Attention In Aphasia As Revealed by Event-Related Potentials: A Preliminary Investigation

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One of the goals of aphasia research has been to describe with greater specificity the disorder's primary nature. Accordingly, McNeil (1982, 1988) has presented a neurophysiologic theory of aphasia that integrates several conceptual approaches into a consolidated perspective in which deficits otherwise thought to be due to cognitive and/or language impairments are viewed as secondary outcomes of more primary disturbances. According to McNeil, "The primary disturbances appear to consist of such dynamic processes as those attributable to the general consequences of brain damage. These consequences might include such factors as increased fatigability, increased sensory thresholds, decreased speed of reaction, fluctuation of attention and effort allocation, and inertia of neuro-physiologic excitation and inhibition." (1988, p. 746–747)

One assumption of McNeil's theory is that aphasia is the outcome of disturbances to language performance but not language competence. The well-documented performance variability across tasks in aphasia, regardless of the type and severity of aphasia, has been offered as support for these assumptions. Internal state factors are viewed as primary contributors to such variability. In short, because the aphasic patient can succeed at a given language behavior on some occasions, minimal language loss of language competence per se is assumed. The theory also suggests that this variability is due, at least in part, to aphasic patients' inability to consistently allocate adequate attention to a task. Thus, variability is viewed by McNeil as the product of a "neurophysiologic malfunction" (1988, p. 757) rather than as the malfunction itself.

Although McNeil's position possesses intuitive appeal, it has yet to be demonstrated empirically whether it accurately portrays the essential nature of aphasia. Guided by McNeil's theory, we investigated attentional processes in aphasic patients to explore disturbances in attention allocation that may impair linguistic or communicative abilities. We analyzed data obtained from event-related potentials (ERPs) to assess attention during two on-line cognitive tasks. Specifically, we examined aphasic subjects' focused attention for auditory information processing.

EVENT-RELATED POTENTIALS, ATTENTION, AND APHASIA

Naatanen (1990) reports that research in attention behavior is classified into studies involving selective or focused attention and those involving divided attention. Studies of selective or focused attention examine resistance to distraction, as well as that point in the processing chain after which the individual responds differentially to relevant and irrelevant stimuli. A standard paradigm used in ERP research to assess these behaviors is the "oddball paradigm." In this paradigm, the subject is presented with a series of repetitive stimuli that are randomly replaced by a deviant one. Stimuli are presented under two conditions: an active or attend condition and a passive or ignore condition. In the attend condition, the subject's task is to count the deviant stimuli. This is a one-channel attentional task in which the subject must attend to all stimuli in order to detect the deviant stimuli; the task therefore requires focused rather than selective attention. The purpose of the active oddball paradigm is to describe brain responses associated with purposeful discrimination of deviant stimuli. In the ignore condition, attention is directed away from the stimuli to a concurrent task usually involving another sensory modality (for example, reading a book while auditory stimuli are presented). Here the purpose is to examine brain responses that are associated with involuntary attentional switching to deviant stimuli among the ignored stimuli.

The ERP response in the ignore condition is characterized by a wave complex that contains similar N1 and P2 components to both the standard and deviant stimuli. These components correspond respectively to early attentional processes such as those described by Kinsbourne (1974). The first of these, preattentive structuring of the sensory field, consists of segmenting the perceptual field according to Gestalt laws. The second involves attentive focusing on some specific aspect of the input that seems to call for further analysis.

Perhaps the only difference between the ERPs to standard and deviant stimuli in the ignore condition is a new component called the mismatch negativity (MMN) (Sams, Paavilainen, Alho, and Naatanen, 1985; Naatanen, 1990). The MMN is elicited only to the deviant stimuli in the ignore condition. Naatanen (1990) has proposed that "the MMN is generated by a brain mechanism for the automatic detection of a change occurring in

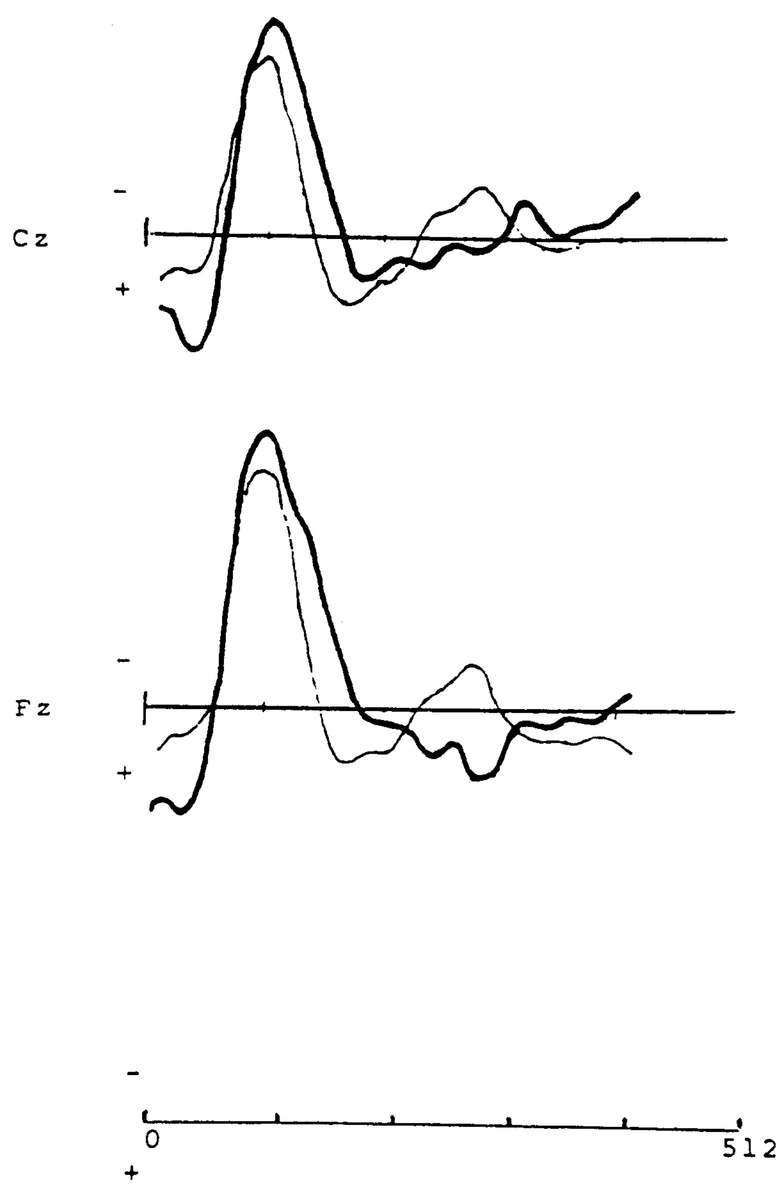
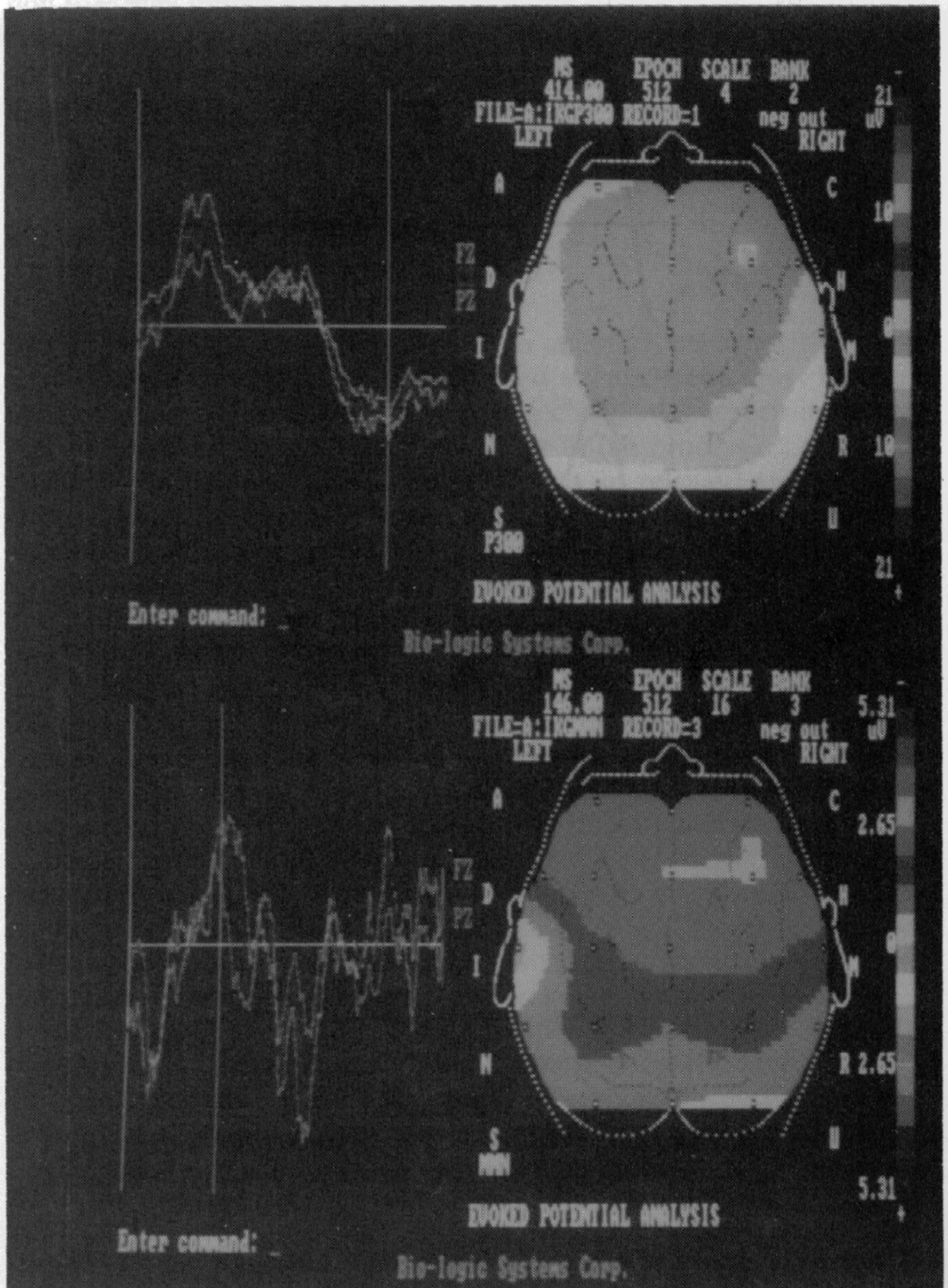


Figure 1. Mismatch negativity demonstrated in the vertex (top) and frontal (bottom) ERPs to the deviants (thick line) and standards (thin line) in the ignore condition.

any repetitive aspect of auditory stimulation." Although the N1 component seems to be a response to individual stimuli, the MMN is related to differences between consecutive stimuli. The MMN component summates with the N1 and P2 components, providing a characteristic appearance that fills in the N1-P2 trough (Figure 1). Its amplitude reaches the maximum frontally but may also be very large near the auditory cortex (Figure 2). The MMN has been used as evidence to suggest that full pro-



Figures 2a and 2b. ERP waveforms and topographic brain maps for a normal (left) and an aphasic subject (right) demonstrating the P300 component (top) and mismatch negativity (bottom).

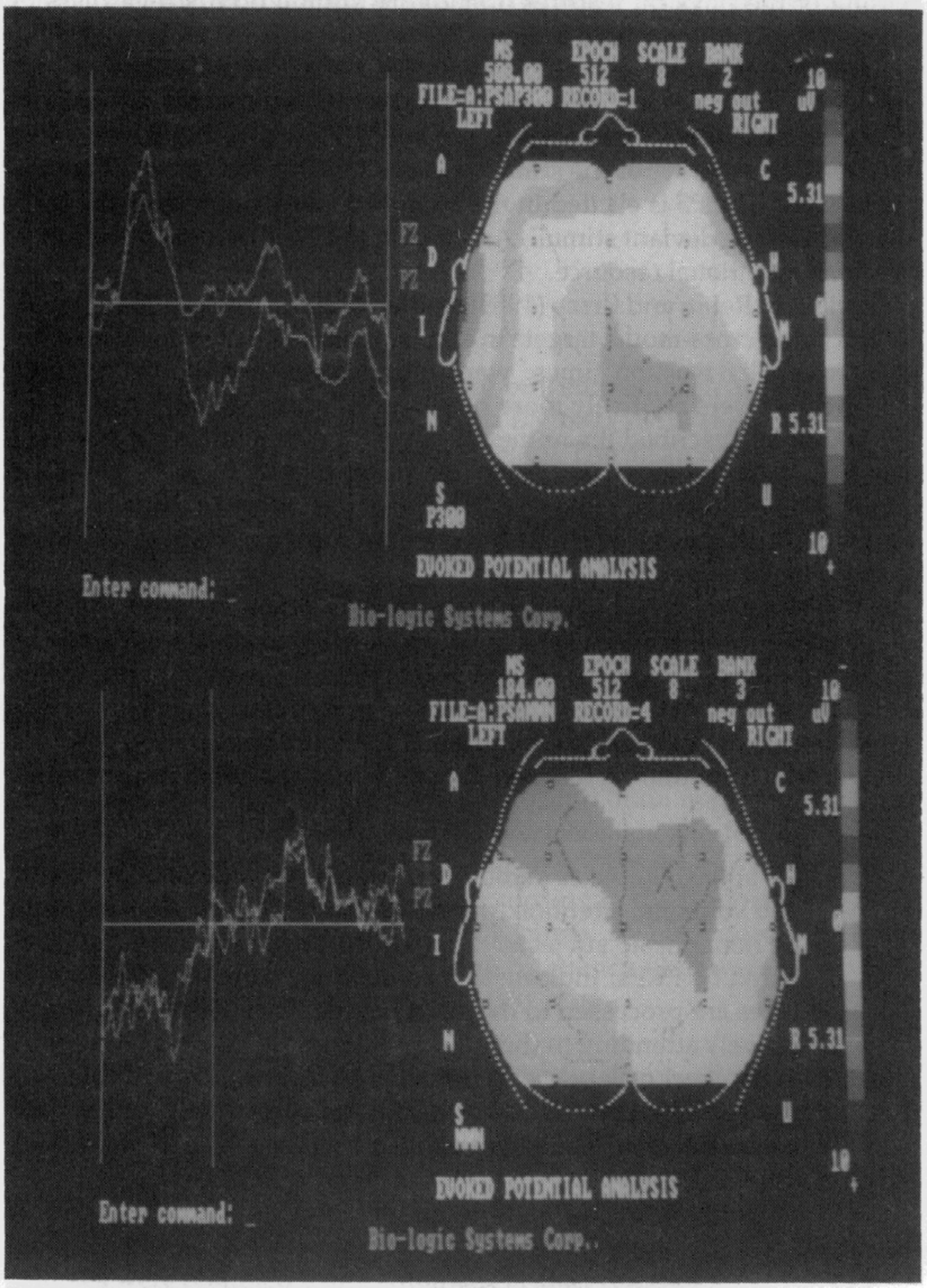

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Figure 2b.

cessing of the physical features of auditory stimuli occurs regardless of whether the listeners attend to them.

Another component in the ERP waveform that has been associated with attentional processes is the P3. With its greatest amplitude at the midline over the central-parietal regions of the scalp (Figure 2), the P3 has been described as a marker of the stimulus event's evaluation (Languis & Wittrock, 1986). The P3 is elicited in the attend condition by having the individual count the deviant stimuli. As a result, the P3 is thought to be sensitive to an attentional resource.

Previously, Robin and Rizzo (1989) studied orienting attention to visual, auditory, and cross-modal targets in aphasic patients. Attentional deficits, as indicated by reaction times, were found regardless of the stimulus modality but were relatively more pronounced in the auditory condition. These authors described the numerous levels at which orienting attention may have been impaired for these tasks and related them to linguistic information processing. However, because of the nature of the tasks, they were unable to specify which of these levels may have been impaired to produce the observed deficits.

In this study, we investigated aphasic subjects' attention during two online cognitive tasks. Focused attention to auditory information was measured via data obtained from event-related potentials. The method permitted us to explore a number of issues related to the presence or absence of attentional deficits in aphasia, the conditions for their appearance, and the levels at which attention is disrupted. Specifically, the following questions were asked:

1. Do aphasic subjects demonstrate the same patterns of automatic and volitional attention to changes in repetitive auditory stimuli as nonaphasic subjects? That is, do their responses, as measured by ERPs, indicate that an auditory stimuli's physical features are processed to the same degree when either ignoring or actively attending to them?
2. What level or levels of attentional processing, as indicated by the patterns demonstrated within the components of the ERP waveform, are impaired in aphasia?

METHOD

Subjects

Six subjects, four aphasic adults and two age-matched normal controls, participated in this study. All were native speakers of English and had normal hearing acuity bilaterally in the frequency range between 500 and 2,000 hertz. The aphasic subjects were three males and one female, ranging in age from 69 to 72 years. They were aphasic secondary to a single left hemisphere cerebrovascular accident. Time post onset ranged from 1 to 2 years with a mean of 1.5 years. The normal controls were one male and one female aged 73 and 70 years, respectively; neither reported a history of neurological impairment.

Procedure

Immediately prior to the experimental procedures, each aphasic subject was administered the Western Aphasia Battery (WAB) (Kertesz, 1982) to obtain a measure of general language ability. The mean Aphasia Quotient for this group was 58.3 and ranged from 17.3 to 88.9 (Table 1). Two subjects were classified as having fluent aphasia and two cases were classified as having nonfluent aphasia. Each subject was administered the Object Naming subtest three times during the experimental period to assess performance variability. The first administration occurred during the usual course of testing with the WAB. The second and third administrations occurred immediately after completion of the language testing and after completion of the evoked response procedures.

Instrumentation. Evoked potential testing and brain mapping were performed using the Biologic Brain Atlas Electrodiagnostic Testing System. Electrode placement was achieved using an ECI electro-cap electrode system. Twenty electrodes were placed according to the International 10–20 system with impedances of less than 3K ohms. All electrodes were referenced to linked ears. The low and high frequency filter were set at .3 Hz and 100 Hz, respectively. Gain was 30,000.

Data Collection. Auditory stimuli consisting of tone bursts were presented over Telephonics TDH-39P headphones at a rate of .8 per second. Each tone was characterized by a 20 ms plateau and a 20 ms rise/fall time. Standard and deviant stimuli consisting of 1,000 and 2,000 Hz tones, respectively, were presented randomly at a ratio of 5:1. Stimulus presentation continued until 50 (samples) were obtained to deviant tones. All samples were obtained using automatic artifact rejection.

The auditory stimuli were presented under two conditions: (a) passive attending and (b) active attending. In the passive task, subjects watched an inaudible segment from a familiar movie while the tone bursts were presented concurrently over phones. Subjects were instructed to ignore the tones and to attend only to the movie. To increase attention to the

TABLE 1. CLINICAL INFORMATION FOR APHASIC SUBJECTS

Ss	*WAB AQ*[a]	*Aphasia Type*	*Object Naming*[b]			*Correlation*[c]		
			N_1	N_2	N_3	r_{12}	r_{13}	r_{23}
A1	17.3	Wernicke	0	0	0	—	—	—
A2	88.9	Anomic	57	60	59	—	—	—
A3	77.2	Broca	48	45	52	.44	.46	.89
A4	49.8	Broca	32	23	29	.60	.40	.37

[a]WAB AQ = Western Aphasia Battery Aphasia Quotient.
[b]Scores obtained from Western Aphasia Battery Object Naming Subtest (maximum score = 60).
[c]Pairwise correlations among Object Naming scores obtained for each subject.

movie and ignoring of the tones, subjects were also told to be prepared to answer questions about the movie.

During the active task, the video was removed. Tone bursts were once again presented over phones and the subjects were asked to count, using a counter, the deviant stimuli.

RESULTS

The first analysis addressed whether these aphasic subjects demonstrated response variability of the type used to support the development of the neurophysiologic theory. Pearson product-moment correlations were computed for each subject among their object naming responses obtained over the three subtest administrations (Table 1). Correlations could not be obtained for the two fluent aphasic subjects because of the restricted range of their naming scores. The correlations obtained for the two nonfluent aphasic subjects, however, demonstrated ranges of .44 to .89 and .37 to .60. These findings suggest that there was appreciable variability in at least two of these aphasic subjects' responses to the Object Naming task. Although the overall raw scores appear to suggest similar naming impairment across administrations, their within-subtest responses demonstrated qualitative differences across administrations, reflecting variability for both error items as well as the level of cueing necessary to elicit an accurate response.

Automatic attentional mechanisms in the aphasic subjects were then investigated by inspection of the ERP waveforms obtained in the ignore condition. The MMN waveform was extracted by subtracting the standard-stimulus ERP from the deviant-stimulus ERP as described by Naatanen (1990). The MMN peak for each subject was established by identifying

TABLE 2. EVOKED POTENTIAL DATA FOR APHASIC AND NORMAL SUBJECTS INCLUDING MISMATCH NEGATIVITY (MMN), P300, AND INTERPEAK LATENCIES AND AMPLITUDES

	MMN				*P300*				*Interpeaks (P3–N2)*			
	ms	*uv*			*ms*	*uv*			*ms*	*uv*		
Ss		*Fz*	*Cz*	*Pz*		*Fz*	*Cz*	*Pz*		*Fz*	*Cz*	*Pz*
A1	208	-3.10	-3.43	-3.51	458	14.86	10.78	6.86	234	19.6	17.8	11.1
A2	132	-2.77	-3.10	-1.87	410	0.65	3.26	4.57	128	0.82	4.98	7.51
A3	184	-1.47	-1.55	-0.08	508	1.96	3.92	4.08	210	1.72	6.21	6.77
A4	104	-2.04	-2.12	-1.38	414	1.06	5.47	7.10	160	0.08	6.94	7.02
N1	112	-2.20	-2.12	-2.36	336	6.20	3.43	1.30	224	6.69	5.88	3.09
N2	156	-3.10	-2.28	-0.81	414	9.39	8.90	7.67	142	13.0	14.4	12.7

the point of maximum negativity corresponding to this component. Identification was assisted by use of the brain maps constructed from the ERP waveforms. Peaks were marked and their latencies and amplitudes computed.

The MMN peak latencies for these aphasic subjects ranged from 104 to 208 milliseconds (Table 2). These findings generally suggest normal temporal relationships in this group for automatic attention to incoming auditory stimuli. The MMN patterns demonstrated by the brain maps also followed expectations by revealing strong negative amplitudes frontally and over the auditory cortex (Figure 2).

Finally, voluntary attention in aphasia was assessed by analyzing the ERP waveforms obtained in the active attending condition and comparing them to the waveforms obtained from the normal subjects. A complex waveform including two components, the N2 and P3, is associated with detecting stimulus changes. The N2 has been described as representing the first stage in the stimulus-evaluation process while the P3 indicates the completion of that process (Languis & Wittrock, 1986). The peaks, latencies, and amplitudes for the P3 components of the waveforms obtained from the aphasic subjects were identified using the methods described previously. Interpeak latencies and amplitudes were also calculated for the N2-P3 waveform complex. These data are presented in Table 2. Although the N2 latencies were found to occur within normal temporal limits, a tendency for increased P3 latencies was observed in the aphasic subjects. For one aphasic subject (A4), the P3 latency was identical to that of a normal subject (N2), but the N2-P3 interpeak latency was found to be increased. These results suggest that the attentional processes for detecting changes in the auditory stimuli are initiated within a normal time frame. Abnormally more time may be required, however, to make decisions regarding discrimination of the deviant stimuli.

DISCUSSION

In this study, we examined the attentional abilities of aphasic subjects during on-line auditory processing. The MMN latencies suggest that automatic attending is preserved in aphasia. It could be further proposed, therefore, that attentional deficits that may be present following aphasia occur after the level of automatic attention. In other words, the deficits are in focused attention. Examination of the N2-P3 waveform complexes supports this latter contention but further describes the impairment in terms of the level at which the breakdown in focused attention may occur. These aphasic subjects focused attention on incoming stimuli much as the nonaphasic individuals did, but they required clinically increased time to complete the discriminative task. Thus, we found patterns of attentional deficits that suggest aphasic subjects engage attention for auditory stimuli as normal listeners do but that attention for completing a discriminative task may be deficient.

How might these findings be interpreted with regard to McNeil's neurophysiologic theory of aphasia? The important issue concerns how these data may relate to attention allocation and effort in aphasia. The patterns suggest that the deficits are not related to the engagement of attention but to the attentional resources available for making discriminative decisions. Such resource deficits may be an underlying factor in impaired attentional allocation. Though not providing direct support for the neurophysiologic theory, these findings are nonetheless consistent with McNeil's description of attentional deficits in aphasia. Moreover, they extend McNeil's model by more precisely identifying the level at which focused attention may break down following aphasia.

Our approach was to examine the temporal characteristics of the ERP components associated with attention to better understand the nature of these processes in aphasic subjects. Currently, we are studying the morphology of these waveforms and are encouraged by the compatibility of the findings from the two approaches. Although these findings are preliminary, event-related potentials appear to provide a promising experimental method for investigating attention issues in aphasia.

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