to these items. Tone 4 was correctly identified on only 30% of the trials. Within the errors, 64% of the errors were made in the direction of Tone 3. That is, listeners identified these productions as a low, level tone. In the Tone 5 production, A-3's productions were heard as such on 33% of the trials. Among the errors committed of Tone 5, 52% were found to be Tone 3 responses where listeners identified Tone 5 productions as Tone 3. This strikes me as a rather unusual error since Tone 3 is a low, level tone while Tone 5 is a low falling tone. However, in reviewing A-3's production, one would see that she raises the pitch level toward the region of Tone 3 by the end of the contour; this unusual change in direction might have been detected by listeners who then treated these tokens as Tone 3 items.

Speaker A-2 is a moderately impaired aphasic. Figure 9 shows her normalized pitch contours across the five tones; Table 14 presents the confusion matrix for this speaker where native listeners' responses to A-2's utterances are reported. Here also, while Tone 1 has been found to be a high rising tone, A-2's productions exhibit only a slight rise and then a level at the end of the contour; 48% of Tone 1 tokens were correctly identified as such. Listeners could have been misled by the fact that these Tone 1 tokens did not have a marked rise at the end of their contours. In addition, onset may also be considered low when compared to the other nine speakers in the study. Indeed, 90% of the errors made in identifying these tones as Tone 1 targets were found to be in the direction of Tone 2. Her productions of Tones 2 and 3 were almost identical for F0 height, duration and contour, so that when errors were committed, listeners largely confused these tones with each other. Her productions of Tones 4 and 5 were also almost identical but with respect to these two tones, listeners found that Tone 4 (48% accuracy) was less susceptible to confusion than Tone 5 (20% accuracy). In reviewing these two contours, one notes that Tone 4 starts within the mid-range and is executed with a dip into the low range. However, listeners would expect a Tone 5 to start in the low range and fall into a lower range, but when this was not heard, listeners assigned these productions into either the Tone 3 (56% of the errors) or the Tone 4 (31% of the errors) category.

Speaker A-5 is a moderately impaired aphasic speaker. Figure 10 shows his normalized pitch contours across the five lexical tones; Table 15 presents the confusion matrix for this speaker where native listeners' responses to A-5's utterances are reported. Despite the apparent drop over time in the Tone 1 productions, these tokens resulted in a 85% level of accuracy in identification. Tone 2 was produced with a very similar contour to Tone 1 and among the errors committed, 74% of these were in the direction of Tone 1. Tone 3, again, because of its proximity to Tone 2 across all speakers, tended to be confusion with Tone 2. In fact, 70% of the errors made on Tone 3 targets were in the direction of Tone 2. Tone 4 was perceived as such with an accuracy score of 65%. Seventy-two percent of the errors committed were in the direction of Tone 3. Tone 5, despite its apparent conformity to a standard Tone 5, was perceived as such on only 3% of the trials. Errors clustered around Tone 4 (46% of errors were made in this direction) and Tone 3 (38% of errors were made in this direction) almost as one would expect. A-5's production of Tone 5 differs only in the level of onset from Tone 4. The onset for Tone 4 was 158Hz; the onset for Tone 5 was 148hz. Thereafter, Tone 5 mimics Tone 4 with respect to contour and duration.

Speaker A-4 is a severely aphasic speaker. Figure 11 shows her normalized pitch contours across the five lexical tones; Table 16 presents the confusion matrix for this speaker where native listeners' responses to A-4's utterances are reported. Of importance to note is that this female speaker's voice was extremely breathy and her pitch range was considered quite low by the examiner's judgment. During the acoustical measurement procedure, several of the Tone 5 tokens could not be accurately measured due to pitch breaks. In order to maintain a reasonable contour (though artificial), pitch levels were assigned based on the relative level of the break. Therefore, while her pitch contours appear relatively normal and distinctive, this was not reflected in listeners' responses. Her Tone 1 was clear and distinctive and listeners responded quite well; an accuracy score of 85% was achieved. Interestingly, her static tones (Tones 2 and 3) were produced with a slight drop in frequency and this movement seemed to confuse the listeners as errors were scattered among Tones 1 through 4. Her Tones 4 and 5 productions also did not appear to conform to established contours and here again, this was reflected in listeners' responses to these production. Error responses were scattered among the five tones when either Tone 4 or 5 was presented to listeners.

Let us now turn to the normal speakers to discuss their patterns of confusability. The order of presentation of speakers will follow the order of presentation of their aphasic counterparts.

Figure 12 shows normalized pitch contours across the five lexical tones for speaker N-1; Table 17 presents the confusion matrix for this speaker where native listeners' responses to N-1's utterances are reported. The marked rise in his Tone 1 productions was clearly appreciated by listeners as these productions attained a 95% level of accuracy. His Tone 2 productions attained a 68% level of accuracy with 100% of the errors in the direction of Tone 3. Again, the observation that across speakers Tones 2 and 3 are close to each other within the tone space is high and therefore this issue of proximity is once again raised. N-1's Tone 3 productions have a slight drop in frequency over time and this is realized by listeners who assigned an accuracy level of only 50% for Tone 3; of the errors committed for it, 45% were in the direction of Tone 4. Tone 4 was also perceived as such at only 50% accuracy; errors among this set of productions were well scattered among all other tones except Tone 1. N-1's productions of Tone 5 were observed to 68% accuracy. These productions were clearly falling over time and as a group, productions were the shortest among the five tones. Among the errors, 77% of these were in the direction of Tone 4, suggesting that listeners were attending to movement over time and/or frequency range of the tone.

Figure 13 shows the normalized pitch contours across the five lexical tones for Speaker N-3; Table 18 presents the confusion matrix for this speaker where native listeners' responses to N-3's utterances are reported. Here, the productions of Tone 1 and 2 are clear and distinctive - conforming to descriptions of their contour. Listeners attended to such cues as evidenced by accuracy scores of 88% for both tones. Tone 3, as seen in other both normal and aphasic speakers, tended to be confused with Tone 2 and for N-3's productions, 75% of the errors were in the direction of Tone 2. Tone 4 achieved an accuracy score of 45%. Review of her productions revealed a only slight drop in frequency over time and this drop might contribute to the difficulty listeners might have with these tokens thus errors were unevenly scattered among all tones except Tone 1. Tone 5 achieved an accuracy score of 55% with errors also scattered unevenly among all tone, except Tone 1. Here also, N-3's production of this tone did not exactly conform to a typical Tone 5.

Figure 14 shows normalized pitch contours over the five lexical tones for Speaker N-2; Table 19 presents the confusion matrix for this speaker where native listeners' responses to N-2's utterances are reported. Her Tones 1 and 2 were easily recognized by listeners as such with accuracy scores of 95% and 93%, respectively. Tone 3, again, despite apparently well produced tokens, were perceived at 58% level of accuracy and as expected, among errors, 74% of those were in the direction of Tone 2. Tone 4 received an accuracy score of 60% and among the errors observed, 56% of those were in the direction of Tone 5. Tone 5, as based on observation of N-2's productions, are clearly low, falling and over a very short period of time. Indeed, listeners were able to attend to one (or more) of these cues as Tone 5 received an accuracy score of 93%.

Figure 15 shows normalized pitch contours over the five lexical tones for Speaker N-5; Table 20 presents the confusion matrix for this speaker where native listeners' responses to N-5's utterances are reported. Tone 1 was observed with 85% accuracy and the errors were of Tone 1 in the direction of Tone 2 - 100% of the errors were committed in this direction. Review of this speaker's Tone 1 contour indeed shows a limited rise in F0, as compared to other speakers. Tone 2 was observed to 68% accuracy with 85% of the errors in the direction of Tone 3. Tone 3 productions received a 70% accuracy score and errors tended to be in the direction of Tone 4, with 67% of the errors in that direction. Tone 4 received a 50% accuracy score and errors tended to be in the direction of Tone 3, with 65% of the errors in that direction. N-5's productions of Tones 4 and 5 seemed to reflect only a slight fall typically associated with these tones so that Tone 5 productions received a 40% accuracy score and errors tended to be in the direction of Tones 3 (42% of the errors) and 4 (58% of the errors) - where listeners probably attended to the frequency range of the production or the slight dynamic nature of the productions.

Figure 16 shows the normalized pitch contours over the five lexical tones for Speaker N-4; Table 21 presents the confusion matrix for this speaker where native listeners' responses to N-4's utterances are reported. Tones 1, 2 and 4 are easily perceived by listeners as evidenced by high accuracy scores: 100%, 88% and 93%, respectively. Though there is a 75% accuracy score for Tone 3, 100% of those errors were committed in the direction of Tone 2. As for Tone 5, 73% of the productions were identified as such and given the relative similarity to Tone 4, 91% of the errors were committed in that direction.

Table 12. Confusion Matrix of Native Listeners' Responses to Speaker A-1.

SUBJECT	TARGET	RESPONSES*	T1	T2	T3	T4	T5
A-1	1	22/18	22	16	1	1	0
	2	21/19	0	21	8	10	1
	3	23/17	1	8	23	4	4
	4	19/21	0	0	1	19	20
	5	19/21	0	1	0	20	19

*Representing the number of correct responses to the number of incorrect responses.

Table 13. Confusion Matrix of Native Listeners' Responses to Speaker A-3.

SUBJECT	TARGET	RESPONSES*	T1	T2	T3	T4	T5
A-3	1	37/3	37	1	1	1	0
	2	21/19	10	21	6	3	0
	3	9/31	8	14	9	4	5
	4	12/28	0	4	18	12	6
	5	13/27	0	7	14	6	13

*Representing the number of correct responses to the number of incorrect responses.

Table 14. Confusion Matrix of Native Listeners' Responses to Speaker A-2.

SUBJECT	TARGET	RESPONSES*	T1	T2	T3	T4	T5
A-2	1	18/22	18	20	1	0	1
	2	20/20	3	20	12	5	0
	3	20/20	0	19	20	0	1
	4	19/21	0	2	9	19	10
	5	8/32	0	4	18	10	8

*Representing the number of correct responses to the number of incorrect responses.

Table 15. Confusion Matrix of Native Listeners' Responses to Speaker A-5.

SUBJECT	TARGET	RESPONSES*	T1	T2	T3	T4	T5
A-5	1	34/6	34	3	1	0	2
	2	17/23	17	17	3	1	2
	3	10/30	0	21	10	7	2
	4	26/14	0	0	10	26	4
	5	1/39	0	6	15	18	1

*Representing the number of correct responses to the number of incorrect responses.

Table 16. Confusion Matrix of Native Listeners' Responses to Speaker A-4.

SUBJECT	TARGET	RESPONSES*	T1	T2	T3	T4	T5
A-4	1	34/6	34	2	1	3	0
	2	9/31	17	9	7	6	1
	3	4/36	10	14	4	12	0
	4	8/32	2	22	6	8	2
	5	0/40	4	7	14	15	0

*Representing the number of correct responses to the number of incorrect responses.

Table 17. Confusion Matrix of Native Listeners' Responses to Speaker N-1.

SUBJECT	TARGET	RESPONSES*	T1	T2	T3	T4	T5
N-1	1	38/2	38	0	2	0	0
	2	27/13	0	27	13	0	0
	3	20/20	0	7	20	9	4
	4	20/20	0	4	9	20	7
	5	27/13	0	0	3	10	27

*Representing the number of correct responses to the number of incorrect responses.

Table 18. Confusion Matrix of Native Listeners' Responses to Speaker N-3.

SUBJECT	TARGET	RESPONSES*	T1	T2	T3	T4	T5
N-3	1	35/5	35	5	0	0	0
	2	35/5	3	35	1	0	1
	3	20/20	0	15	20	3	2
	4	18/22	0	13	4	18	5
	5	22/18	0	8	2	8	22

*Representing the number of correct responses to the number of incorrect responses.

Table 19. Confusion Matrix of Native Listeners' Responses to Speaker N-2.

SUBJECT	TARGET	RESPONSES*	T1	T2	T3	T4	T5
N-2	1	38/2	38	1	0	0	1
	2	37/3	2	37	1	0	0
	3	23/17	0	17	23	0	0
	4	24/16	1	0	6	24	9
	5	37/3	0	0	2	1	37

*Representing the number of correct responses to the number of incorrect responses.

Table 20. Confusion Matrix of Native Listeners' Responses to Speaker N-5.

SUBJECT	TARGET	RESPONSES*	T1	T2	T3	T4	T5
N-5	1	34/6	34	6	0	0	0
	2	27/13	1	27	11	0	1
	3	28/12	0	2	28	8	2
	4	20/20	0	1	13	20	6
	5	16/24	0	0	10	14	16

*Representing the number of correct responses to the number of incorrect responses.

Table 21. Confusion Matrix of Native Listeners' Responses to Speaker N-4.

SUBJECT	TARGET	RESPONSES*	T1	T2	T3	T4	T5
N-4	1	40/0	40	0	0	0	0
	2	35/5	3	35	1	0	1
	3	30/10	0	10	30	0	0
	4	38/2	0	0	0	38	2
	5	29/11	0	0	1	10	29

*Representing the number of correct responses to the number of incorrect responses.

Picture Pointing Task

Ability to perceive lexical tone was found to be impaired in the aphasic group as compared to the control group. Both groups had some difficulties distinguishing among the tones of Toisanese as observed from the results of the Picture Pointing Task. While there was a minimal number of errors committed by the normal speakers, the number of errors observed for the aphasic group varied with the severity of aphasia - where the most severe aphasic had the most difficulty with this task. Table 22 reports on each subject's successful identification of each of the tones of Toisanese. Figure 18 depicts the average PPT scores by speaker group. Figure 19 provides a comparison of individual speakers' ability to perceive tone across all five tones of Toisanese. Figure 20 present the relationship between aphasia severity and ability to perceive lexical tone.

The Nature of Toisanese Tones

Each tone of the system seems to have a different level of perceptibility. That is to say, the tones are not equally distinguishable by native listeners so that when listeners were asked to identify single words based on tone differences

Table 22. Comparison of normal speakers' and aphasic speakers'ability to perceive lexical tone. Percentage of correct responses on the Picture Pointing Task are reported for each speaker group.

Aphasic Speaker	T1	T2	T3	T4	T5	(avg)
A-1	100%	100%	75%	75%	25%	75%
A-2	100%	75%	50%	50%	50%	65%
A-3	75%	50%	50%	25%	50%	50%
A-4	100%	50%	0%	50%	25%	45%
A-5	100%	75%	50%	75%	50%	70%
	====	====	====	====	====	
(avg)	95%	70%	45%	55%	40%	

Normal Speaker	T1	T2	T3	T4	T5	(avg)
N-1	100%	100%	100%	100%	100%	100%
N-2	100%	100%	100%	100%	100%	100%
N-3	100%	100%	50%	50%	50%	70%
N-4	100%	100%	50%	75%	75%	80%
N-5	100%	100%	75%	75%	100%	90%
	====	====	====	====	====	
(avg)	100%	100%	75%	80%	85%	

T1=Tone 1 T2=Tone 2 T3=Tone 3 T4=Tone 4 T5=Tone5

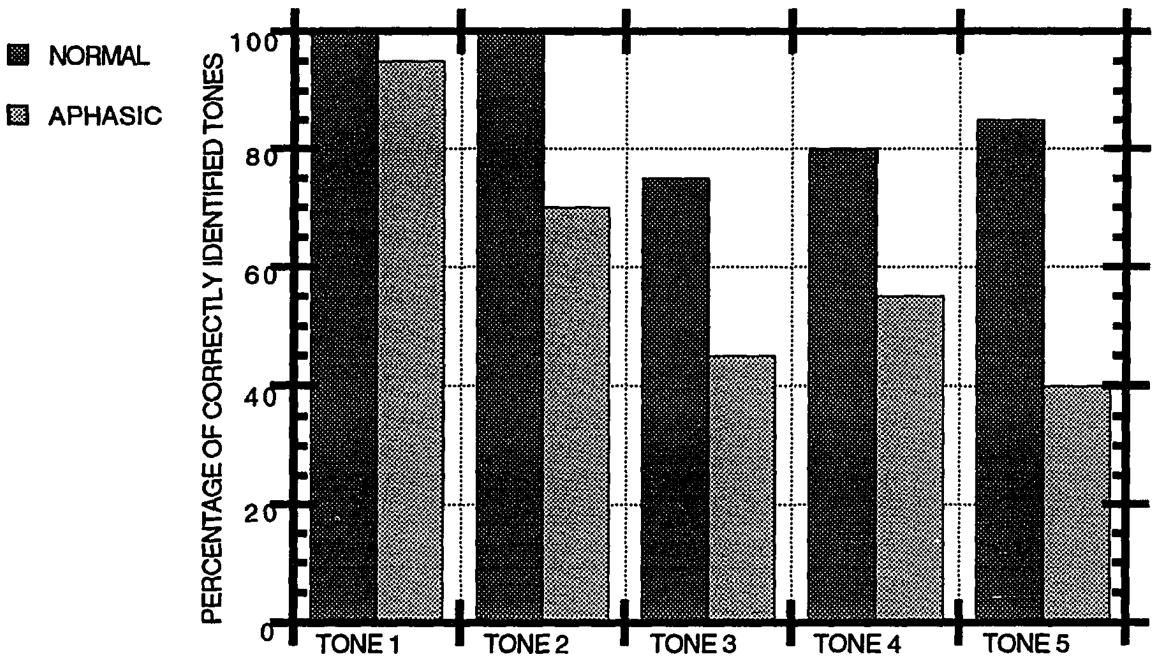

Figure 18. Average PPT scores of the two speaker groups across the five lexical tones.

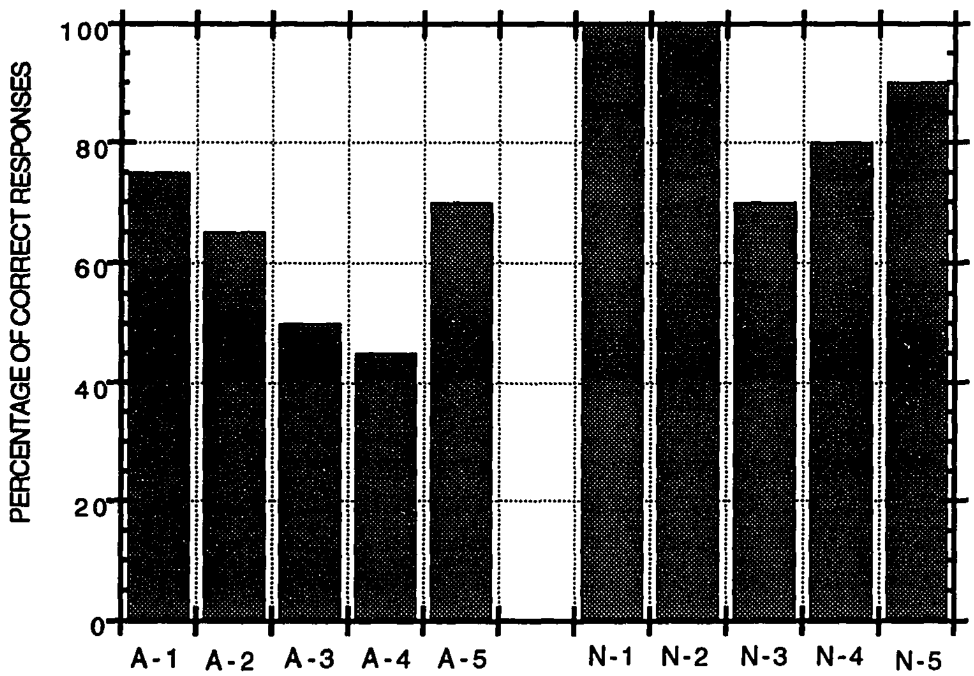

Figure 19. Individual speaker scores on the PPT.

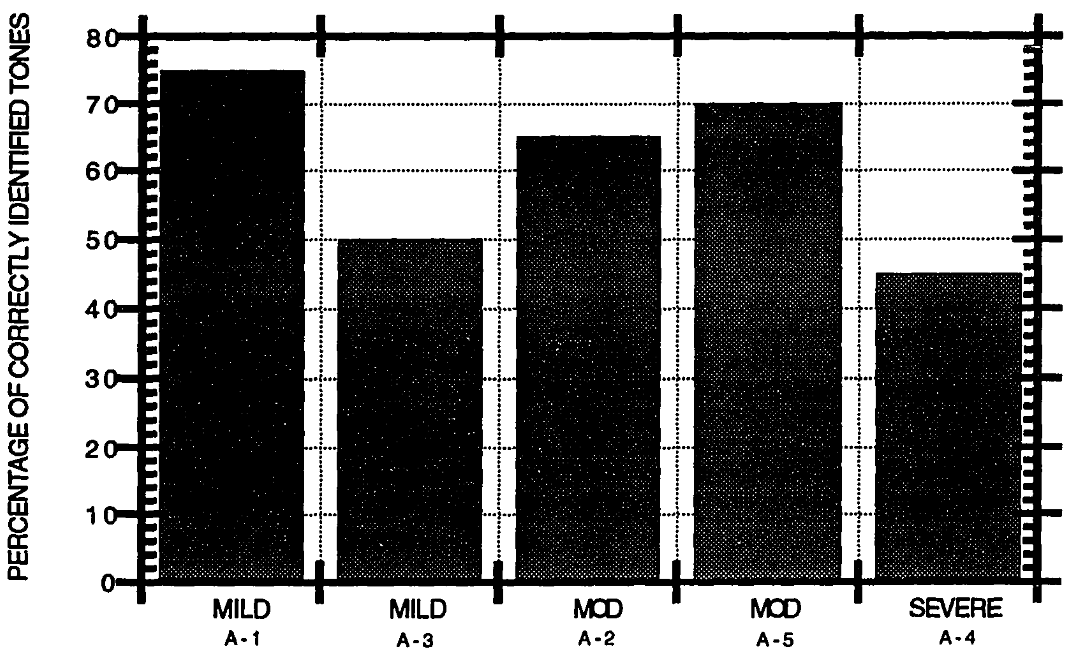

Figure 20. Comparison of aphasia severity and PPT scores.

only, performance differed by the target tone. We noted that in general, Tones 1 and 2 were easier to distinguish than Tones 3, 4 and 5. Table 23 and Figure 21 provide information performance of native listeners attending to tone on different tasks.

It was observed that single word utterances might not provide listeners with enough information to make tonal distinctions. We found that even on the Picture Pointing Task, where normal native listeners listened to live voice stimuli (instead of an audio-tape), they did not consistently perform at 100% accuracy across tones, suggesting that additional contextual cues might be necessary to make more reliable tone decisions.

Several post hoc analyses were conducted to further understand the nature of the Toisanese tone system. These were constructed to determine whether these was a discernible frequency of occurrence of tones in the dialect. The first of these approaches was to collect discourse samples from native speakers; second, a frequency count of tones as they appeared in a short article of a local newspaper was taken and last, the items from the minimal sets used in the present study were presented to native listeners for a frequency-of-occurrence rating.

Table 23. Comparison of native listeners' responses to lexical tone presented on three different tasks. Numbers represent the percentage of correctly identified tones on each task.

	Picture Pointing Task (PPT)	Tone Decision Normal Speakers (WIT-N)	Tone Decision Aphasic Speakers (WIT-A)
Tone 1	100%	93%	73%
Tone 2	100%	81%	48%
Tone 3	85%	61%	33%
Tone 4	80%	60%	42%
Tone 5	85%	66%	21%

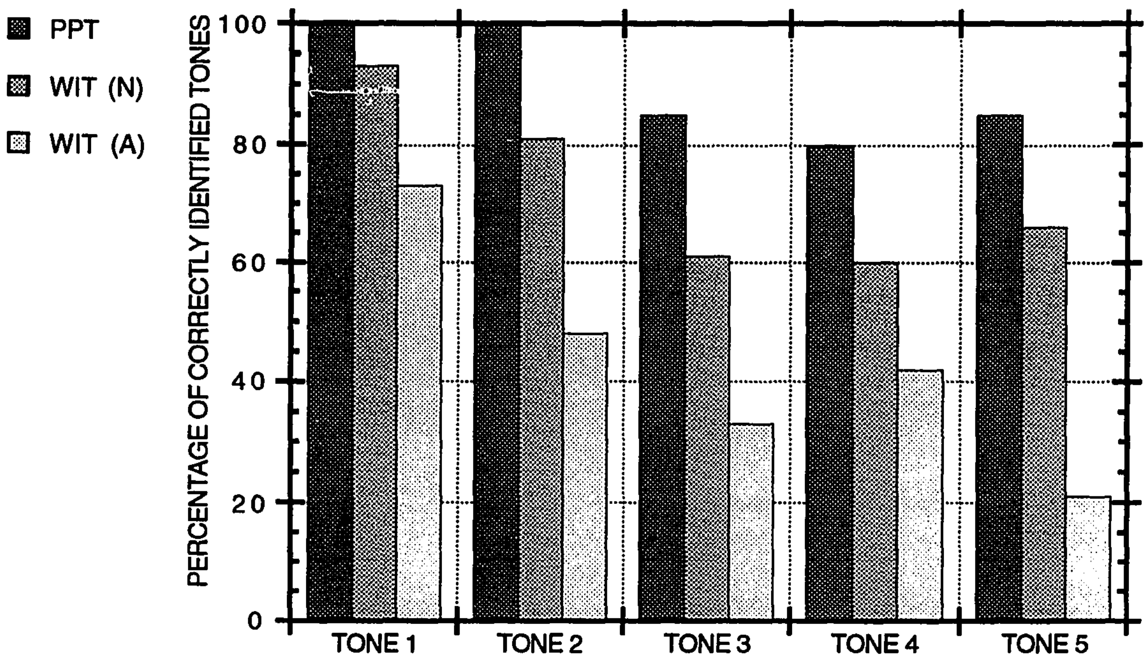

Figure 21. Comparison of native listeners' performance on the PPT, WIT(N)* and WIT(A)**.

*WIT(N)=Performance of normal speaker group on WIT.
**WIT(A)=Performance of aphasic speaker group on WIT.

Discourse samples were gathered from two normal native speakers of Toisanese using the Cookie Theft Picture from the BDAE and from conversational exchanges with these speakers. A total of 642 morphemes were collected. Data was analyzed for the frequency of occurrence of the five lexical tones. Discourse data revealed that Tones 1, 2, 3, 4 and 5 occurred in these proportions: 38%(n=244), 30%(n=193), 17%(n=109), 10%(n=64) and 5%(n=32), respectively. This demonstrates that in discourse, tones are not evenly distributed; there is a greater occurrence of Tones 1 and 2 in the spoken language, as compared to Tones 4 and 5.

A frequency count of tone occurrence was also collected from a local newspaper article. The article contained a total of 390 morphemes. Data analysis revealed that Tones 1, 2, 3, 4 and 5 occurred in these proportions: 31%(n=122), 31%(n=119), 15%(n=57), 13%(n=52) and 9%(n=37), respectively. Here also, Tones 1 and 2 occur more frequently as compared to Tones 4 and 5.

In addition to these analyses of tone frequency occurrence in Toisanese, we asked whether the frequency of the specific stimulus items used in this study might influence the results. Two normal native speakers of Toisanese were asked to rate morphemes from the minimal sets used in the present study.

Each was asked to rate the frequency of occurrence of each morpheme using the following scale: "1" for frequently occurring; "2" for occasionally occurring and "3" for infrequently occurring. A total of 40 responses was collected. Results indicate that the Tone 1 words were judged to be frequently occurring ("1") in 88% of the instances; Tone 2 words were judged to be frequently occurring ("1") in 38% of the instances; Tone 3 words were judged to be frequently occurring ("1") in 50% of the instances; Tone 4 words were judged to be frequently occurring ("1") in 38% of the instances; Tone 5 words were judged to be frequently occurring ("1") in 25% of the instances. Under this particular paradigm, the predominance of Tones 1 and 2 and the reduced representation of Tones 4 and 5 are not as obvious though Tone 1 items were clearly judged as being most frequently occurring as compared to Tone 5. See Tables 24 and 25 for a comparison of these data.

There was a positive correlation (r=0.61) between frequency judgments for the stimulus items and scores from the WRT. That is, more frequently occurring words are more accurately repeated. However, there was no correlation (r=0.01) between frequency judgments for the stimulus items and scores from the PPT. That is, word frequency does not relate to the ease of tone identification.

Table 24. Comparison of Frequency of Occurrence of Tones on Two Different Measurements.

	Tone 1	Tone 2	Tone 3	Tone 4	Tone 5
Cookie Theft Picture	38%	30%	17%	10%	5%
Newspaper Article	31%	31%	15%	13%	9%

Table 25. Judgments of frequency of occurrence on minimal set items. Percentages represent judgments of two normal listeners.

Tone	Frequently Occurring	Occasionally Occurring	Infrequently Occurring
Tone 1	88%	12%	0%
Tone 2	38%	50%	12%
Tone 3	50%	50%	0%
Tone 4	38%	25%	38%
Tone 5	25%	25%	50%

DISCUSSION

This study investigated the ability of aphasic Toisanese speakers to produce and to perceive the lexical tones of their dialect. Results indicated that tone production is disrupted following damage to the dominant hemisphere, suggesting that a prosodic feature would assume linguistic value when it serves a linguistic function. The degree of tonal disruption appears to be related to the severity of the aphasia where the most impaired subject had the most difficulty on tasks presented and similarly, the less impaired subjects had less difficulty. There were, however, certain features of pitch contours which were relatively spared for all aphasic speakers, including F0 height and duration of pitch contour.

Results also indicated that there is a pattern of perceptibility among the five Toisanese tones as observed in native listeners' responses on the PPT (Picture Pointing Task). This pattern is also observed in a more exaggerated form among the aphasic speakers. Here again, the deficits in tone perception varied with the severity of aphasia.

Analysis of the error patterns from the response sets demonstrate a subtle but rather consistent pattern of tonal confusion whereby Tone 1 is occasionally confused with Tone 2;

Tones 2 and 3 are more likely confused with each other as were Tones 4 and 5.

In the remainder of this chapter, the importance of these findings will be discussed in greater detail. In particular, the discussion will focus on the tone production and tone perception abilities and deficits in aphasic speakers, detailed information regarding the Toisanese tone system, speaker variability as these bear on tone perception and tone production and directions for future studies.

Tone Production Abilities of Aphasic Speakers

The findings from the WIT (Word Identification Task) and the acoustical measurements of aphasic speakers revealed that all aphasic speakers have some awareness of tonal distinctions as they made attempts to distinguish among these tones. The success of these attempts were determined by how well native listeners were able to attend to the tonal information. Not unlike responses to the PPT, native listeners evidenced a pattern of perceptibility for the five tones of Toisanese as produced by the aphasic speakers and a similar but much more subtle pattern of tonal confusion whereby the high rising tone (Tone 1) is relatively spared as compared to the remaining four tones. Likewise, the two static tones (Tones 2 and 3) tend most likely to be confused with each other and the two dynamic tones are most likely to be confused with each other.

Measurable parameters of tone contours including F0 height and tone durations were well preserved for the aphasic speakers. Danly and Shapiro (1982) proposed that it is the size of the linguistic unit that determines how successful the production of fundamental frequency is in the productions of aphasic speakers. The smaller the unit over which the contour covers, the more likely productions are accurate. The present study supports their hypothesis in that the aphasic Toisanese speakers were able to distinguish among the five tones, as illustrated by the significant group and tone main effects but without any Group x Tone interaction.

Furthermore, the relative durational differences in the tonal system were well presevered. Not only did the aphasic speakers, as a group, maintain durational differences, but the differences were clearly relative to all tones in the system. The finding that the falling tones (Tones 4 and 5) were the shortest tones is consistent with the reports of Ohala and Ewan (1973) and Gandour (1977) where falling tones of normal speakers were less effortful to produce and therefore faster in execution. Recall that Ohala and Ewan found that in normal Mandarin speakers, falling tones were produced faster than rising tones over the same interval. Recently, Baum (1993) in her work with English-speaking non-fluent aphasics, found that these subjects were able to maintain durational differences inherent in both lax and tense vowels. Taken together, measurements of F0 height and duration suggest that these features of lexical tone are fairly resistant to break-down following brain damage.

Tone Perception Abilities in Aphasic Speakers

Findings from the PPT substantiate what had been reported by April and Han (1980). Their Chinese-speaking aphasic had some difficulties distinguishing between two items of a minimal set; that is, the subject had difficulty distinguishing between two different utterances of the same segmental string distinguished by lexical tone only. In the present study, there was some tonal confusion when listeners were asked to distinguish among the five lexical tones of Toisanese when spoken by normal subjects. This confusion becomes even more evident among the aphasic speakers. When compared to the normal speakers, the aphasic speakers had more difficulty identifying tones, regardless of the target tone. However, the aphasic speakers maintained a similar hierarchy of ease of perception. That is, for both groups, Tones 1 and

2 were easier to identify as compared to Tones 3, 4 and 5. Specifically, the high rising tone (Tone 1) was typically not confused with any other tone. The low tone (Tone 3) tended to be confused with the mid level tone (Tone 2). The mid falling tone (Tone 4) tended to be confused with the low falling tone (Tone 5) and vice versa. Gandour et al. (1992) also reported of a similiar type of breakdown.

The relative dynamic nature of Tone 1 seems to preserve or signal its identity. The large amount of confusion among the tones within the mid and low pitch range might simply be due to the fact that there is a relatively large number of tones (or parts of tone contours) sharing the same space, thus providing the impetus for potential confusion.

These findings are in agreement with those of Lin and Repp (1989) as well. If Toisanese were viewed as having potentially three dynamic tones (Tones 1, 4 and 5) and two static tones (Tones 2 and 3), then listeners would rely on F0 movement to cue tone identity. In the present study, the aphasic listeners seemed to be employing a similar strategy to that of the subjects in the Lin and Repp study. Recall that in their study, Taiwanese speakers relied on contour (rather than F0 height) as a cue to tone identification. In that dialect, there are three dynamic tones and two static ones.

Application of this strategy to Toisanese can by hypothesized for this study where the high rising tone was typically not confused with any other tone; the static tones (Tones 2 and 3) tended to be confused with each other and the dynamic tones (Tones 4 and 5) tended to be confused with each other.

Observations About the Toisanese Tone System

The acoustical measurements taken from the tone contours of both speaker groups indicate that the high level tone, typically referred to as Tone 1, is better described as a high rising tone because of its dynamic nature. As Abramson (1976) described, dynamic tones are those having a discernible change over the duration of the contour. More accurate and descriptive terms allow for reliable predictions on tone perception and listener behaviors, i.e., tone-identification strategies.

As discussed earlier, Toisanese speakers might well be relying on tone contour instead of pitch levels as cues to tone identification. This presents an interesting parallel to an earlier study by Gandour (1983) in his work with Cantonese speakers, a dialect with six distinctive lexical tones; four of the six tones are dynamic in nature. In his work, results indicated that subjects relied on pitch contour for tone identification. In the organization of dialects and dialect families, Toisanese is a variety of the Cantonese family. The two are not completely mutually intelligible but they are certainly closer in distance than two dialects from different dialect families. In my observations of these two groups of speakers (Cantonese and Toisanese), Toisanese speakers attempting to speak Cantonese tend to impose a "dynamic" quality in their productions, whereas Cantonese speakers attempting to speak Toisanese tend to have a monotonous quality in their productions, possbily focusing on the two static tones of that dialect. The current findings from this study along with observations of speakers "importing" features which are salient in their respective dialects onto a new dialect system can also be observed in adult speakers of Cantonese, Toisanese and Mandarin Chinese learning English. It has been my experience that the spoken English of these adult language learners is so heavily marked with the influence of speakers' native dialects that it is often easy to predict what the native dialect is based on the spoken English.

Measurements of tone duration revealed that each of the tones of Toisanese has a different duration which was observed to be maintained by the aphasic group. Yet despite the apparent availability of rate as a cue for tone identification, Ohala and Ewan's Mandarin speakers did not appear to appreciate this feature shown by on their confusion between Tones 2 and 3 (1973). In the present study, the findings indicate that for both speaker groups, the tone durations for each tone were distinctively and significantly different from each other. Although the errors made in identification do not indicate listeners' exclusive use of duration as a cue for identification, there was only a handful of errors committed where the shorter tones (Tones 4 and 5) were not confused with each other. However, both these tones are also dynamic (falling) tones so that whether listeners attended to contour only, duration only, or a combination of both cannot be determined as yet.

The notion of having information with respect to speakers' tone space was first introduced by Abramson (1976). Recall that the findings from this study indicated that native listeners' responses to the PPT as compared to their responses on the WIT(N) were slightly different: the PPT scores were higher for all tones. The critical distinction between the PPT procedure and the WIT was that in the case of the former, each morpheme was preceded with the orally presented instruction, "Show me the _______". By providing access to the examiner's tone space, listeners were then provided with a framework within which to "fit" the target tone presented. So that while the differences between the PPT and the WIT(N) scores might simply be an artifact of the presentation differences, it does support for those who claim that information regarding speakers' tone space is necessary for tone identification.

This notion is further supported by the acoustical measurements of the present study. The results showed that the confusion among the Toisanese tones appear to be determined by the proximity of individual tones within a tone space. That is, the findings reflect a pattern of confusion in which target tones are typically confused with their neighboring tone so that Tone 1 is occasionally confused with Tone 2; Tones 2 and 3 tend to be confused with each other; Tones 4 and 5 tend to be confused with each other. Availability of tone space information offers listeners a point of reference which they can use to categorize tones.

The post hoc studies with respect to word frequency and lexical frequency indicate that there does appear to be a trend in terms of the frequency of occurrence with respect to the lexical tones of Toisanese. Findings may be interpreted as being a plausible contributing factor to the observation that listeners demonstrate a hierarchy of perceptibility among Toisanese tones. That is, there appears be a higher number of Tones 1 and 2 morphemes as compared to Tones 4 and 5 morphemes. In addition, there is a suggestion that certain tones such as Tones 4 and 5 are less frequent in occurrence as compared to other tones. Refer back to Table 25. These observations seem to suggest that native listeners are unevenly exposed to the tones of the system. With this type of bias inherent in native listeners, the finding that more frequently occurring tones would be more likely to be correctly identified would be expected. This was reflected in a number of different analyses designed to look at frequency of occurrence via different approaches and modalities.

Word frequency of occurance as measured with the stimulus items developed for this study showed a positive correlation for word repetition but not for tone identification.

Subject Characteristics

Consistent with previous reports on tone deficit in aphasic speakers of tonal languages, the findings from this study indicate that indeed markedly impaired aphasics exhibit tone production deficits, (Chan and Naeser, 1980; Packard, 1986; Gandour et al.,1982a, 1982b, 1985). However, contrary to earlier reports, even mild aphasic speakers had some difficulties in tone production. Recall that even the mild aphasics A-1 and A-3 achieved 52% and 46% averages on the WIT, respectively.

With respect to tone perception, findings from the present study illustrate that the more severe aphasics exhibited a greater amount of tone perception deficit, as compared to the mild aphasics. That is, each aphasic speaker had difficulties on the PPT and that the degree of difficulty increased with the degree of severity of aphasia. The most severely impaired aphasic (A-4) achieved a score of 45% while one of the mild aphasics achieved a score of 75%.

Since this study involved a limited number of aphasic subjects with varying degrees of aphasia, all subjects' data were treated individually to look at similarities and differences. By construction of individual confusion matrices and pitch contours for data on individual speakers, the pattern of confusibility was more readily detectable for each speaker. For example, one was able to correlate normal listeners' tonal confusions with the position of each tone as it appears within the speaker's tone space. Also, by treating the data as individual speakers, occasional misidentifications were presented more clearly; this was especially important for the normal speakers since as a group, there was only a limited number of tonal confusions observed.

The issue of time post brain damage has been reported in the literature as an important variable. Packard (1986) tested 50% of his aphasic Mandarin-speakers within 2 months post stroke and found tonal deficits in speech production while Gandour et al. (1982a, 1982b) tested their Thai-speaking aphasic subjects, at least three years post stroke and found no tone production deficits in their subjects' speech production. These researchers found that tone deficits tended to be resolved over time. However, in the present study, the time post onset brain damage seems to be independent of the severity of the tone deficits. Subjects A-2 (moderate aphasic) and A-4 (severe aphasic) are 35 and 22 months post CVA, respectively and they exhibited a fair number of tone production (and perception) problems. This suggests that tone deficits might not be restricted to only severely impaired aphasics and more importantly that this problem may persist over time, at least among Toisanese aphasic speakers.

In the present study, the factor of age did not appear to be an advantage (or disadvantage) with respect to tone production or perception. Speaker N-2 was significantly younger than any of the other subjects from both subject groups, yet her average scores on both the PPT and WIT 100% and 80%, respectively, were not markedly different from other members of her speaker group.

Time away from the native land varied with the subjects in this study although this variable did not seem to impact on speakers' responses in any remarkable manner. For example, speakers A-1 and N-1 have been in this country for over forty years while speakers A-5 and N-5 have been in this country for 5 years and two years, respectively. In the case of the normal speakers, N-1 achieved an intelligibility score from the WIT of 66% and N-5 achieved a 63%. However, the role of language (or in this case, tone attrition cannot be ruled out without having studies conducted in the native land.

In conclusion, the present study has served as a springboard for continued research in the areas of tone production and tone perception in both aphasic speakers and normal speakers of tonal languages. The findings indicate differences in perceptual and production capacities among aphasic and normal speakers and these differences might be influenced by linguistic and experiential factors indicating the need for research on the effects (individual or cumulative) that these factors may have on the lexical tone aspect of tone language speakers. More specifically, other tonal parameters such as vocal quality, amplitude and amplitude changes should be considered in future studies of tonal languages. Research on the efficacy of traditional intervention approaches with this group of speakers is lacking so that development of therapeutic approaches is essential in addressing the needs of tonal language speakers. Current rehabilitation approaches do not readily address such issues as auditory comprehension or discrimination of lexical tone or production of lexical tones.

SUBJECT SCREENING FORM

NAME:______________________________SEX:_______DOB__________

ADDRESS:____________________________________PHONE:__________

FACILITY:______________________________________RM:_________

PRIMARY DX:__________________SECONDARY DX:____________________

ONSET:______________________________MD:____________________

C-T SCAN/MRI:____

HANDEDNESS:______________________HEARING:____________________

LANGUAGE BACKGROUND

A1. Primary Dialect_________________Secondary Dialect_________

A2. Second Language_________________When Acquired_____________

A3. Use of A1_______________________Use of A2_________________

B1. Birth Place(Village)__________________Yrs in B1___________

B2. Other residence in China______________Yrs in B2___________

B3. Years in USA____

C1. Formal Education: Yes___ No___

C2. Where?______________________________Number of Yrs_________

D1. Employment/Occupation in China____________________________

D2. Employment/Occupation in USA______________________________

E1. Informant______________________________Reliability________

Availability of sibling(s)_____________________________________

Willingness to participate in study?___________________________

Severity of Aphasia_________MMS__________Therapy______________

Appendix B.

Non-standardized translation of
Boston Diagnostic Aphasia Examination
adapted from Goodglass and Kaplan, 1983

CARD 1: Cookie Theft

CARD 2: Letters are changed to high-frequency morphemes with less than five strokes each.

1. 十 2. 上 3. 心 4. 大 5. 中 6. 日

Geometric shapes are left unchanged.

"Which is the______________?"

1.	circle	3.	star	5.	square
2.	cone	4.	triangle	6.	spiral

Common objects are left unchanged.

"Which is the ______________?"

1.	chair	3.	feather	5.	cactus
2.	hammock	4.	glove	6.	key

CARD 3: Numbers are presented in Arabic script.

"Which is__________________?"

1.	42	3.	721	5.	1936
2.	7000	4.	15	6.	700

Colors are left unchanged.

"Which is____________________?"

1.	red	3.	pink	5.	blue
2.	grey	4.	purple	6.	brown

CARD 4. Repeating words: Words were selected to reflect the same number of syllables as found in the English version.

/mama/ 媽媽 /tɪt sɪp/ 七十 /fai sju/ 快手

/sʌn nin fai lɔk/ 新年快樂

/se bak lʌ sɪp tsɪt/ 四百六十七

CARD 5. Repeating words

1. chair
2. hammock
3. brown
4. triangle
5. fifteen
6. seven twenty one
7. smoking
8. circle
9. purple
10. dripping

CARD 6. Repeating Phrases: (High and low probability). the number of syllables were taken into consideration in addition to trying to preserve the orignal meaning of the stimulus. All Toisanese phrases are well formed.

High Probability

A. You know how. /ni hɛl du/

B. Down to earth. /ho sit dai/

C. I got home from work. /ngoi fɔŋ gʌn fʌn ki/

D. You should not tell her. /ni m ho gɔŋ kju hɪŋ/

Low Probability

E. Limes are sour. /mɔŋ ho ɬɔrn/

F. The Chinese fan had a rare emerald.
/ba sɛn jɛw lip mɛn gi lʌk bo sɛk/

G. The barn swallow captured a plump worm.
/dɛk dɔɪ dzɔk o hɛ o fi ɬɔŋ/

Appendix C.

MINI-MENTAL STATE SCORING FORM
(Folstein, Folstein and McKlugh, 1975)

Subject____________________Date________________Score___________

ORIENTATION

___1. What is the date? (month, day, date, session, yr) 5pts.
___2. Where are we? (state, country, town, hospital/building and floor) 5pts.

REGISTRATION

___3. Ask if you can test memory. Name 3 unrelated objects presented 1 seconds each. Ask subject to repeat these. One point for each item recalled. Repeat these until he learns all items; count number of trials needed. 3pts

ATTENTION AND CALCULATION

___4. Serial 7's; Ask him to start with 100 and count backwards by 7. Stop after 5 subtractions (93, 86...65). One point for each correct answer. 5pts.

RECALL

___5. Memory: Ask subject to name three objects presented above.

LANGUAGE

___6. Name: Show subject a watch, ask him to name; repeat with pencil. 2pts.
___7. Repetition: Ask subject to repeat 1pt
___8. 3 stage command: Give subject paper and ask him to "take the paper in your right hand and fold it in half; then put it on the floor". 1 pt for each part.
___9. Read: have subject read and follow printed directions "close your eyes". 1pt if eyes are closed.
__10. Write: give subject paper and ask him to write a sentence. Must have noun and verb; must be coherent. 1pt.
__11. Copy: have subject copy design (intersecting pentagons). All 10 angles must be present and 2 must intersect. 1pt.

Assess level of consciousness on continuum

Alert Drowsy Stupor Coma

Appendix D.

Lexical Tone inNon-Fluent Chinese-Speaking Aphasics
Principal Investigators: Nancy Eng Huie,MA & Sun-Hoo Foo,MD

1. The PURPOSE of this study is to learn how language behavior changes in Toisanese Chinese speakers who have had a stroke.

2. The PROCEDURES to be followed will include various language tests such as listening to words and sentences, repeating words and sentences and looking at pictures.

A tape recorder will be used during some of the testing to record exactly what the participant says. The tape will be listened to by native speaking raters and members of the research team.

The results of testing will be kept confidential unless the participant asks that they are released.

3. The RISK or INCONVENIENCE associated with these test is mild fatigue as a result of mental exertion.

4. The major BENEFIT associated with these tests is the enjoyment of mental stimulation. Most participants report that they enjoy the experience overall.
An immediate benefit is that the participant will receive a written speech/language evaluation of his/her language skills, in his/her native language.

5. WITHDRAWAL from the study: the participant may withdraw from this study or refuse to participate in it at any time after it has begun. Such withdrawal or refusal will in no way jeopardize future treatment at this Hospital.

6. The participant's QUESTIONS have been answered satisfactorily; if at any time in the future there are additional questions about the study, about participation in it or about the right of participants, I may call Nancy Eng Huie, MA at (212) 962-6066, Sun-Hoo Foo, MD at (212) 213-0270 or Loraine Obler, Ph.D at (212) 642-2352.

I understand the above statement of informed consent.

________________ ______________________________
(date) Subject or Guardian

________________ ______________________________
(date) Witness

________________ ______________________________
(date) Investigator

Appendix E.

Words Constituting the Four Minimal Sets Used in this Study

Tone	Graph	Level	Description	Word	Gloss	Referent
1		55	high level	口	/hau/	mouth
2		33	mid level	孝	/hau/	filial
3		11	low level	頭	/hau/	head
4		31	mid falling	後	/hau/	behind
5		10	low falling	厚	/hau/	thick
Tone	Graph	Level	Description	Word	Gloss	Referent
1		55	high level	苦	/fu/	bitter
2		33	mid level	副	/fu/	quantifier
3		11	low level	扶	/fu/	support
4		31	mid falling	父	/fu/	father
5		10	low falling	衭	/fu/	pants
Tone	Graph	Level	Description	Word	Gloss	Referent
1		55	high level	兩	/l	/two
2		33	mid level	靚	/l	/pretty
3		11	low level	量	/l	/measure
4		31	mid falling	亮	/l	/bright
5		10	low falling	領	/l	/collar
Tone	Graph	Level	Description	Word	Gloss	Referent
1		55	high level	攬	/laum/hug	
2		33	mid level	欖	/laum/collapse	
3		11	low level	藍	/laum/blue	
4		31	mid falling	纜	/laum/carry	
5		10	low falling	籃	/laum/basket	

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