

# Cortical-evoked Potentials and Aphasia: A Follow-up Case Study

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Our previous findings (Selinger, 1984; Selinger, Prescott, & Shucard, 1989; Selinger, Shucard, & Prescott, 1980; Shucard, Cummins, Thomas, & Shucard, 1981) using auditory evoked potentials (AEP) as noninvasive measures of hemispheric language processing in aphasic patients has shown higher amplitude right-hemisphere responses to a verbal task. The aphasic patient group showed a different pattern of hemispheric asymmetry across conditions from the normal group. Of particular significance was the relatively larger right-hemisphere response that occurred during the processing of verbal information. The normal group did not exhibit statistically significant ( $p < .05$ ) task-dependent asymmetries. In addition, there was a relationship between increased severity on aphasia tests and greater involvement of the right hemisphere to the verbal tasks.

The evoked potential technique that was used is known as a *probe paradigm*, in which a task-irrelevant sensory stimulus is superimposed on an ongoing complex task. The technique assumes that processing the information required for the complex task will reduce the active neuronal systems' ability to respond to the irrelevant stimulus. Conclusions are subsequently drawn about the hemisphere most involved in the complex task based on each hemisphere's response to the irrelevant probe stimulus. In addition, probe paradigms assume that as the complex task increases its demand on the neurological system, the amplitude of the response to the probe will diminish (Papanicolaou & Johnstone, 1984).

These assumptions are based on the notion that the brain is a limited capacity system—limited by more than structure in the number of things it can do at one time. Also, increasing the demand of the task causes some performance to deteriorate. Therefore, we concluded that differential hemispheric activity in a task was measured by the hemisphere's responses to the irrelevant probe. In addition, the inverse relationship between severity of language deficits and larger degree of right-hemisphere pro-

cessing led to the conclusion that once the left hemisphere had reached its level of reduced limited capacity severe deficits resulted from the right hemisphere exhibiting larger engagement in language.

Specifically, the various errors in language that are exhibited in aphasic patients may result from the unsophisticated or undeveloped attempts by the right hemisphere at language processing. Although the right hemisphere appears to be somewhat adaptable to simple auditory comprehension, it is believed to use a style of information processing that differs from the left hemisphere's. Therefore, these differences may make the right hemisphere less effective in language processing (Gazzaniga and Smylie, 1984; Holtzman & Gazzaniga, 1982; Zaidel, 1976).

In order to determine the stability of the cortical activity measurements a single subject replication of the original (Selinger et al., 1980; 1989) auditory evoked potential paradigm was utilized.

This investigation aimed to compare aphasia test results and auditory evoked potential test results on an aphasic patient who had participated in our original study in 1980 and who was re-tested in 1990 using the same evoked potential paradigm.

The following specific questions were addressed:

1. Were the occurrences of the evoked potential peaks stable over the test/re-test period?
2. Were the hemispheric microvolt asymmetries stable over the test/re-test period?

## SUBJECTS

The aphasic patient was a 62-year-old, premorbidly right handed, single-incident left posterior-temporal lobe damaged male. He was 9 years post onset of cerebrovascular accident (CVA) at the time of the second testing and his Porch Index of Communicative Abilities (PICA) (Porch, 1967) Overall scores were 2 percentile points higher than his scores of 9 years ago. His Boston Severity Rating Scale Score (Goodglass & Kaplan, 1972) had changed from 1 to 4. (See Tables 1 and 2.)

**TABLE 1. BEHAVIORAL TEST SCORE COMPARISONS**

	<i>PICA O.A.</i>	<i>PICA VI</i>	<i>PICA X</i>	<i>Boston Severity</i>
1980	13.69 (87)	14.5 (58)	14.4 (54)	1
1990	14.0 (89)	14.2 (53)	15.0 (99)	4

All items in parenthesis represent percentile scores.

TABLE 2. PICA SCORE COMPARISONS

	<i>PICA O.A.</i>	<i>Gestural</i>	<i>Verbal</i>	<i>Graphic</i>
1980	13.69 (87)	14.36 (92)	13.15 (66)	13.17 (93)
1990	14.00 (89)	14.40 (87)	13.60 (76)	13.73 (93)

All items in parenthesis represent percentile scores.

## METHODS

To examine hemispheric differentiation in processing, three tasks previously found to produce hemispheric asymmetries were presented (Shucard, Shucard, & Thomas, 1977). The left-hemisphere task was verbal, the right-hemisphere task was music, and the neutral task was noise. Each task consisted of presenting five 3-minute taped segments to the subject through headphones. The neutral task contained a hissing noise with randomly imbedded clicks. The verbal task contained five listening passages (Sequential Tests of Educational Progress [STEP], 1959). The music task contained five classical music pieces with simple recurring melodies. The subject was instructed to listen to each task and to respond by exhaling through the nostrils each time he heard a click in the baseline task, a recurring word in the verbal task, or a recurring melody in the music task. A specified key word, melody, or click was presented to the subject prior to the onset of the appropriate segment. In addition, the subject was asked two multiple-choice questions following each verbal segment. These tasks were used to indicate the subject's alertness, understanding of and ability to perform the task. Each target item occurred 6 to 14 times within each segment.

Approximately 20 600 hertz, 100 msec. auditory tone pairs were superimposed on the tasks as probes and the evoked potentials were averaged to these tones. These tone pairs, beginning 15 to 20 seconds after onset of each segment, were irrelevant to the target detection tasks. The delay of the tones' onset allowed the subject sufficient time to become involved in the task. Auditory AEPs were averaged on-line separately for tone 2 of each pair as the subject performed the tasks.

Test sessions occurred once a week for two consecutive weeks. All three tasks were presented during each session, with a five-minute rest period separating each task and a 30-second rest period separating each segment. The neutral task was always presented first, with the verbal and music tasks counterbalanced for order across session. During each session the subject was seated in a sound-attenuated electrically shielded room. The subject kept his eyes closed during each three-minute seg-

ment. Bipolar electrode measurements were made from left and right temporal placements (T3, T4) referenced to the vertex (Cz) (Jasper, 1958). Glass gold-plated disc electrodes were affixed to the scalp sites. Impedances from each electrode were measured at the beginning and end of each session. Electrode impedances were no greater than 5,000 ohms.

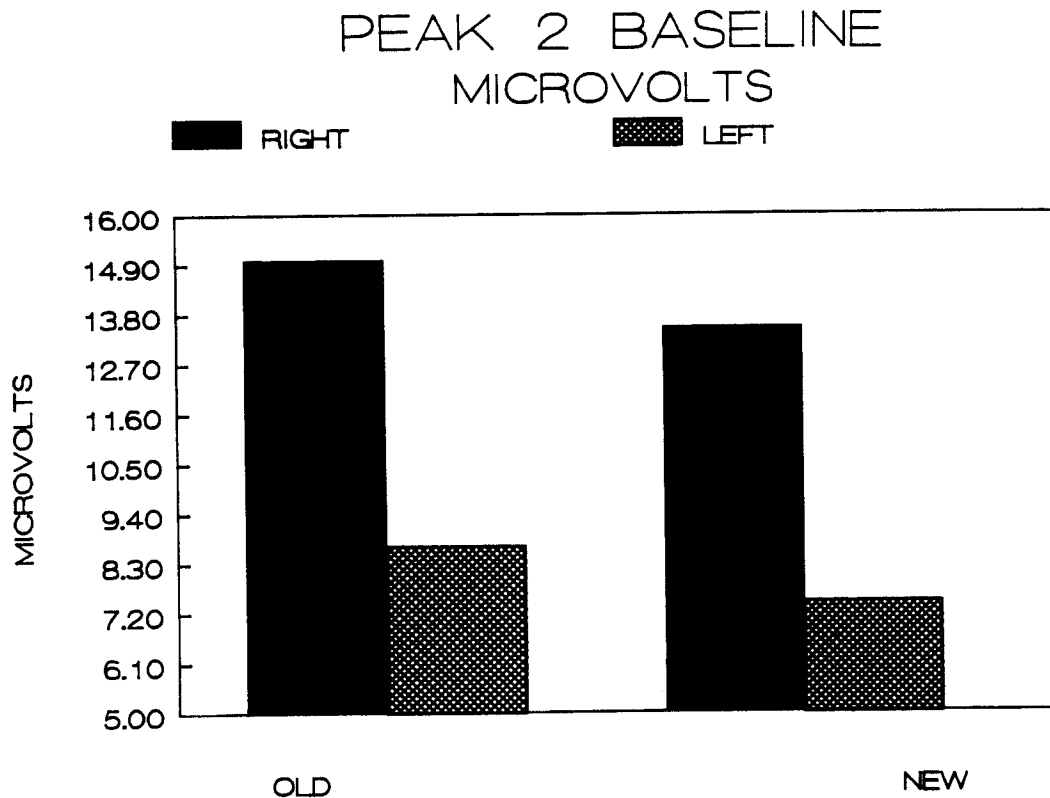
A Modular Instruments Signal Averaging system, interfaced with an AMDEC computer, generated the tones and averaged and scored the data. Scores include microvolt amplitudes and msec. latencies of three AEPs. Peak N1 (a negative going peak, mean latency, 117 msec); P2 (a positive going peak, mean latency, 177 msec); and N2 (a negative going peak, mean latency, 222 msec).

## RESULTS

To determine if there were any systematic AEP millisecond differences between the 2 10-year-separated tests, Analyses of Variance (ANOVAs) (Madigan & Lawrence, 1982) for repeated measures were performed separately for each AEP peak and each task. No significant ( $p < .05$ ) session effects were obtained for any of the peak millisecond measures. The descriptive statistics are summarized in Table 3.

**TABLE 3. AMPLITUDES IN MICROVOLTS FOR PEAKS 2 AND 3**

<i>Conditions</i>	1980			
	<i>Peak 2</i>		<i>Peak 3</i>	
	MEAN	S.D.	MEAN	S.D.
Baseline Right	15.00	1.62	11.59	2.97
Baseline Left	8.71	2.47	7.10	2.02
Verbal Right	13.65	5.50	12.89	1.89
Verbal Left	5.95	2.80	5.41	.61
Music Right	8.98	.56	6.84	.87
Music Left	7.45	2.11	5.12	3.09
1990				
Baseline Right	13.50	3.67	6.40	2.96
Baseline Left	7.45	1.62	3.10	.42
Verbal Right	6.09	1.55	5.00	.00
Verbal Left	7.15	2.61	5.53	2.16
Music Right	8.10	5.37	4.88	2.76
Music Left	5.70	1.97	4.35	2.51

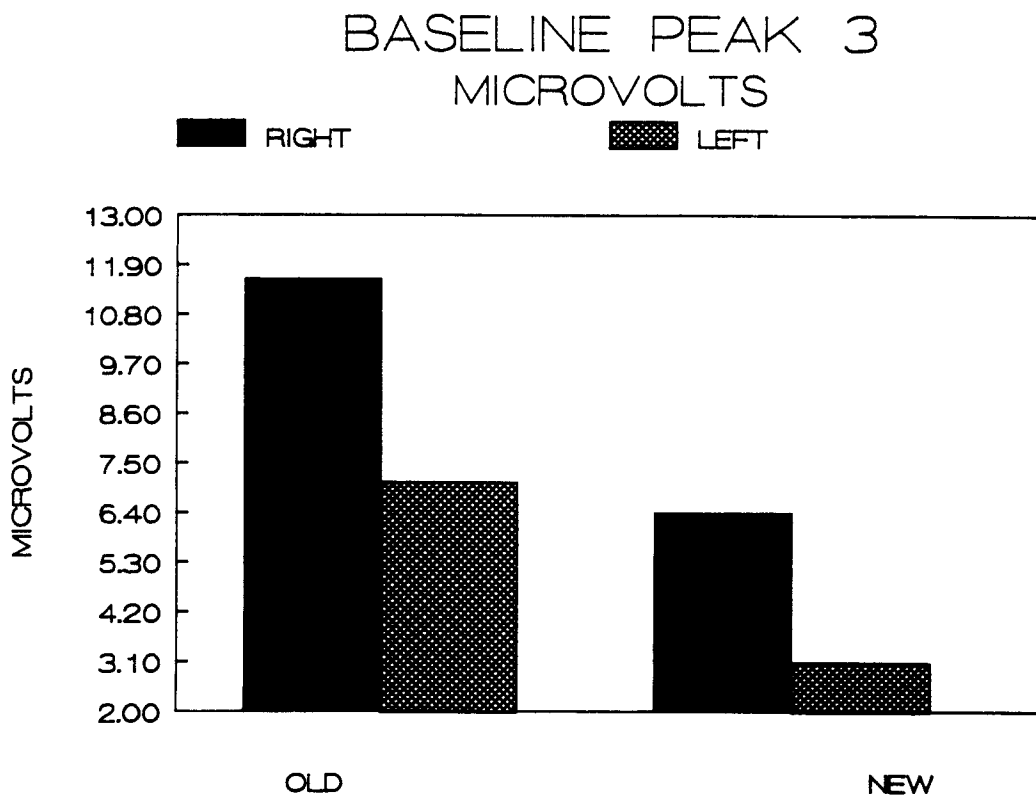


**Figure 1.** Evoked Potential right and left peak 2 (a positive going peak with a mean latency of 177 msec) comparisons on the baseline task for the 10-year testing period.

The results indicate that, for all tasks, the right hemisphere response was smaller in amplitude than it had been previously. On the Baseline Task there was not much change in amplitude for either hemisphere over the testing periods. In all cases the right hemisphere had a larger amplitude response than the left hemisphere (see Figures 1 and 2). On the Verbal Task, the left hemisphere exhibited almost no amplitude differences over time, while the right hemisphere reduced in amplitude by almost half (see Figures 3 and 4). During the initial test sessions, the right hemisphere consistently exhibited a larger amplitude response than the left. The recent assessment exhibits virtually no differences. The Music Task exhibited no major hemispheric differentiation during either set of sessions (see Figures 5 and 6).

## DISCUSSION

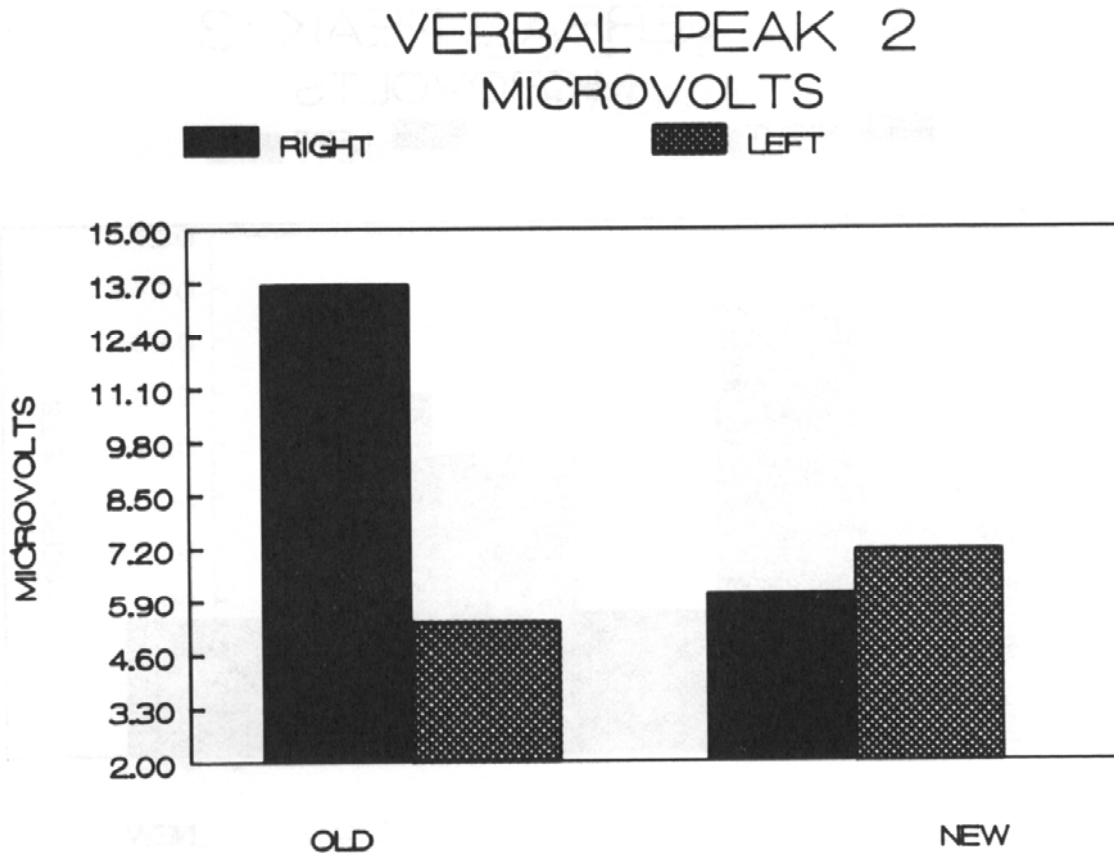
Because on initial testing this subject responded with a large right-hemisphere asymmetry, it appeared that his severe language deficits resulted



**Figure 2.** Evoked Potential right and left peak 3 (a negative going peak with a mean latency of 222 msec) comparisons on the baseline task for the 10-year testing period.

from inadequate attempts by the right hemisphere to process language. This subject's current EP responses exhibited a profile similar to the milder aphasic patients' from the first study. Indeed, the patient behaviorally exhibited the profile of a milder aphasic. As the changes on The Porch Index of Communicative Ability (PICA) (Porch, 1967) and Boston Diagnostic Aphasia Examination (BDAE) (Goodglass & Kaplan, 1972) indicated, the patient had moved from showing marked impairment to exhibiting no impairment on PICA Subtest X, and from showing marked impairment to exhibiting a moderate impairment on the Verbal Subtests. His BDAE Severity had changed from 1 to 4, suggesting an increase in expressive and receptive abilities permitting the patient to be successfully involved in most dialogues.

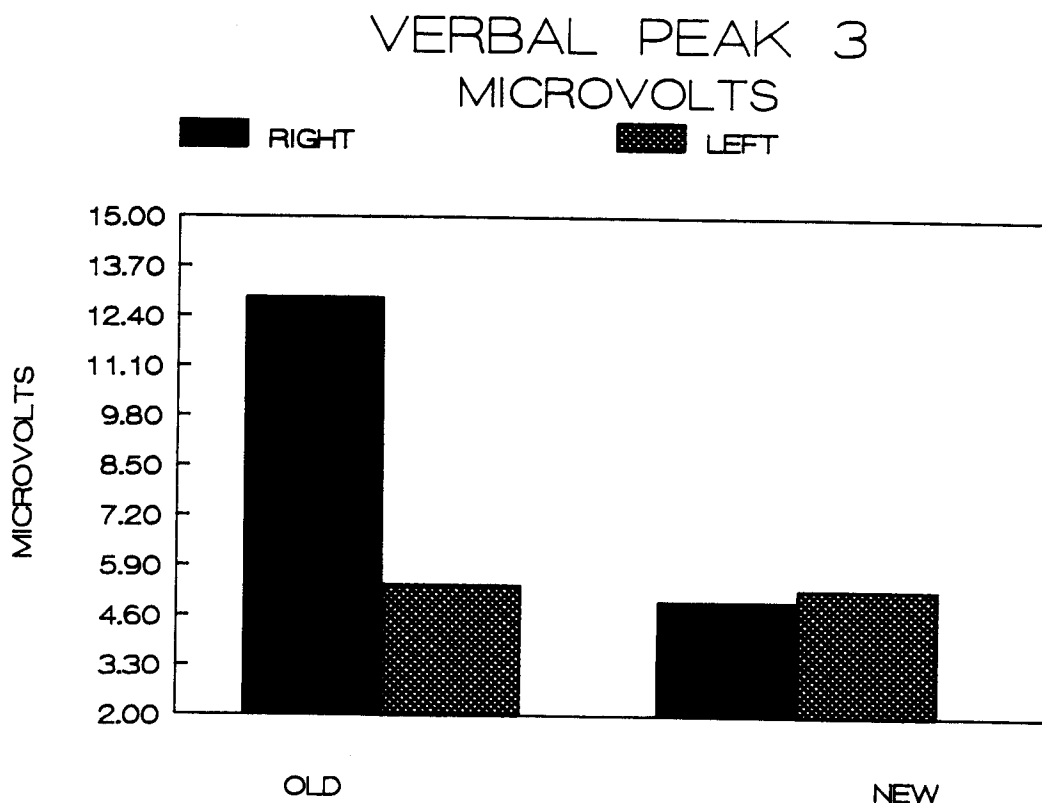
Ten years ago, the AEP pattern of our patient deviated from that of normal subjects and from that of most aphasic patients by exhibiting inter-hemispheric AEPs that were markedly asymmetrical. Ten years later, this patient exhibited AEP waveforms with peaks equal in number and latencies similar to those observed at the time of the first testing. However, at this time the AEP interhemispheric responses were no longer markedly



**Figure 3.** Evoked Potential right and left peak 2 (a positive going peak with a mean latency of 177 msec) comparisons on the verbal task for the 10-year period.

asymmetrical. In fact, the AEP profile closely resembled that of normal subjects in that (1) distinct AEPs were present from both left and right hemisphere placements, (2) recordings from each hemisphere exhibited qualitatively similar AEP amplitudes, and (3) recordings from each hemisphere exhibited the same number of AEP peaks at similar latencies. Specific differences of response by the right and left hemispheres suggest that the patient's right hemisphere increased its involvement in the processing of neutral and verbal information at some time following the CVA. The increased activity in the right hemisphere may have contributed to the severe impairment initially seen in the patient.

During the 10-year period that followed the initial series of tests, the AEP patterns in this subject showed some change. The right hemisphere became less involved in verbal and baseline processing, though its involvement in music processing remained unchanged. (Since music in the unsophisticated individual has previously shown to be a right hemisphere task, it is not surprising that there were no hemispheric changes in response to this task.) The baseline or neutral task continued to exhibit a right response larger than the left response over the 10 years, but the right hemisphere has decreased in amplitude, reflecting less marked asymmetry. During the ver-

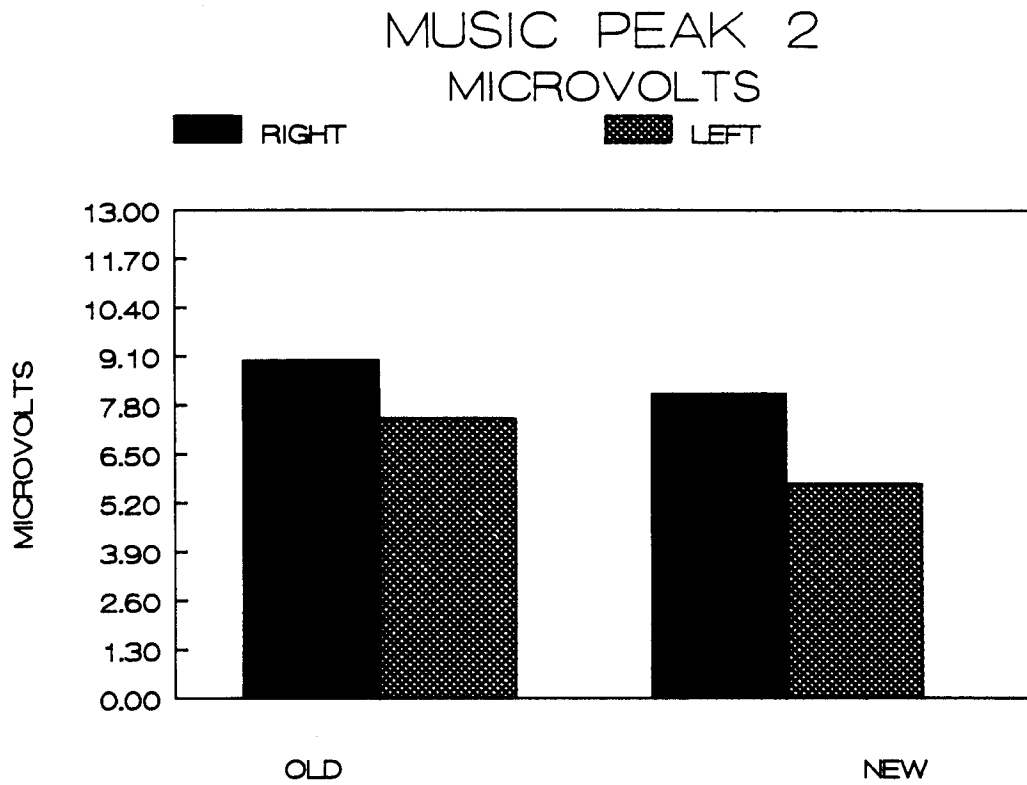


**Figure 4.** Evoked Potential right and left peak 3 (a negative going peak with a mean latency of 222 msec) comparisons on the verbal task for the 10-year period.

bal task the greatest changes occurred, with the right-hemisphere response reduced in amplitude by approximately half, resulting in almost equal interhemispheric amplitude responses. During all conditions and over all testing sessions, in the 10-year period, the left hemisphere exhibited almost no changes. The markedly asymmetrical response in the right hemisphere was reduced over the 10-year period between testing sessions.

At this point it appears that the probe paradigm and the assumption that it is measuring a limited capacity system are supported through resource allocation theory, whose models postulate that both hemispheres have the capacity to process given tasks (Friedman & Polson, 1981; Norman & Bobrow, 1975). Cognitive activity, then, could be considered a group of independent processors that interact by exchanging information and competing for a common pool of resources. Both hemispheres, then, may increase their involvement in a task until they reach the ceiling of their competencies. If the conceptual ability of the more competent hemisphere is reached, then there could be an added load or processing shift to the other hemisphere, thereby forcing one hemisphere to use an inappropriate strategy for the task at hand. Neurological damage may reduce the capacity or the allocation of resources in the more competent hemisphere.



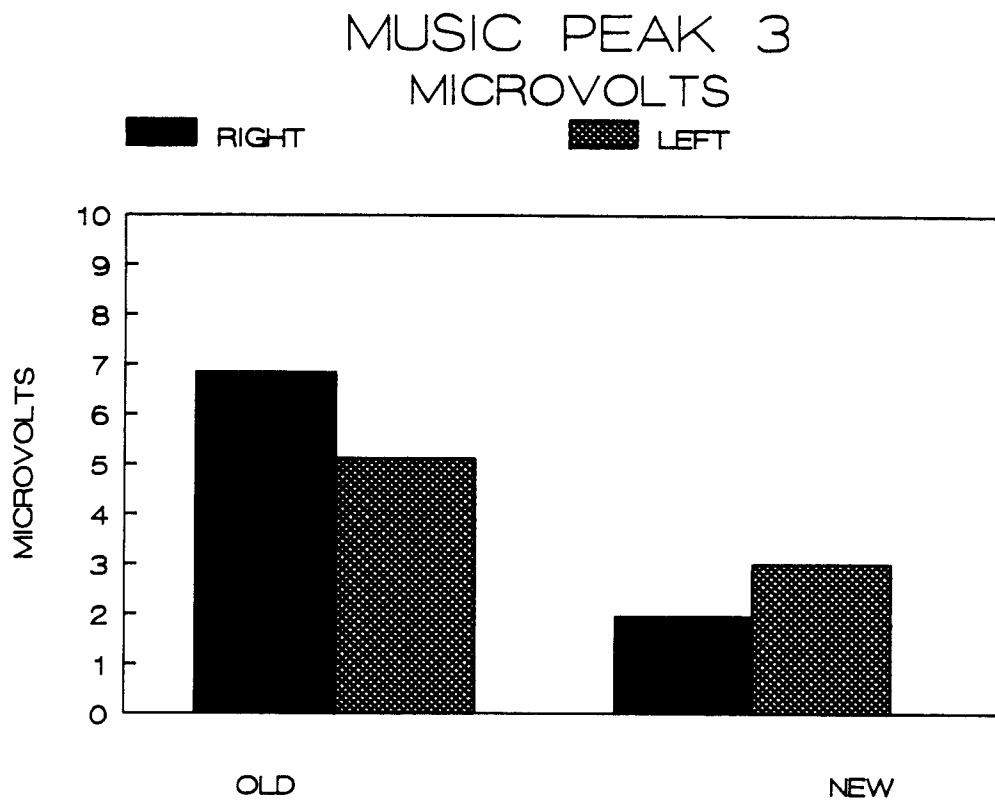


**Figure 5.** Evoked Potential right and left peak 2 (a positive going peak with a mean latency of 177 msec) comparisons on the music task for the 10-year period.

Subsequent transfer of the load to the less competent hemisphere may then force processing that exceeds the natural abilities of that hemisphere. The activated hemisphere may selectively process information in terms of its natural competency. In the case of language, the right hemisphere is not as competent as the left for this function, thus producing the increased severity of language impairment seen earlier in this subject.

Resource allocation is a dynamic model that highlights energy rather than the implied static functional and structural changes of earlier models of higher cortical functioning following neurological damage. The findings of our current investigation may indicate that resources for added load are no longer being allocated to the right hemisphere. The patient exhibited milder aphasia profiles than had been previously observed with co-occurring lack of differential hemispheric activity during language tasks. It is possible that over time, as the damaged left hemisphere stabilized and recovery continued, there was decreased effort for processing language within the left hemisphere and therefore it was again able to attend to the task at hand.

Task demand has been compared to attention and automation abilities for the individual (Allen, 1983; Crossley & Hiscock, 1987; McNeil, Odell,



**Figure 6.** Evoked Potential right and left peak 3 (a negative going peak with a mean latency of 222 msec) comparisons on the music task for the 10-year period.

& Tseng, 1991). When the task required a great deal of effort it also required increasing amounts of allocation of resources. A task that is simple or well practiced requires little attention (Crossley & Hiscock, 1987) and decreased amounts of resources allocated to the task. Measurements of laterality using evoked potentials appear to be related to the effort required to complete the task. A severely involved aphasic patient may need increased effort for language processing while a less involved patient may use less effort during the language task.

The lack of asymmetry seen in both less involved patients and normal controls is believed to be due to task demand. A complicated and difficult task uses more resources, and measured asymmetries may result. In our previous work severely aphasic patients exhibited language asymmetries while normal controls and more mildly impaired subjects did not. Our current subject exhibited asymmetries during an earlier stage of his recovery. Since the left hemisphere response remained essentially stable over the 10-year period it is possible that, with practice, language processing required less effort, the left hemisphere resources were less utilized, and no load overflow occurred.

It is important to note that the observed changes occurred sometime following one year post onset of the CVA in this patient. Such physiological changes obviously raise issues concerning the well-established idea that all recovery occurs during the first 6 months post onset and that treatment of aphasia should be limited to the first year following stroke. Naturally, these findings are preliminary, and we have not been able to study appropriate treatment paradigms or time periods of functional change for the recovery profile in this patient. Since we have previously reported that there are different profiles of asymmetry for different patients (Selinger, Prescott, & Shucard, 1989; Selinger, Shucard, & Prescott, 1980), we would like to suggest that use of electrophysiological testing as part of the diagnostic battery in individual patients may lead to information about the patient's recovery that will allow clinicians to adapt specific treatment programs to the neurological processing styles of each patient, as well as to develop time line predictions for continuing treatment in each patient. These preliminary findings suggest that the physiological responses of the hemispheres may continue to change pattern even after behavioral tests indicate stability.

## ACKNOWLEDGMENT

Special thanks go to Kathy Adams Walker, without whose help it would be impossible to run any subjects or produce any documents, and to T. Williams who believed that a contribution to science was a foremost obligation. This paper was funded by a Veterans Affairs Rehabilitation Research and Development Grant #C-493.

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