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Cerebral dominance for pitch contrasts in tone language speakers and in musically untrained and trained English speakers

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Abstract: Speakers of a tone language, Thai, recognize pitch contrasts which are linguistically significant in their language better at the right ear in a dichotic listening task, but show no ear advantage for the same pitch contrasts occurring in a nonlinguistic context. American English speakers, divided into musically untrained and trained groups, show no ear advantage for those same pitch contrasts. The only effect of musical training is an enhancement of left ear accuracy for pitch contrast recognition.

A large number of studies on cerebral function have investigated left and right hemispheric specialization (Mountcastle, 1962; Bogen, 1969; Dimond, 1972; Dimond & Beaumont, 1974; Schmitt & Worden, 1974). For auditory stimuli, some researchers have asked whether lateralization to one cerebral hemisphere is based on acoustic features or on the functional context of the stimulus. Normal humans can be tested by dichotic listening (Berlin, Lowe-Bell, Cullen & Thompson, 1973; Cutting, 1973; Van Lancker, 1975), in which a subject hears two different, simultaneous sounds (one at each ear). The subject typically makes errors in reporting what he or she hears. These errors are greater at one or the other ear, depending on the type of stimulus. Because of stronger contralateral connections (than ipsilateral) between ear and hemisphere, a "right ear advantage" (higher accuracy at the right ear than the left) is assumed to indicate preferential processing by the left hemisphere, and vice versa. Such findings for many diverse stimuli have contributed to hypotheses on hemispheric specialization.

Most dichotic listening results have suggested that the functional context of a given stimulus predicts ear advantage. For example, if a stimulus is perceived as part of the linguistic system native to the subject, then those stimuli are more accurately heard at the right ear. In one study, vowels in syllables yielded a right ear advantage, whereas the same sounds embedded in a nonlinguistic context yielded a left ear advantage (Spellacy & Blumstein, 1970). Environmental sounds (Chaney & Webster, 1966; Curry, 1967), and some musical stimuli (Gordon, 1970) have shown a left ear advantage. These data support the "functional" theory of hemispheric specialization for processing auditory (and visual and other) stimuli.

Our experiments on Thai tones strongly confirm the functional theory of hemispheric specialization. In the first experiment (Van Lancker & Fromkin, 1973), we found that pitch contrasts were better identified at the right ear when constituting the tone contrasts of a tone language (Thai), but not when presented (to the same subjects) as hums. In a tone language, pitch alone may contrast the meanings of words which are otherwise identical in sounds. In a non-tone language, such as English, pitch is used to convey information (e.g. the intonation of an interrogative sentence will differ from that of a declarative) but the meaning of "cat" will remain the same whether it is produced with a high, medium, low, rising or falling pitch in a sentence such as "The cat is on the mat". In Thai, however (or in languages such as Chinese, Twi, Hausa, etc.) a word like "naa" will mean different things depending on the pitch (see Table I).

Table I Three sets of stimuli used

	Stimulus	Tone	Length (ms)	English gloss
(1) *Tone words*				
	naa	mid tone	625	"field"
	nàa	low tone	650	(a nickname)
	naa	falling	575	"face"
	náa	high tone	625	"aunt"
	naa	rising	650	"thick"
(2) *Consonant-words*				
	daa	mid tone	700	(a nickname)
	naa	mid tone	650	"field"
	saa	mid tone	700	"diminish"
	caa	mid tone	650	"tea"
	laa	mid tone	600	"goodbye"
(3) *Hums*				
		mid tone	650	
		low tone	550	
		falling	550	
		high tone	575	
		rising	525	

For the dichotic listening study, we prepared three audio tapes, using stimuli produced by a female native Thai speaker. The stimuli were three kinds: (1) five Thai words differing only in tone (the tone-word stimuli); (2) five Thai words contrasting only in initial consonant (the consonant-word stimuli), all occurring on mid-tone; (3) and five "hums" (to produce these the five Thai tone contrasts were hummed) (Table I).

For each of the three sets, every stimulus was paired with every other stimulus, producing 20 pairs. These were presented twice, with channels reversed the second time; the earphones were then shifted and the 40 pairs presented again. Thus there were 80 stimulus pairs for each set. The pairs were presented with a 6-s interval, with the exception of a block of 40 pairs in the tone word set, which were presented as doubled pairs. This was done to increase errors.

The subjects were provided with eight answer sheets with five columns, 10 rows per page, eight pages for each stimulus set. Each column was headed by the appropriate "tone-word" or "consonant-word", designated in both Thai and English orthography, and by iconic diacritics to represent the tones. These diacritics plus the Thai word for the tones headed the "hum" column. For each stimulus pair, the subjects were directed to respond by marking an *L* under the appropriate column to indicate the stimulus heard in the left ear, and an *R* under the column that identified the stimulus heard in the right ear. The order of reporting left-ear-right-ear, or right-ear-left-ear was reversed every 10 pairs.

Before each of the three stimulus sets, practice sessions were conducted for all subjects using binaurally presented stimuli.

For the first study using 23 right-handed native Thai speakers, we found a significant right ear effect for tone-words and consonant-words, but no ear effects for hums. We inferred that the Thai speakers were processing the feature contrasts in the pitches (tone-words) and consonants as language, and were therefore engaging the left hemisphere for these two tasks. The hums yielded no significant ear effects because they were not linguistically significant (although containing the same contrasts as the tones) (Van Lancker & Fromkin, 1973).

Our second experiment was conducted to determine whether a similar result would be obtained using subjects who were not native speakers of a tone language but who were musically trained. Our interest was to see if the right ear effect found in the Thai subjects was primarily due to the linguistic system of these speakers or whether it could have been due to greater familiarity with pitch contrasts. Our interest in this question was enhanced by a recent finding of Bever & Chiarello, 1974, who reported that musically trained subjects recognized melodies better at their right ear, whereas untrained subjects demonstrated the usual left ear advantage for musical sounds (in a monaural listening task). These authors suggested that musical training may have "real neurological concomitants" in requiring different strategies which engage the left hemisphere for otherwise right hemisphere tasks.

For this experiment, therefore, we selected 40 right-handed male native English speakers as subjects, divided into two groups with respect to musical training. The musically untrained group had had no formal musical training in the past 10 years and had four years or less total exposure. Nearly all had had zero to one year in elementary school and no musical activity since. The musically trained subjects had had at least eight years formal training, some as many as 40 years active participation. Most were currently playing an instrument or singing in a chorus.

These subjects received the binaural training session and heard the same dichotic stimuli as the Thai population.

For both untrained and trained subjects, a Wilcoxon signed ranks test on total errors (counting wrong answers *and* ear location errors, which we called intrusions) yielded a significant difference between ears for the consonant-word recognition. (This was also true of the Thai subjects.) No significant difference by this scoring was found for either group

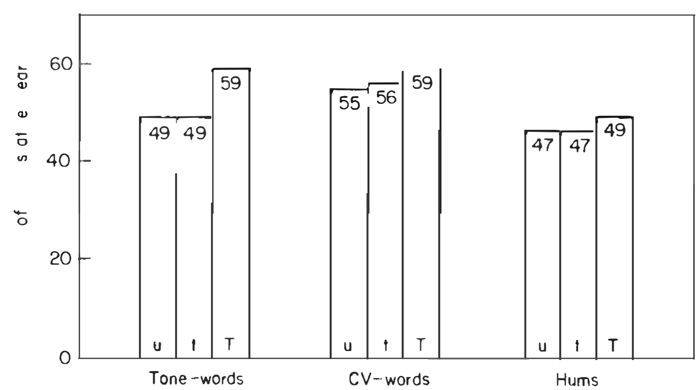

Figure 1 Percentage of errors (made at the left ear) for musically untrained (u) musically trained (t) and Thai groups (T) on the three dichotic listening talks.

(untrained or trained) on either the tones or the hums. This is in contrast with the Thai subjects, who showed a significant right ear effect on the tone-words (but not on the hums).

Figure 1 summarizes the results of the three groups, musically untrained (u), trained (t) and Thais (T). The percentage of error scores for the left ear ("right ear advantage") are nearly identical in the untrained and trained English speakers in each task. In the tone-word task, both groups of English speakers perform differently from Thai speakers. In the consonant-words task, all three groups show a right ear advantage, and no significant difference between the groups is found. In the hums task, all three groups show no significant ear advantage.

When wrong-answer errors only (not intrusions) were subjected to statistical analysis, the trained (but not the untrained) subjects were found to have a left ear advantage for tone-words ($p < 0{\cdot}05$) and for hums ($p < 0{\cdot}01$).

Our experimental results do not support the hypothesis that musical training leads to the engagement of the left hemisphere in tasks involving non-linguistic pitch contours.

We did find support for Gordon's (Gordon, 1975) claim that musical sophistication correlates with degree of advantage, because (when wrong-answer errors only were analyzed in our data) a significant left ear superiority was found for tones and hums for the trained subjects only. However, the direction of the ear advantage was in contradiction to what might be predicted from either the Bever & Chiarello (1974) or the Gordon (1975) studies. This may be because our stimuli were pitch contours presented in single or doubled pairs, while the other two studies used melodies.

	Tones	CVs	Hums
	ns	$P<0{\cdot}05$	ns
	ns	$P<0{\cdot}02$	ns
T	$P<<0{\cdot}01$	$P<0{\cdot}01$	ns

Figure 2 Significance levels for ear difference in musically untrained (u), musically trained (t) and Thai groups (T) on the three dichotic listening tasks.

A summary of our findings can be seen in Fig. 2 which presents the significance levels of right vs left ear percentage of error scores for the three subject groups on the three tasks.

Standard interpretation of dichotic listening results leads us to conclude that Thai speakers processed pitch contrasts which have a linguistic function more efficiently in their left (language) hemisphere. English speakers, regardless of musical training, did not show a left hemisphere preference for these same contrasts, but did show a significant ear difference for consonant–word contrasts as did the Thai subjects. The only effect of musical training in English speakers was to increase the degree of *right* hemisphere processing of tones and hums. Left hemisphere specialization was found for sounds only when they were part of a linguistic system in the perceiver.

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