Using Cortical Evoked Potentials in Aphasiology

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The development of signal averaging techniques provided researchers with a way of measuring from the scalp the brain's response to external sensory stimuli (e.g., tones, flashes) (Lindsley, 1969). The averaging technique preserves the brain's responses, which are time-locked to the onset of the sensory stimuli. By repeatedly presenting the stimulus, the time-locked response increases in amplitude while unrelated, somewhat random electrical activity, such as the ongoing EEG, is reduced in amplitude. Thus, eventually, the event-related potential (ERP) becomes visible over the more random, higher amplitude background EEG (Callaway, 1973; McCandless and Best, 1964).

The ERP represents the interaction of post-synaptic potentials of hundreds, if not thousands, of neurons involved in the processing of a particular stimulus. Although it is not completely clear which specific populations of neurons are measured when ERPs are recorded, some relationships have been established between cortical sites and electrode placements used as well as with the type of stimuli presented. Using specifically defined stimulus conditions, it is possible to obtain information about the functional sensory cortex that responds to the external stimuli as well as information about more complex cortical functioning related to the effects of psychological factors on stimulus processing (Goff, Allison, and Vaughn, 1978).

The ERP is defined in terms of <u>phase</u>, <u>latency</u>, and <u>amplitude</u>. These measures are illustrated in Figure 1. The phase of the ERP refers to polarity changes in the response. The symbols N and P are used to denote negative and positive shifts, respectively (Goff *et al.*, 1978).

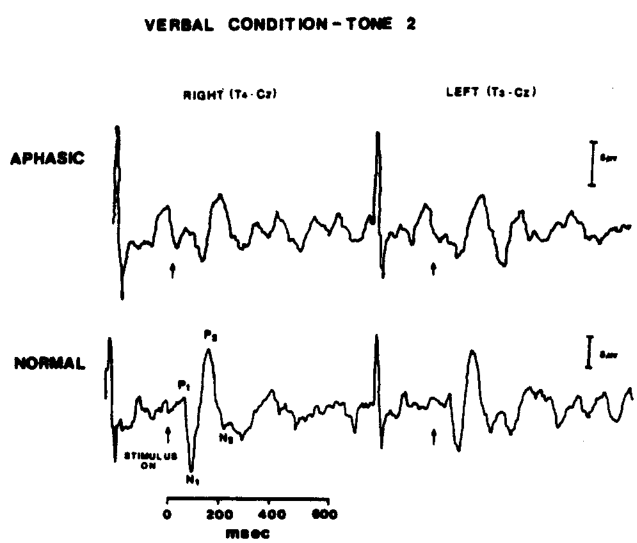

Figure 1. Sample event-related potential. Arrow indicates stimulus onset, amplitude is defined as the distance from P_1 to N_1 (first positive-going peak) etc.[1] Peak latency is defined as the time in milliseconds from the onset of the stimulus. The deflection in the waveform prior to th stimulus onset is the calibration signal.

The latency of the response refers to the time in milliseconds from the onset of the stimulus to a particular ERP peak. For example, a positive peak occurring 100 milliseconds from stimulus onset would be expressed as P_{100}.

Higher order cognitive events have usually involved relationships with ERP peaks later than 100 msec (Goff et al., 1978; Donchin, Kutas and McCarthy, 1977). The ERP peak amplitude measure usually refers to the peak to trough distance in microvolts of a given part of the ERP wave form.

It would be an impossible task for one paper to review all of the studies related to cortical evoked potentials and higher cortical function in man. There is an extensive literature on the relationship between ERP measures and such variables as attention, expectancy, information processing, reaction time, language, and hemispheric specialization (Pritchard, 1981; Donchin, 1979; Goff et al., 1978; Donchin et al., 1977; Donchin, 1975; Begleiter, Porjesz, Yerre, and Kissin, 1973; Buchsbaum, Silverman, Henkin, and Pfefferbaum, 1971).

The clinical applicability of evoked potentials has been recognized in the literature for demonstrating abnormal sensory system functioning, localizing lesions, and defining the distribution of a disease process. The use of ERPs for medical diagnoses has largely remained in the areas of multiple sclerosis, nervous system tumors, operative procedures, CVAs, and in matters of brain death (Chiappa and Ropper, 1982). Therefore, the main area of interest has been structural rather than functional or rehabilitative. In addition, the vast majority of these studies utilize brainstem rather than cortical ERP techniques.

Little information is currently available pertaining to the relationship between ERPs and abnormal processing of language in the aphasic patient. The few studies reported in the literature have confined their investigations to measurement of recovery, comparisons of levels of severity, and localization of lesions (Duffy, 1982; Harmony and Alvarez, 1981). Most of these studies have yielded inconclusive results. For example, Kolman and Shimizu (1972) investigated the relationship between recovery from aphasia based on comparisons on the Minnesota Test for Differential Diagnosis of Aphasia (MTDDA) (Schuell, 1965) and ERPs obtained from tone and click stimuli. According to this investigation, as language scores on the MTDDA improved over a seven month period, ERPs recorded from C_Z to linked mastoids increased in amplitude and the peaks became more reliable.

In another study, Liberson (1966) classified aphasic patients (without the use of any standard aphasia test) into groups, based on severity. Recording ERPs from left and right Central, Parietal and Occipital to ipsilateral ear leads, the author reported inconsistent patterns of auditory and visual ERPs among patients and concluded that such responses were not correlated with the degree of aphasia. An alternative conclusion may be that such inconsistent response patterns may be indicative of the type of aphasia rather than the degree of aphasia in the sample studied. Since the subjects in this study were grouped only according to severity, the alternative hypothesis could not be examined. Liberson concluded that only ERPs obtained by median nerve stimulation appeared to be good indicators of aphasia severity in these patients.

Greenberg and Metting (1974) tested a group of six aphasic patients who were classified on severity according to the Functional Communication Profile. The patients were asked to discriminate between single words (bug-duck) or similarly shaped envelopes of white noise. Subjects presented inconsistent and variable ERPs recorded from both T_5-F_3 and T_6-F_4. No effect was found when data were analyzed for hemisphere or stimulus effects. The use of discrete words as linguistic stimuli and similarly shaped envelope white noise as nonlinguistic stimuli for eliciting ERPs may only have tapped into lower levels of processing, such as discrimination or perception. Thus, these findings cannot be generalized to the processing of more complicated stimuli.

In an attempt to localize lesions in aphasic patients, Morley and Liedtke (1976) studied ERPs to tones and clicks presented to the left, right, and both ears; light flashes presented to both visual fields; and somatosensory stimulation of the median nerve. ERPs were recorded from FP_1, T_5, O_1, P_3, C_3 (and homologous areas on the right hemisphere) and references to a scalp site below and anterior to C_3 for the left hemisphere placements and C_4 for the right hemisphere placements. Their classification of aphasia groups was based on measurements derived from amplitudes and latencies of specific ERP peaks. The resulting localization of lesions agreed with 80 percent of the lesion findings obtained with EEG measures, 85 percent with brain scans, and 86 percent with angiographic results on lesion localization. This study lends support for the potential use of ERPs in classification and diagnosis of aphasic patients.

Using three patients exhibiting alexia without agraphia, Neville, Snyder, Knight, and Galambos (1979) attempted to use neutral and differentially activating tasks for both the right and left hemispheres to measure hemispheric asymmetry. Two differences in the ERPs, recorded from P_3, P_4, C_3, C_4, O_1,O_2 referenced to linked mastoids, occurred between the patient and control groups. First, a significant hemispheric amplitude asymmetry (left greater than right) was present between the parietal leads for ERP peaks with a latency of 325 msec in the patients but not in controls. Second, N_{150} was absent over the right occipital leads in the patient population.

Selinger (1982) examined the relationship between electrophysiological measures of differential hemispheric processing and the auditory comprehension deficits exhibited by aphasic patients. Each subject completed a standard administration of the _Porch Index of Communicative Ability_ (PICA), a _Revised Token Test_ (RTT), and a _Boston Diagnostic Aphasia Examination_ (BDAE). The AERP to pairs of tone stimuli were obtained under three experimental conditions (Baseline, Verbal, and Music) from left and right temporal scalp electrode placements referenced to the vertex.

During the Verbal Condition aphasic patients showed higher amplitude right hemisphere responses compared with left. Normal subjects, on the other hand, showed little to no AERP amplitude asymmetries across conditions. The results of the comparisons between the electrophysiological measures and the aphasia tests indicated a relationship between greater severity and right hemisphere processing of language related tasks.

Recently, Woods, Knight and Neville (1984) reported a case study of a patient with bitemporal lesions exhibiting symptoms of cortical deafness. Despite abnormal audiometric data, evoked responses appeared to be normal. This investigation exhibits the potential uses of ERPs in functional diagnoses.

In summary, although there have been only a few studies which have used the ERP in investigations of aphasia, those that have suggest that the ERP method may provide useful information about aphasia. Most of these investigations, however, attempted to relate ERPs to recovery or severity factors. Few of them used standardized measures for aphasia assessment or reliable classification techniques. In addition, a lower level control task was employed in only two studies (Neville _et al._, 1979). Thus, comparison could not be made between task and no task conditions. Most of these studies used discrete stimuli, some of which had no relation to language, to elicit ERPs; only one studied connected language. Although most of the investigations used left and right hemisphere electrode placements, only two used tasks which were believed to differentially activate left and right hemisphere functions. Failure to use such tasks limits any conclusions one might make concerning hemispheric involvement in the various measures. Finally, most of these studies use a medical model as their basis for studying aphasia. That is, their strong interest seems to lie in making conclusions about diagnostic categories and prognostic statements. Few of these studies are concerned with ascertaining functional profiles of aphasic patients that would be of value in language treatment programs.

Future research should consider each patient individually. For example, Selinger, Shucard and Prescott (1980) reported that five of the aphasic subjects they studied exhibited different patterns of hemispheric activation during a verbal task. Both left and right hemispheric activation was represented among these patients. Selinger (1982) found that seven of ten aphasic patients exhibited greater right than left hemisphere processing of language. In both reports patients exhibiting patterns with left hemisphere activation appeared to be less severely impaired. Analysis of individual differences is an important aspect of further research in this area.

Absence of session effects or interactions of session with any of the factors examined by Selinger (1982) provided further support for the use of ERPs as a means of assessing language comprehension in aphasic patients. Since aphasia is often believed to be a disorder showing considerable variability over time, any measure that exhibits consistent findings from week to week may prove to be a valuable tool for measurement of aphasic disturbances. Further study using these techniques is needed to examine aphasic variability in order to clarify inconsistent behaviors exhibited by these patients. Advancements in electrophysiological instrumentation which allow for analysis of single as compared to summated ERPs may contribute additional information about variability in aphasia.

The notion that the right hemisphere possesses some language abilities may be incorrectly taken to mean that release of the right hemisphere from inhibition by the left hemisphere would be beneficial to the recovery of language function. Further, the idea that the right hemisphere takes over language function to the exclusion of the left appears to be too simplistic. Instead, there appears to be a range of right hemispheric involvement across aphasic subjects and the degree of right hemisphere activation is related to aphasia severity as measured by behavioral assessment (Selinger, 1982).

The vast majority of treatment techniques for aphasia are aimed at stimulating language recovery by analytical breakdown of the stimulus items and tasks. Such treatment paradigms may be inappropriate for the patient with right-left AERP amplitude asymmetries which show a much higher right hemisphere response. Addition of the AERP technique to a battery of evaluative measures for aphasia could clarify this issue, and allow aphasiologists to more completely assess the patient's language function.

Previous findings lend support to the potential usefulness of electrophysiological techniques in the field of aphasiology. While standard measures of aphasia provide information concerning observable behavioral deficits in this disorder, the AERP measures may enhance our knowledge about the functional organization of the brain. The use of both techniques may provide a more complete understanding of aphasia. The behavioral measures could provide information about the "what" of aphasia while the electrophysiological measures could provide information about the "where" and "how." Thus, these methods used in combination could provide a more accurate profile of an aphasic individual.

Applications of electrophysiological techniques to aphasia have a wide variety of implications for further research. First, use of larger numbers of subjects, and more varied groups would allow previous conclusions to be generalized to a broader population of aphasic patients with a broader range of impairment. It is of importance, therefore, to study patients whose deficits cover a large range of severity. Second, future projects should rigorously examine the relationships between widely used aphasia assessment tools and evoked potential response. Third, as is always the case in research with pathological populations, it will be crucial to use longitudinal designs in subsequent studies. Although conclusions resulting from group data are important to the knowledge of neurological mechanisms, findings obtained with group data are limited in their application to individual patients. Longitudinal designs could contribute information to the field of aphasiology in terms of severity, prognosis, recovery, and treatment approaches.

For example, information concerning which hemisphere is most actively involved in processing of verbal information in an individual patient could contribute to the development of treatment approaches tailored to the manner in which the active hemisphere deals with incoming information. In addition, the AERP technique may have predictive value in terms of initial severity. A study designed to longitudinally test individual subjects may allow information that would prove to have prognostic utility for aphasic patients to be obtained shortly after the brain lesion has occurred.

At this point we have only begun to consider the possibilities available to aphasiologists for examining the many aspects of the disorder. The following years promise to be an interesting time for the application of electrophysiological measures to the field of aphasia.

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