PHONEME AND TIMBRE MONITORING IN LEFT AND RIGHT CEREBROVASCULAR ACCIDENT PATIENTS

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Dichotic listening studies in normal subjects have indicated a right ear (left hemisphere) preference for many linguistic stimuli, including stop consonant, initial nonsense syllables (Shankweiler & Studdert-Kennedy, 1967; Studdert-Kennedy & Shankweiler, 1975), digits, and other lexical items (Kimura, 1961); as well as a left ear (right hemisphere) preference for certain nonlinguistic stimuli, including melody (Kimura, 1964), chords (Gordon, 1970), environmental sounds (Curry, 1967), and nonverbal vocalizations such as laughing and sighing (King & Kimura, 1972).

In contrast to the concept of a left hemisphere specialization for verbal material, and a right hemisphere specialization for nonverbal material, many investigators believe the left hemisphere is specialized for analytic processing and the right for holistic processing. On this view, when musical tasks share properties with speech such as temporal order, duration, simultaneity, and rhythm (Krashen, 1973), the left hemisphere is responsible for stimulus processing. Conversely, when the musical task is free of temporal constraints (i.e., not time bound), the right hemisphere is presumably processing the information in a gestalt manner. In other words, time-dependent (sequential or temporal) processing is best performed by the left hemisphere while time-independent processing is best performed by the right hemisphere (Carmon & Nachson, 1971; Albert, 1972; Gordon, 1979). This approach is consistent with an interpretation of lateral asymmetries on the basis of degree of processing (Brown 1983) rather than parallel systems or separate processing components.

There are relatively few studies on timbre and cerebral specialization, though a left ear superiority has been demonstrated with dichotic listening techniques (Gordon, 1970). Others have found a left ear superiority for limited duration only, suggesting that the ability to detect target timbres may disappear after repeated trials (Kallman & Corballis, 1975). In one study showing no significant difference between the ears for the detection of timbre (Spellacy, 1970), the intervals between dichotic presentation and recognition stimuli were 5 and 12 sec, suggesting that a different pattern of ear advantage emerges with shorter intervals, as in the case of pitch (Wyke, 1977). With shorter intervals, the procedure approaches a discrimination task, suggesting that it is the dimension of stimulus discrimination rather than the material discriminated which gives the right hemisphere effect. Thus, Mazziota, Phelps, Carson, & Kuhl, (1982) found diffuse right hemisphere PETT metabolic activation with a timbre discrimination task.

There is some evidence for selective left hemisphere involvement in phonological processing. For example, rCBF methods have demonstrated that rhyme or suffix monitoring engages left temporal regions preferentially (Maxmillian, 1982; Knopman, Rubens, Klassen, & Meyer, 1982). Conversely, Zaidel (1977) demonstrated poor phonological feature discrimination in the right but not left hemispheres of commissurotomy subjects. To date, there are no studies of phoneme monitoring in aphasics, though it has been determined that aphasics are impaired in the discrimination of phonological contrasts (Blumstein, Baker & Goodglass, 1977) and in the labeling or identifying of consonants presented in a consonant-vowel context (Basso, Casati & Vignolo, 1977). This would be of particular interest in light of evidence that phoneme monitoring involves operations that are not essential for normal language: children who have difficulty learning to read fail on such tasks, though their ability to speak and to understand spoken language is approximately normal (Liberman, 1974; Calfee, Chapman, & Vanesky, 1972). Level of reading skill, however, does not predict performance on a phonological task (Morais, 1975) though it has been suggested that performance on such tasks might identify dyslexic individuals.

METHODS

Subjects

Twenty right-handed subjects with reportedly normal hearing (as confirmed by audiological data), English as a native language, and ranging in age from 40 to 70 years were participants in this study. All subjects sustained a single, CT scan documented unilateral (10 left, 10 right) cerebral vascular accident and had no history of other neurological disorders. Left hemisphere damaged subjects included 4 nonfluent aphasics, 3 fluent aphasics and 3 total aphasics, with lesion location as follows: 4 anterior, 3 posterior and 3 anterior/posterior. Lesion location in the right hemisphere damaged subjects included 4 anterior, 5 posterior and 1 anterior/posterior. Three left hemisphere damaged and 2 right hemisphere damaged patients were deemed musically sophisticated; each had actively played a musical instrument for at least 8 years prior to CVA.

Materials and Procedure

Each subject wore a pair of Pioneer SE-305 stereo headphones and listened to recordings on an AKAI GX4000D tape recorder. Each subject was required to indicate recognition of targets by raising the hand ipsilateral to the lesion. All stimuli were prepared at the Haskins Laboratory, New Haven, Connecticut.

Language stimuli. Stimuli consisted of monosyllabic (CVC, CVCC, CCVC) words spoken by a female. Words were arranged in two 5-min blocks of 52 stimuli each, at the rate of one every 3.7 sec, with an 8-sec interval between blocks. Stimuli ranged from 850 to 1180 msec in length. Targets consisted of words beginning with the sound/b/ and foils consisted of words beginning with the sound /s/, /j/, /r/,/k/, /w/, and /m/. No target or foil ended with the sound /b/. Targets constituted 15% of the stimuli. None of the targets or foils were repeated.

Nonlanguage stimuli . Electronically generated sounds produced by an Apple computer with Syntauri software were used as stimuli. Parameter values for these stimuli are shown in Table 1. Seven different timbres were used. Each timbre was generated at four pitch levels corresponding to middle C through F above middle C. In perform ing the task, subjects were trained to identify one timbre as a target. Seven other timbres judged in pilot studies to be maximally different from the target served as foils. Stimulus presentations were identical to those used for phoneme monitoring. Sounds were presented in two 5-min blocks at the rate of one per 3.7 sec. Individual stimulus durations ranged from 973 to 1183 msec. Targets represented 15% of the stimuli and were presented in the same list locations as phoneme targets.

In order to motivate subjects and to ensure attention to the task, each subject was paid 15 cents for each target detected.

RESULTS

A three-factor analysis of variance with repeated measures on one factor (number of errors) was performed, with number of errors (false positives and omissions) as the dependent variable. The two between-group factors were left hemisphere damage vs. right hemisphere damage, and anterior lesion site vs. posterior lesion site. One repeated within-group factor was task stimuli (phoneme vs. timbre.

The results (Table 2) show a main effect for task stimuli ($F = 13.57$, $p = .0025$). Left hemisphere CVA patients performed poorly on the phoneme task only, and right hemisphere CVA patients exhibited the opposite effect. False positive responses for both groups of patients for both listening tasks were categorized in comparison to target stimuli. For phonemes, high acoustic frequency (/f/, /s/) and low acoustic frequency (/m/,/j/) responses were sorted; for timbres, octave and nonoctave responses were sorted. Chi square analysis revealed no pattern of false positive phoneme responses for either group of patients but a strong pattern of false positive timbre responses ($F = 1$, $p = .0065$) for left hemisphere damaged patients only, indicating that this group of patients made errors that were in octave relation to the target.

DISCUSSION

The principle finding in the study is that left brain-damaged aphasics have more difficulty with phoneme monitoring than with timbre monitoring, while the right brain-damaged nonaphasic patients show the reverse pattern. This finding appears to be material specific, since the two tasks were designed to be (1) as analogous as possible, (2) similar in such features as volume, stimulus duration and spacing, percentage of "hits," and relative distance of foils from targets; and (3) comparable in response mechanisms (ipsilateral hand).

The observation of a reciprocal performance on these analogous tasks in left and right damaged patients supports the association of phonological processing with the left hemisphere and its disruption in aphasia, and provides support for the view that phoneme monitoring involves linguistic rather than purely acoustic or attentional mechanisms. The pattern of impairment according to hemisphere damaged is also inconsistent with an interpretation of the aphasics' performance based on task complexity or degree of effort. In fact, in pilot studies with normals monitoring for two phonemes or two timbres, the latter task was judged the more difficult.

No clear relationship was found between lesion localization (anterior vs posterior) or aphasia type and performance on the phoneme monitoring task, though the number of patients was small. Severity of aphasia, as determined by Boston Diagnostic Aphasia Examination scores, was also not correlated with task performance. Furthermore, a separate analysis of patients deemed musically sophisticated prior to their strokes failed to disclose patterns deviating from the froup mean. Specifically, musically sophisticated subjects did not make errors consistent with a left hemisphere shift for timbre processing.

Of note is the fact that these tasks were employed as activation measures in a PETT study of glucose metabolism in normal subjects (Bartlett, Brown, Wolf, & Brodie, 1985). In this study, phoneme and timbre stimulation resulted in similar patterns of metabolic rates - namely, slightly greater left than right values- though regional data showed greater intersubject variability on language activation. Specifically, we did not find task-dependent metabolic asymmetries on the phoneme and timbre stimuli such as reported by Mazziota et al. (1982) for language and timbre activation. In the latter study, however, stimuli were different in material (story vs. timbre pairs), operations (listening vs. same/different judgments); and response measures (subsequent retrieval vs. motor response). When these operations are controlled, as in the present study, phoneme and timbre stimuli give similar metabolic patterns. Thus, the data indicate that lesion effects and behavioral dissociations are perhaps more sensitive than currently available metabolic correlations.

TABLE 1
Parameter Values for Timbre Stimuli

Timbre parameter	A(target)	B	C	D	E	F	G
Percussion rate	51	225	97	11	150	250	120
Percussion volume	224	222	226	222	250	250	250
Fall rate	40	40	57	45	100	80	140
Fall volume	224	0	218	0	220	80	80
Attack rate	40	225	97	189	180	250	120
Attack volume	224	225	226	227	250	250	250
Decay rate	25	17	28	19	180	40	120
Release rate	40	40	57	68	80	80	140
Release volume	0	0	0	0	0	0	0

TABLE 2
Individual Responses for Both Groups of Patients on Phoneme and Timbre Monitoring Tasks

	Correct		False positives		Omissions	
	Ph	Ti	Phoneme	Timbre	Ph	Ti
Aphasics						
A	15	15	2	0	0	0
A	3	14	22	3	12	1
A/p*	9	14	11	5	6	1
A	14	14	0	1	1	1
A/P	7	10	12	1	8	5
P	15	15	0	2	0	0
P*	15	15	0	4	0	0
P	13	12	24	3	2	3
A/P	8	10	7	2	7	5
A*	9	14	1	3	6	1
Mean	10.8	13.3	7.9	2.4	4.2	1.7
Total stimuli 104			Total targets 15			
A	13	13	0	6	2	2
A/P	13	5	0	10	2	10
P	13	15	0	2	2	0
P*	15	15	0	2	0	0
P	14	0	0	7	1	15
P	15	7	0	29	0	8
A	15	15	0	14	0	0
A	14	1	1	21	1	14
A	14	3	0	8	1	12
P*	15	15	0	0	0	0
Mean	14.1	8.9	0.1	9.9	0.9	6.1
Total stimuli 104			Total targets 15			

Note. * = Musically sophisticated; A.P., and A/P refer to anterior, posterior, or combined lesion localization.

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