The N400 event-related potential in aphasia

Shuko Kitade*,†, Toshihiro Enai‡, Hiroyoshi Sei* and Yusuke Morita*

Department of Physiology, The University of Tokushima School of Medicine, Tokushima, Japan ; †Department of Speech Therapy, Kagawa Rehabilitation Center, Takamatsu, Japan ; and ‡Department of Education for Handicapped, School of Education, The University of Kagawa, Kagawa, Japan

Abstract : Although the N400 component of event-related potentials (ERPs) is suggested to reflect language processing, exactly which language processing functions N400 is sensitive to is not clear. We investigated this component in aphasic patients with some impairments of language processing. Meaningful and meaningless words in Kana (Japanese characters) were used as stimuli under a visual oddball paradigm. Increases in N400 latency and amplitude in the aphasic group were significant in comparison with the control group. In the aphasic group, N400 latency correlated significantly with the performance intelligence quotient employed besides language quotients. Moreover, the N 400 effects were seen more clearly in the left hemisphere than in the right hemisphere for both groups.

We propose that the abnormal variations in amplitude or latency of N400 in the aphasic group reflect language processing functions (controlled processing and automatic processing) that are different between slight and severe cases of aphasia. Moreover, N400 effects are sensitive to intellectual abilities besides language ability. We also suggest that N400 effects in the left hemisphere for the aphasic group are a reflection of active language processing as the substitution function. J. Med. Invest. 46 : 87-95, 1999

Key words : *event-related potentials, N400, aphasia, language processing, semantic memory*

INTRODUCTION

New brain imaging techniques like positron emission topography (PET) and functional magnetic resonance imaging (fMRI) have advanced our knowledge about the brain regions involved in the network subserving language. They have considerable precision in their spatial resolution, but these techniques are less precise in their temporal resolution. Techniques of event-related electroencephalography (EEG) and magnetoencephalography (MEG) have higher temporal resolution. Event-related potentials (ERPs) have become an important means for studying the neurophysiological basis of language processing (1).

As for the N400, since Kutas and Hillyard (2) discovered this component of the ERP, it has been actively studied. They recorded the N400 following presentation of a semantically inappropriate word at the end of a sentence and found an inverse correlation between the N400 amplitude and the ' Cloze probability ' that is defined as the proportion of subjects using that word to complete a particular sentence (3). Stuss *et al*. (4) and Picton (5) believe the N400 to be involved in the memory search process, with its amplitude reflecting the amount of search required.

The N400 has been elicited in response to phonological mismatches, word pairs, random word lists, ambiguous words in context, faces, color patches, or pictures, but it is not entirely clear whether cognitive processes are exactly reflected in this component.

Recently, N 400 has been argued to reflect non-automatic processes in a cross-modal conceptual system. That is, it probably reflects the functioning of a system different from that tapped by a lexical decision task. As Young *et al*. (6) pointed out, it is by no means inferred from the observed implicit

Received for publication December 7, 1998 ; accepted January 14, 1999.

Address correspondence and reprint requests to Yusuke Morita, M.D., Ph.D., Department of Physiology, The University of Tokushima School of Medicine, Kuramoto-cho, Tokushima 770-8503, Japan and Fax : +81-88-633-9521.

effects in lexical decision tasks that the same semantic representations which are used for conscious understanding are accessed implicitly. Instead, what is being implicitly accessed by these tasks is probably an automatically activated word recognition system which simply represents the associative relations between lexical items. Subsequently, this system may mirror semantic relation, but it is in fact a rather stupid system which merely appears to represent the meanings of the words. By contrast, the conceptual system, which underlies our ability to interpret and consciously understand stimulus contents, represents meanings at a cross-modality or cross-domain level (7, 8).

The results of the word priming studies with aphasic patients deviated in two aspects from the standard picture on semantic deficits in Wernicke's and Broca's aphasia. First, despite significantly longer response latencies, Wernicke's aphasics consistently showed the same pattern of results as the normal control subjects. Both the control subjects and the Wernicke's aphasics needed less time to recognize the target as a word when it was preceded by an associatively related word (9-12). Secondly, surprisingly, Broca's aphasics had a less stable pattern of performance. Some investigators reported no priming effects in these patients (10, 13). In other studies, however, Broca's aphasics showed the expected priming effect (9, 12, 14, 15).

As one objective of this study, we aimed at investigating the relationships between language processing and N400, by comparing aphasic patients with some impairments of language function to control subjects, employing a lexical decision task. Another objective was to investigate the relationships between psychometric measurements and N400.

MATERIALS AND METHODS

Subjects

Thirty aphasic patients, mean age 52.2±14.3 years (range 26-75), participated in this study. Twenty three non-brain-injured healthy subjects, mean age 46.8±12.5 years (range 27-72), served as control subjects. The etiology of aphasia included left cerebral infarction (n=22), left cerebral hemorrhage (n=5), and left cerebral contusion (n=3). In aphasic classification, 15 patients were diagnosed with Broca's aphasia, 7 patients with Wernicke's aphasia and 8 patients with amnesic aphasia. All subjects were right-handed. Due to right hemiparesis, 6 patients used their left hands to depress the button. All subjects were at least 6 months post onset. Patients gave written informed consent according to the guidelines of the Declaration of Helsinki.

The diagnosis of aphasia was based on clinical interviews and the following psychometric tests : the Standard Test of Aphasia (SLTA) (16), the Western Aphasia Battery (WAB) in Japanese (17), and a performance task of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) in Japanese (18). The Reading Score in WAB (RA) and the Aphasic Quotient in WAB (AQ) were used as indexes of reading ability and language abilities in all language sites, respectively (highest score of RA : 10, highest score of AQ : 100).

Table 1 shows a summary of the patients' age, sex, PIQ (Performance Intelligence Quotient), aphasic classification, RA, AQ, etiology and CT or MRI information. Patients are shown in the order of higher RA.

Experimental procedure

Table 2 shows the word stimuli used in ERP recording. The stimuli were 250 two Kana-letter (Japanese character) words, 50 meaningful (target : 10 words) and 200 meaningless (non-target : 40 words) words, delivered at an interval of about 2.5 sec in a random oddball paradigm. The words were selected from the new standard table of nonsense syllables (19), while meaningful words were familiar everyday words.

Subjects were seated in a sound-attenuated electrically shielded room and the experimenters ensured that the subjects adequately understood the tasks. The stimuli were presented on a TV screen, about 100 cm in front of the subject's eyes. When a meaningful or a meaningless word was presented, subjects were required to press an on-off button for the target stimuli as rapidly as possible. Nonpolarizable Ag-AgCl electrodes were secured to the subject's scalp, and the EEG recorded from Fz, Cz, Pz, C3 and C4 (10-20 international system), using linked earlobes as a common reference. Electrode impedance did not exceed 2 kΩ. The time constant was 1.5 sec, and the high-frequency cut-off filter set at 25 Hz. Electrical activity was concurrently amplified and recorded on magnetic tapes of a data recorder (TEAC XR-30, Tokyo, Japan). The EEG data were sampled at 250 Hz for periods beginning 200 msec before stimulus onset and continuing for 1200 msec, using a personal computer (NEC PC 9801 VX, Tokyo, Japan). Trials in which EEG activity exceeding

Table 1. Summary of aphasic patients

Patient	Age	PIQ	Type	RA	AQ	Etiology	Lesion site
P 1	52	113	A	9.8	83.9	LCI	Left posterior inferior frontal gyrus
P 2	42	124	A	9.7	97.2	LCH	Left operculum
P 3	26	124	A	9.7	94.5	LCH	Left putamen
P 4	36	122	A	9.4	91.0	LCI	Left posterior inferior frontal gyrus
P 5	35	95	A	9.3	92.2	LCH	Left anterior medial frontal gyrus
P 6	55	81	B	9.2	89.2	LCH	Left basal ganglia
P 7	39	63	A	8.9	80.8	LCI	Left superior temporal-occipital lobe
P 8	50	105	A	8.5	89.8	LCC	Left anterior superior temporal gyrus
P 9	29	112	B	8.3	72.6	LCC	Left insula and left parietal lobe
P 10	42	63	A	8.2	80.6	LCI	Left temporal-occipital lobe
P 11	76	93	B	7.7	67.6	LCI	Left inferior frontal gyrus-parietal lobe
P 12	68	80	W	7.7	65.8	LCI	Left temporal lobe
P 13	32	112	B	7.5	83.8	LCC	Left posterior inferior frontal gyrus-parietal lobe
P 14	64	67	W	7.5	68.4	LCI	Left temporal lobe
P 15	58	66	B	7.4	66.2	LCI	Left subcortical lesion : frontal lobe, temporal lobe
P 16	74	93	B	7.2	72.5	LCI	Left inferior frontal gyrus-parietal lobe
P 17	63	104	W	7.2	60.9	LCI	Left superior temporal gyrus-parietal lobe
P 18	69	62	B	7.0	83.0	LCI	Left medial and inferior frontal gyrus-temporal lobe
P 19	56	86	B	6.5	55.5	LCI	Left posterior inferior frontal gyrus
P 20	66	60	B	6.2	64.4	LCI	Left frontal-temporal lobe
P 21	64	111	B	6.2	63.8	LCI	Left inferior frontal gyrus-temporal and parietal lobes
P 22	38	85	B	5.2	43.8	LCI	Left inferior frontal gyrus-temporal lobe
P 23	63	62	B	4.9	49.0	LCI	Left inferior frontal gyrus, anterior superior temporal gyrus
P 24	42	68	B	4.8	17.2	LCH	Left medial and inferior frontal gyrus
P 25	46	81	W	4.1	65.6	LCI	Left temporal lobe
P 26	54	81	W	4.1	39.6	LCI	Left temporal-occipital lobe
P 27	67	60	W	4.1	30.0	LCI	Left temporal lobe
P 28	37	80	B	4.0	28.3	LCI	Left inferior frontal gyrus-temporal lobe
P 29	66	71	B	3.5	16.6	LCI	Left inferior frontal gyrus-superior temporal gyrus
P 30	60	60	W	3.0	24.5	LCI	Left posterior inferior frontal gyrus-superior temporal gyrus

PIQ : Performance intelligence quotient, RA : Reading score, AQ : Aphasic quotient, LCI : Left cerebral infarction, LCH : Left cerebral hemorrhage, LCC : Left cerebral contusion, A : Amnesic aphasia, B : Broca's aphasia, W : Wernicke's aphasia

Table 2. Word stimuli in Japanese for target and non-target words

Target (meaningful words-10 words)

みそ (soybean paste), めし (boiled rice), さる (monkey)

すし (sushi), いか (squid), たこ (octopus), せみ (cicada)

ねこ (cat), いも (potato), かめ (turtle)

Nontarget (nonmeaningful words-40 words)

ぬね, はゆ, ぬせ, るや, せへ, るえ, るへ, もぬ てゆ, ぬそ and so on.

±100 μV was automatically rejected. The N400 scored the most negative peak around 400 msec. Amplitude was measured from the prestimulus baseline.

Statistical analysis

Results are expressed as means±standard deviations. To assess significant differences between subjects, Mann-Whitney's U Test was used. To assess significant differences within subjects, Wilcoxon Signed-Rank Test was used. Moreover, to assess significant correlation, Fisher Z Test was used. The significance level was set *a priori* at p<0.05.

RESULTS

Psychometric measurements

Comparison between the control and aphasic groups

Table 3 shows the mean values of the psychometric measurements employed in the control and aphasic groups, which did not significantly differ in age. Significant differences were found for reaction time (RT) and percentage of correct responses (C%) in the word task, (RT : control group 621.3±86.0 msec *vs*. aphasic group 845.6±215.7 msec p<0.0001, C% : control group 99.3±1.5% *vs*. aphasic group 89.6±10.2% p<0.0001).

Table 4 shows the correlations between the psychometric measurements employed in the aphasic group. There were significantly high correlations between RA and AQ, AQ and C%, RA and C%, PIQ and C%, AQ and PIQ, AQ and AGE, PIQ and AGE, RA and PIQ, and C% and AGE. However, RT did not correlate with psychometric measurements assessed. There were no significant differences in correlations among AGE, RT and C% in the control group.

Comparison between the control and three aphasic subgroups

The aphasic group was classified into three subgroups according to the WAB reading scores : RA-HIGH (high reading score : 10~7.5, n=12), RA-MIDDLE (middle reading score : 7.5~5, n=10) and RA-LOW (low reading score : less than 5, n=8). The RA-HIGH score signifies a near normal reading ability. There was no significant difference in age among the three aphasic subgroups. The mean values of psychometric measurements for the three aphasic subgroups are shown on the right side of Table 3. RT was significantly longer in the RA-HIGH and RA-MIDDLE groups in comparison with the control group, but there was no significant difference between the control and RA-LOW groups. C% was significantly decreased from the RA-HIGH to the RA-LOW group in comparison with the control group. PIQ, RA and AQ were also decreased in order from the RA-HIGH to the RA-LOW group.

N400 effects

Comparison between the control and aphasic groups

Figure 1 shows the grand averages with target and non-target words in the control and aphasic groups. In both groups, the N400 amplitude with target and non-target words was greatest at Cz among three electrode sites and greater at C3 than at C4. The reduction of the potential from the N400 peak in the aphasic group was slower for both target and non-target words than that in the control at the three electrode sites.

Table 5 compares the mean N400 values for the control and aphasic groups. N400 latency in the aphasic group was significantly longer at the three electrode sites with target and non-target words than that in the control group. N400 amplitude in the aphasic group was significantly larger at the three electrode sites with non-target words than that in the control group.

Comparison between the control and the three aphasic subgroups

Figure 2 shows the grand averages for target and non-target words in the control and three aphasic subgroups. A slow attenuation of the negative potential from the N400 peak in the aphasic group was

Table 3. Psychometric measurements in the control and aphasic patients

	Control	Aphasic	Aphasic		
			RA-HIGH	RA-MIDDLE	RA-LOW
AGE	46.8	52.2	45.8	58.4	54.3
RT	621.3	845.6***	800.7***	972.8***	769.8
C%	99.3	89.6***	97.4*	88.5***	79.2***
PIQ	-	87.0	98.0	84.2	70.4
RA	-	6.9	8.9	6.8	4.1
AQ	-	64.6	83.8	66.2	33.8

RT : Reaction time, C% : Percentage of correct responses, PIQ : Performance intelligence quotient, RA : Reading score, AQ : Aphasic quotient
*p<0.05, **p<0.01, ***p<0.001, *vs*. control by Mann-Whitney's U Test.

Table 4. Correlation between psychometric measurements in the aphasic group

	AGE	RT	C%	PIQ	RA
AGE					
RT					
C%	-0.48*				
PIQ	-0.59*		0.70**		
RA			0.71***	0.55*	
AQ	-0.60**		0.76***	0.67**	0.82***

RT : Reaction time, C% : Percentage of correct responses, PIQ : Performance intelligence quotient, RA : Reading score, AQ : Aphasic quotient
*p<0.05, **p<0.01, ***p<0.001, by Fisher Z Test.

also clearly observed in order from the RA-HIGH to the RA-LOW group at the three electrode sites with target and non-target words.

Table 6 compares the mean N400 values in the three aphasic subgroups. When compared with the control, N400 latency in the RA-MIDDLE group was significantly longer at the three electrode sites with target and non-target words, and that in the RA-LOW group was significantly longer at the three electrode sites with target words and at C3 with non-target words, than that in the control group.

N400 amplitude in the RA-HIGH group was significantly larger at C3 and C4 with non-target words than that in the control group. N400 amplitude in the RA-LOW group was significantly larger at C4 and CZ with non-target words than that in the control group.

Comparison between C3 and C4

In the control group, N 400 amplitude was significantly larger at C3 with both target and non-target words than at C4 (N400 amplitude for target words : C3 -2.6±3.9 μV *vs*. C4 0.1±4.1 μV p<0.001, N400

Table 5. Comparison of N400 mean values between the control and aphasic groups

		Control		Aphasia	
	Site	Target	Non-target	Target	Non-target
N400L	C3	365.2	346.9	420.6**	417.8***
	C4	356.0	351.6	392.8*	385.5*
	CZ	370.8	349.0	410.4*	414.5**
N400A	C3	-2.6	-0.3	-3.3	-3.2**
	C4	0.1	1.1	-1.3	-1.5*
	CZ	-1.5	0.0	-2.7	-2.9*

L : Latency (msec), A : Amplitude (μV), *p<0.05, **p<0.01, ***p<0.001 *vs*. control by Mann-Whitney ś U Test.

Table 6. Comparison of N400 mean values in the three aphasic subgroups

		RA-HIGH		RA-MIDDLE		RA-LOW	
	Site	Target	Non-target	Target	Non-target	Target	Non-target
N 400 L	C3	381.0	400.7*	446.0**	450.2***	454.5**	403.3*
	C4	364.0	387.6	411.6**	436.6**	415.0**	389.3
	CZ	369.5	379.3	420.4*	433.1**	455.5**	446.5
N400A	C3	-4.5	-3.7**	-1.5	-2.2	- 3.4	-3.8
	C4	-2.2	-1.4*	-1.4	-1.5	-0.4	-1.8*
	CZ	-3.1	-2.3	-0.4	-2.4	-4.8	-4.2**

L : Latency (msec), A : Amplitude (μV), RA : Reading score, *p<0.05, **p<0.01, ***p<0.001 *vs*. Control by Mann-Whitney ś U Test.

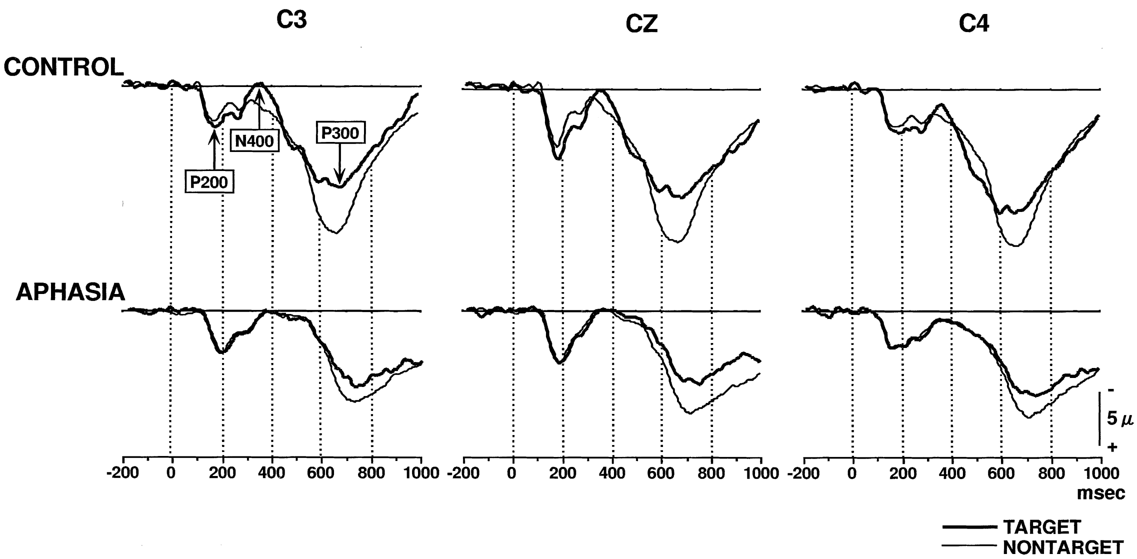

Fig.1. Grand averaged event-related potentials in the control and aphasic groups at C3, C4 and Cz. N400 in the aphasic group has a rather flattened peak at all three electrode sites with targets and non-targets compared to the control.

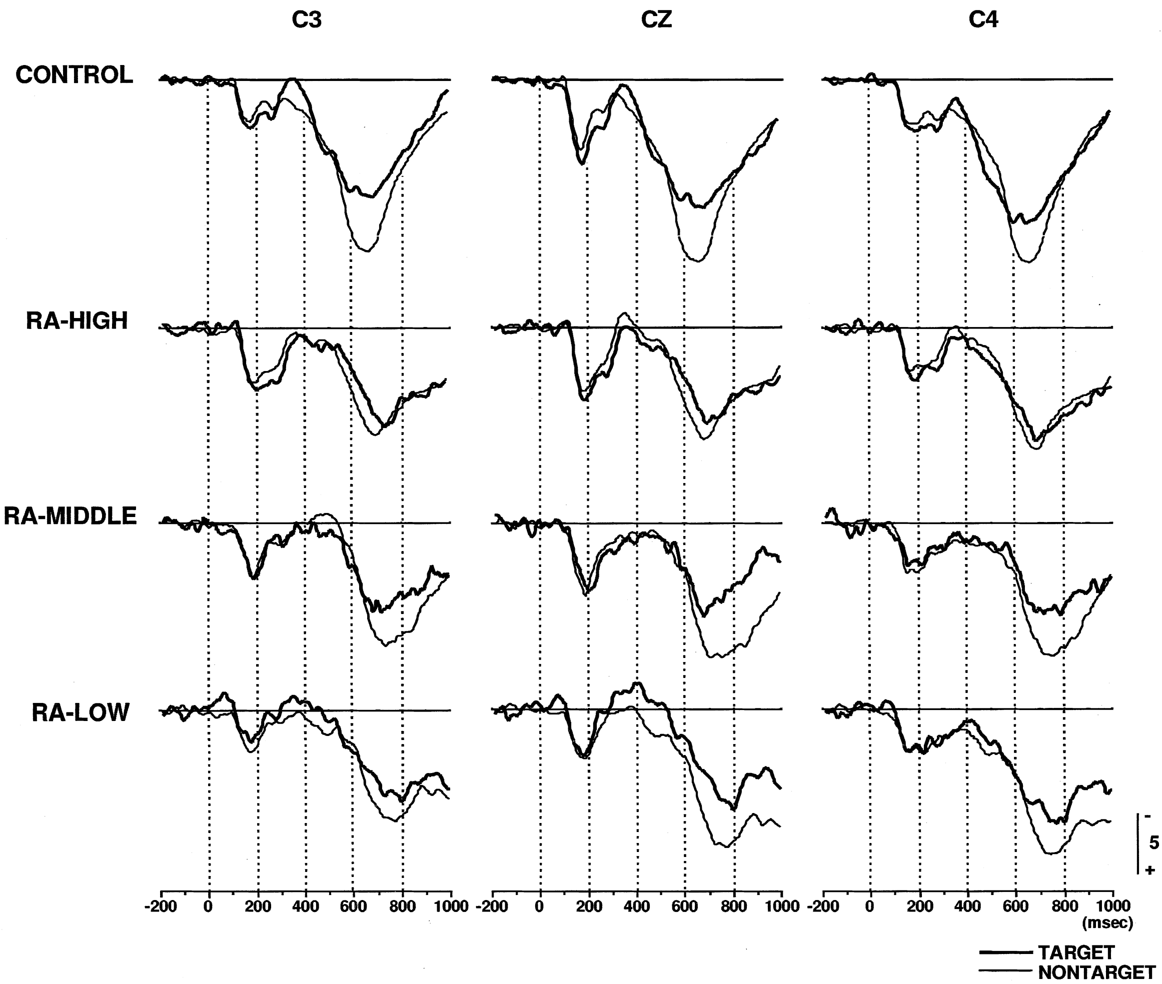

Fig. 2. Grand averaged event-related potentials in the control and three aphasic groups classified by reading score in WAB (RA). Flattened peak of N400 can be seen in the three aphasic groups clearly at three electrode sites with targets and non-targets.

amplitude for non-target words : C3 -0.3±2.8 μV *vs.* C4 1.1±2.9 μV p<0.05). In the aphasic group, N400 latency was significantly longer at C3 than at C4 with target words (N400 latency with target words : C3 420±63.6 msec *vs.* C4 392.8±52.9 msec p<0.05), and N400 amplitude was significantly larger at C3 than at C4 for non-target words (N400 amplitude in non-target words : C3 -3.2±3.3μV *vs.* C4 -1.5± 3.1 μV p<0.01).

Relationship between psychometric measurements and N400

Table 7 shows the correlation between the psychometric measurements investigated and N400 in the aphasic group. There was a significant correlation between the psychometric measurements and N400 latency. N400 latency at C3 with target words was significantly correlated with C%, PIQ, RA and AQ, respectively, but that with non-target words significantly correlated with C% and PIQ, and was not significantly correlated with RA or AQ.

Table 7. Correlation between psychometric measurements and N400 in the aphasic group

	Site	AGE	RT	C%	PIQ	RA	AQ
N400L-T	C3			-0.67**	-0.58*	-0.61**	-5.9*
	C4			-0.75***	-0.78***	-0.68**	
	CZ						
N400A-T	C3						
	C4						
	CZ						
N400L-N	C3			-0.55*	-0.55*		
	C4			-0.86***	-0.74**	-0.62*	
	CZ						
N400A-N	C3						
	C4						
	CZ						

L : Latency (msec), A : Amplitude (μV), T : Target, N : Non-target, RT : Reaction time, C% : Percentage of correct responses, PIQ : Performance intelligence quotient, RA : Reading score, AQ : Aphasic quotient *p<0.05, **p<0.01, ***p<0.001, by Fisher Z Test.

DISCUSSION

To our knowledge, there are only a few reports of the N400 ERP in aphasic patients with some impairments in semantic processing of symbolic function, although it is claimed that N400 is related to semantic processing or language processing. In this study, we obtained interesting N400 effects in the aphasic group and relationships between psychometric measurements and N400.

Psychometric measurements

We could confirm a strong relationship between the quotients of language abilities, as shown by the highly significant correlation between RA and AQ (r=0.82). In spite of the word comprehension task, the C% was strongly correlated with AQ, RA and PIQ (r=0.76, 0.71, 0.70). This suggests that C% may be related to a performance intellectual ability besides language ability. The word task in this study was performed in the form of an oddball paradigm. This paradigm has proven useful in cognitive psychological studies, as well as in clinical diagnosis of mental deterioration (20, 21). We assume that in solving the word task in the oddball paradigm, which requires a speedy solution, performance intellectual ability is relatively important compared with language ability.

N400 effects

N400 latency in the aphasic group was significantly longer than that in the control group. Niznikiewicz *et al*. (22) reported that the N400 latency was prolonged in patients with schizophrenia to both congruent and incongruent sentence endings, and assuming that latency indexes the speed of the cognitive process, indicated greater difficulty in performing these operations. In the word recognition task, Koyama *et al*. (23) suggested that the extended N370 (N400) found for schizophrenics indicated a prolonged memory search. For aphasic patients, there are ambiguities in a word's meaning, and their semantic memory search in the language processing time requires more time for lexical operations than do the controls. We consider that this search is related to the prolongation of N400 latency.

N400 amplitude in the aphasic group was greater at all three electrode sites than in the control group, and there was a significant difference with meaningless words. However, in the three aphasic subgroups, although N400 amplitudes in the RA-HIGH and RA-LOW groups were significantly larger, that in the RA-MIDDLE group did not show a significant difference compared to the control group.

It is thought that N400 amplitude varies inversely with the degree of semantic relatedness of word primes (24-26). Hagoort *et al*. (26) reported that Wernicke's aphasics showed a larger reduction in the size of the N400 effect than Broca's aphasics, and that there were no qualitative differences in the pattern of results for these two aphasic patient groups. They suggested that a semantic matching process generated N400 priming effects. Revonsuo and Laine (27) reported a global aphasia that showed evidence of implicit semantic processing of spoken words. Auditory ERPs to semantically congruous and incongruous final words in spoken sentence were recorded. This means that whatever cognitive process it is that the N400 context effect reflects, it can not be a direct manifestation of the explicit (conscious) recognition of semantic incongruity. The N400 can be elicited even when the meaningfulness of the stimulus cannot be interpreted at a level supporting conscious decision making.

In this study, N400 amplitude was not reduced in the RA-LOW group. It is thought that this is closely related to the short RT in the RA-LOW group. Half the RA-LOW group (50%) were Wernicke's aphasic patients (RA-HIGH : 8.3%, RA-MIDDLE : 20%). That is, the RA-LOW group includes many Wernicke's aphasic patients who show short RT and N400 effects in automatic processing. We suggest that in automatic processing tasks, Wernicke's aphasia with severe comprehension deficits accounts for the N400 effects. This is consistent with the report by Revonsuo and Laine (27). However, the RA-HIGH group which included only one Wernicke's aphasic patient also showed larger N400 effects in comparison with the control group. Although the lexical decision task in this study is an automatic processing task, for the control with normal comprehension ability and the patients with slight cases of aphasia, lexical processing may be accomplished as controlled processing task. However, the aphasic patients with less severe deficits find slight ambiguities in the word meaning, whereas the control subjects do not find any of these ambiguities. In the RA-HIGH group, the activity elicited in trying to solve this problem explicitly, that is, the active matching made between a word and semantic memory may be reflected in a larger N400 amplitude than that of the control group.

N 400 and cerebral laterality

N400 amplitude at C3 was significantly larger than that at C4 in both the control and aphasic groups. There was significant difference between target and non-target words in the control group and with non-target words in the aphasic group. N400 latency in the aphasic group was significantly longer at C3 with target words than at C4.

Recording of the ERP from intracranial electrodes has suggested a left-temporal generator for the N400. ERP recorded intracranially from medial temporal structures has been found to be sensitive to the congruity of sentence endings (28) and to lexical and repetition effects with single word presentation (29). Schmidt *et al.* (30) recorded both MEG field and scalp electrical potentials while subjects read sentences with congruous and incongruous endings. Like the scalp potentials, the MEG responses differed with the congruity of the sentence. Mapping of the neuromagnetic N400 was consistent with a left mid-temporal generator. Beeman *et al.* (31) reported that the right hemisphere processes words with relatively coarser coding than the left hemisphere, a conclusion consistent with a recent suggestion that the right hemisphere coarsely codes visual input (32).

In the aphasic patients, although C3 corresponds with the site of their brain damage, they showed an increase in N400 amplitude at C3. We suggest that this reflects the increase of nervous activity in language processing as a substitution function in the cells surrounding damaged cells, and the prolongation of N400 latency at C3 reflects a prolongation of neural activation in language processing.

Psychometric measurements and N400

In the aphasic group, N400 latency was significantly correlated with the performance intelligence quotients investigated besides the language quotients. It is suggested that the N400 sensitively receives signals from other higher brain functions (performance intelligence ability, etc.) besides language ability. This agrees with the result in psychometric measurements that C% in the word task significantly correlate with the performance intelligence quotient besides the language quotients. Brown and Hagoort (33) suggested that N400 was sensitive to violations of semantic properties of linguistic stimuli, and that it requires some attentive involvement.

In aphasic patients, it is necessary to perform psychometric tests from various sites besides language tests

Absence or presence of the N400 effect may be used as a diagnostic criterion for language impairment (27). As reported by Friederici (1), future ERP studies with brain lesion subjects may tie the functional relationship between online language processes and its neuronal substrate. However, there is much room for the further study of N400.

REFERENCES

1. Friederici AD : Neurophysiological aspects of language processing. Clin Neurosci 4 : 64-72, 1997
2. Kutas M, Hillyard SA : Reading senseless sentences : brain potentials reflect sematic incongruity. Science 207 : 203-205, 1980
3. Kutas M, Hillyard SA : Contextual effects in language comprehension : studies using event-related brain potentials. In : Plum F, ed. Language, Communication and the Brain. Raven Press, New York, 1988, pp. 87-100
4. Stuss DT, Picton TW, Cerri AM : Searching for the names of pictures : an event-related potential study. Psychophysiology 23 : 215-223, 1986
5. Picton TW : The endogenous evoked potentials. In : Basar E, ed. Springer Series in Brain Dynamics 1. Springer-Verlag, Berlin, pp. 258-265, 1988
6. Young AW, Newcombe F, Hellawell D, DeHaan E : Implicit access to semantic information. Brain Cogn 11 : 186-209, 1989
7. Damasio AR : Concepts in the brain. Mind and Language 4 : 24-28, 1989
8. Revonsuo A : Words interact with colors in a globally aphasic patient : evidence from a Stroop-like task. Cortex 31 : 377-386, 1995
9. Blumstein SE, Milberg W, Shrier R : Semantic processing in aphasia : evidence from an auditory lexical decision task. Brain Lang 17 : 301-15, 1982
10. Milberg W, Blumstein SE, Dworetzky B : Processing of lexical ambiguities in aphasia. Brain Lang 31 : 138-50, 1987
11. Friedman RB, Glosser G, Diamond H : Semantic *versus* associative lexical priming in Alzheimer's disease and fluent aphasia. Annual meeting of the academy of aphasia, Montreal, Canada, 1988
12. Hagoort P : Impairments of lexical-semantic processing in aphasia : Evidence from the processing of lexical ambiguities. Brain Lang

45 : 189-232, 1993
13. Milberg W, Blumstein SE : Lexical decision and aphasia : evidence for semantic processing. Brain Lang 14 : 371-85, 1981
14. Katz WF : An investigation of lexical ambiguity in Broca's aphasics using an auditory lexical priming technique. Neuropsychologia 26 : 747-52, 1988
15. Ostrin RK, Tyler LK : Automatic access to lexical semantics in aphasia : evidence from semantic and associative priming. Brain Lang 45 : 147-59, 1993
16. Hasegawa T : Standard Language Test of Aphasia Manual of Directions (in Japanese). Homeido Press, Tokyo, 1975
17. Kertesz A : The Western Aphasia Battery (in Japanese). In : Sugishita M, Ariga K, Endo K, Kaga K, Kabe S, Kamewada F, Kawabata S, Kawamura M, Konno K, Seki K, Soma Y, Tagawa K, Nagata K, Hasegawa K, Fukada T, Makishita H, Motomura A, Yamazaki K, eds. Igaku-shoin Ltd, Tokyo,1986
18. Wechsler D : Manual for the Wechsler Adult Intelligence Scale revised (in Japanese). In : Shinagawa F, ed. The Psychological Corporation, USA, 1990
19. Hayashi S : The new standard table of nonsense syllable (in Japanese). Tokai Univ Press, Tokyo, 1976
20. Goodin DS, Squires KC, Starr A : Long latency event related components of the auditory evoked potentials in dementia. Brainr 101 : 635-648, 1978
21. Goodin DS, Starr A, Chippendale T, Squires CK : Sequential changes in the P3 component of the auditory evoked potential in confusional states and dementing illness. Neurology (Cleveland) 33 : 1215-1218, 1983
22. Niznikiewicz MA, O'Donnell BF, Nestor PG, Smith L, Law S, Karapelou M, Shenton ME, McCarley R : ERP assessment of visual and auditory language processing in Schizophrenia. J Abnorm Psychol 106-1 : 85-94, 1997
23. Koyama S, Nageishi Y, Shimokochi M, Hakama H, Miyazato Y, Miyatani M, Ogura C : The N400 component of event-related potentials in schizophrenic patients : a preliminary study. Electroenceph Clin Neurophysiol 78 : 124-132, 1991
24. Bentin S, Kutas M, Hillyard SA : Electrophysiological evidence for task effects on semantic priming in auditory word processing. Psychophysiology 30 : 161-169, 1993
25. Kutas M, Hillyard SA : An electrophysiological probe of incidental semantic association. J Cogn Neurosci 1 : 38-49, 1989
26. Hagoort P, Brown CM, Swaab TY : Lexical-semantic event-related potential effects in patients with left hemisphere lesions and aphasia, and patients with right hemisphere lesions without aphasia. Brain 119 : 627-649, 1996
27. Revonsuo A, Laine M : Semantic processing without conscious understanding in a global aphasic : evidence from auditory event-related brain potentials. Cortex 32 : 29-48, 1996
28. McCarthy G, Wood CC : Intracranial recorded event-related potentials during sentence processing. Soc Neurosci Abst 10 : 847, 1984
29. Smith ME, Stapleton JM, Halgren E : Human medial temporal lobe potentials evoked in memory and language task. Electroenceph Clin Neurophysiol 63 : 145-159, 1986
30. Schmidt AL, Arthur DL, Kutas M, Flynn E : Neuromagnetic responses during reading meaningful and nonmeaningful sentences. Psychophysiol Abs, 26 : S 6, 1989
31. Beeman M, Friedman RB, Grafman J, Perez E, Diamond S, Lindsay MB : Summation priming and semantic coding in the right hemisphere. J Cogn Neurosci 6 : 26-45, 1994
32. Kosslyn SM, Chabris CF, Marsolek CJ, Koenig O : Categorical *versus* coordinate spatial relations : Computational analyses and computer simulation. J Exp Psychol Hum percept performa 18 : 562-577, 1992
33. Brown CM, Hagoort P : The processing nature of the N400 : Evidence from masked priming. J Cong Neurosci 5 : 34-44, 1993