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DURATIONAL ASPECT OF PROSODY IN BROCA'S APHASIA

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Introduction

Prosodic disturbance is one of the main characteristics of the speech of Broca's aphasia. Contributions to this have been suspected to include a tendency toward equal stress, inappropriate intersyllabic pauses, restriction and alteration of normal intonation and loudness contours, effortful groping and repetitive attempts to produce sounds accurately and a slow rate (Rosenbek and Werz, 1976). Among these we (Konno, Sugishita and Hirose, 1984) have studied the pitch aspect of the disturbance and concluded that a flattening of the fundamental frequency (F0) contours is not always observed in Broca's aphasia, nor does it distinguishes the prosodic disturbance in Broca's aphasia from that in pseudobulbar dysarthria. We have suggested that the disturbance in prosody unique to Broca's aphasia might be a durational abnormality rather than a reduced range of the F0. In the present paper, therefore, the durational aspect of the prosodic disturbance in Broca's aphasia will be discussed, focusing on whether the durational pattern of Broca's aphasia differs from that of normal subjects, especially when the latter speak more slowly than usual.

Subjects

The subjects included 2 Broca's aphasics and 10 normal adults.

Case 1

A 65-year-old, right-handed male who suddenly suffered a right-hemiparesis, swallowing difficulty and speech disturbance in March, 1983. While the hemiparesis, swallowing difficulty language disturbance lessened shortly after admission, his speech disturbance was still apparent. Neurological examination revealed a slight reduction in grip strength in the right hand and a slight hemiparetic gait in the right leg. Deep tendon reflexes were hyper in the right arm and leg. Babinsky sign was detected on the right. CT scan revealed a low density area in the left frontal lobe, but not extending beyond the left central sulcus. He was diagnosed as having had a cerebral infarction.

Case 2

A 56-year-old, right-handed male who suddenly developed a right-hemiparesis and motor aphasia in October, 1984. Two months after onset his speech disturbance was still severe, and he pronounced only a limited range of sounds, such as vowels.

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Neurological examination revealed a right-hemiparesis, which was complete in the upper limb, right facial palsy, right hemihypesthesia and right facial hypesthesia. Deep tendon reflexes were hyper in the right arm and leg. Babinsky sign was positive on the right. CT scan showed a low density area predominantly in the left frontal lobe involving partly the left, post-central gylus. He was diagnosed as having had a cerebral infarction.

Procedure

All normal subjects were asked to read aloud sentences in their normal speech style five times, while the aphasic patients read them after an experimenter to help exclude the factor of reading difficulty. All utterances were tape-recorded. The stimuli were 5 different sentences consisting of 3 lexical items of from 7 to 11 syllables. Additionally, the normal subjects were asked to read the sentences according to two different speech styles: 1) slow speech rate and 2) syllabic speech. Segmental durations were determined from the sound waves with reference to the formant pattern using a VAX 11-780 computer(Imagawa,1984).

Results

Since there was no significant difference among the five utterances in each subject, only the results for the first utterance were analized. Table 1 shows the total durations of each sentence in the two patients, and the mean total durations for the normal subjects with its SDs. All of the durations in the patients with Broca's aphasia were twice to four times longer than the mean of those in the normal subjects, indicating that the patients spoke abnormally slowly (exceeding more than 4 SDs from the mean of the normal subjects). The gap between the two groups tended to enlarge as the number of syllables in a sentence increased.

Table 2 contains the segmental durations for the two patients' utterance 'are wa buta desu' ("That is a pig") and those of the normal subjects (average). It can be seen that the percentage of silent periods in the patients is about double that in the normal subjects. While the silent period just after a phrase (that is, the pause) is prolonged in case 2, accounting for most of the increase, in case 1 silent periods which are not observed in the normal subjects' utterances are inserted among the syllables. In addition, the distributional pattern of syllable duration deviates from that of the normal subjects, partly because some of the syllables maintain durations within normal limits, while others are greatly prolonged. The normal pattern of shortening the first syllable in a sentence is also distorted, this syllable being the longest among the syllables.

Table 3 shows the average percentages of the duration per

Table 1

Total Duration for Each Sentence in the Patients with Broca's Aphasia and the Normal Subjects

	S1 7syl.	S2 8syl.	S3 9syl.	S4 9syl.	S5 11syl.	
Case 1	2753	3913	3860	/	/	msec.
Case 2	2279	3680	3833	4127	5607	msec.
Normal Subjects						
Mean	1058	1228	1372	1196	1383	msec.
SD	256	155	197	150	199	msec.

Table 3

Mean(%) and SD of Syllable Duratoin

		S1*	S2	S3	
Case 1	$\bar{X}$	9.22	8.00	8.21	%
	SD	2.78	4.15	3.40	%
Case 2	$\bar{X}$	9.96	8.43	7.60	%
	SD	1.36	1.46	2.80	%
Normal Subject					
	$\bar{X}$	11.60	10.99	9.95	%
	SD	1.74	1.15	0.70	%
Maximum SD					
	$\bar{X}$	12.95	9.90	9.82	%
	SD	3.60	2.60	2.21	%
Minimum SD					
	$\bar{X}$	9.90	11.00	10.15	%
	SD	0.96	1.53	0.87	%

* $\bar{X}$ and SD in sentence 1 (S1) were calculated excluding the last syllable duration because it is devoiced in some utterances.

Table 2

Segmental Durations and The Percentile Distribution

	a		re		wa		bu		ta		de		su	Total
Case 1	380	93	300	0	160	447	287	113	253	287	173	33	227	2753 msec.
	13.8	3.3	10.9	0	5.8	16.2	10.4	4.1	9.2	10.4	6.3	1.2	8.2	%
Case 2	200	0	293	0	213	500	233	60	213	67	220	67	213	2279 msec.
	8.8	0	12.9	0	9.4	21.9	10.2	2.6	9.4	2.9	9.6	2.9	9.4	%
Normal Subject														
Mean	111	0	145	0	149	86	102	73	129	21	120	0	122	1058 msec.
SD	25	0	50	0	29	83	27	28	26	26	26	0	53	256 msec.
Mean	10.5	0	13.7	0	14.1	8.1	9.6	6.9	12.2	2.6	11.3	0	11.5	%
SD	2.4	0	2.1	0	2.5	4.2	2.1	1.5	1.9	2.2	2.1	0	4.8	%

Table 4

Percentage of Segmental Durations and The Mean and SD of The Syllable Durations

		a		re		wa		bu		ta		de		su	Total	Mean	SD
Nor 1.	usu.	8.4	0	13.0	0	12.3	5.8	9.7	5.2	10.3	3.9	12.3	0	19.4%	1033 msec.	11.0%	1.18%
	slo.	13.0	0	14.1	0	14.1	6.1	7.2	7.2	11.9	5.8	9.4	0	11.2%	1847 msec.	11.6%	2.78%
	syl.	5.9	5.9	8.9	10.2	7.0	5.9	7.0	10.0	6.7	8.1	8.1	8.1	8.1%	2473 msec.	7.3%	1.07%
Nor 2.	usu.	9.5	0	14.0	0	11.7	4.5	8.9	6.1	12.3	3.6	14.5	0	15.1%	1193 msec.	11.8%	2.28%
	slo.	17.3	0	16.2	0	13.7	32.1	11.2	3.6	13.4	2.1	10.2	0	5.3%	3740 msec.	13.8%	2.64%
	syl.	7.8	6.1	9.8	7.6	8.2	7.1	8.4	10.0	6.5	7.8	7.6	7.8	5.5%	3267 msec.	8.1%	1.08%
Nor 3.	usu.	12.8	0	14.2	0	19.1	6.4	10.6	5.7	12.8	5.7	8.5	0	4.3%	940 msec.	12.9%	3.60%
	slo.	14.2	0	13.1	0	11.1	12.3	12.3	5.7	13.4	0	11.4	0	6.8%	2340 msec.	12.5%	1.22%
	syl.	7.0	6.4	9.8	7.4	6.6	7.2	9.6	9.2	6.4	8.1	7.7	10.1	4.4%	3620 msec.	7.8%	1.50%

* X and SD are calculated excluding the last syllable duration because it is devoiced in some utterances.
usu.: with usual speaking rate slo.:slow speech syl.:syllabic speech

Table 5

Segmental Durations in Usual and Slow Speech and The Percentile Distribution of The Increase

Nor 6 usu.	80	67	13/ 67	0	33/100	153	47	27	20/ 47	27	33/ 47	67	13/ 60	0	87	100	27/127 msec
slo.	153	100	13/173	0	40/147	133	100	130	27/127	67	40/113	93	13/127	0	173	113	40/133 msec
	9.0	4.0	0/13.0	0	0.9/5.8	-2.4	6.5	12.7	0.9/9.8	4.9	0.9/8.1	3.2	0/8.2	0	10.6	1.6	1.6/0.7 %
	V=71.7/9=8.0%			C=4.3/6=0.7%		P=24/8=3.0%											
Nor 7 usu.	80	87	10/ 90	53	23/ 77	0	73	100	13/ 93	67	27/ 80	87	13/ 60	0	87	140	47/173 msec
slo.	167	167	20/187	133	20/167	0	207	287	20/160	180	47/167	200	17/190	0	173	307	67/153 msec
	5.1	5.1	0.6/6.2	5.1	0.2/5.8	0	8.6	12.0	0.5/4.3	7.3	1.3/5.6	7.3	0.3/8.4	0	5.5	10.7	1.3/1.3 %
	V=48.1/9=5.3%			C=4.1/6=0.7%		P=47.5/8=5.9%											
Nor 8 usu.	60	33	17/ 83	0	27/80	0	80	60	17/ 70	20	23/ 50	73	17/ 83	0	73	113	43/ 83 msec
slo.	60	67	13/120	33	13/87	0	153	93	20/ 80	80	27/ 60	107	17/ 97	0	153	167	33/107 msec
	0	7.2	-0.8/7.8	7.0	-3.0/1.5	0	13.3	7.0	0.6/2.1	12.7	0.9/2.1	7.2	0/3.0	0	17.0	11.4	-2.1/5.1 %
	V=51.6/9=5.7%			C=-4.4/6=0.7%		P=52.8/8=6.6%											
Nor 9 usu.	80	47	13/ 87	0	20/ 53	0	60	67	17/ 57	40	37/ 50	60	13/ 40	0	53	87	23/110 mse
slo.	133	14	13/147	12	13/107	70	14	12	15/118	147	33/120	140	13/ 93	113	140	147	33/113 mse
	7.1	-4.4	0/8.0	1.6	-0.9/7.2	9.3	-6.2	-7.4	-0.3/8.2	14.3	-0.5/9.4	10.7	0/7.1	15.1	11.6	8.0	1.3/0.4 %
	V=52.8/9=5.9%			C=-0.4/6=-0.07%		P=47.2/8=5.9%											
Nor 10 usu.	80	60	13/87	0	10/ 50	0	87	73	13/53	67	10/ 43	80	10/ 43	0	67	140	40/ 93 mse
slo.	113	120	13/87	33	30/ 70	0	100	87	20/67	93	13/ 63	87	13/153	153	147	267	33/247 mse
	3.7	6.7	0/0	3.7	2.2/2.2	0	1.5	1.6	0.8/1.6	2.9	0.03/2.2	0.8	0.3/12.4	17.2	9.0	14.3	-0.8/17.3 %
	V=49.9/9=5.5%			C=2.5/6=0.4%		P=47.2/8=5.9%											

usu.: with usual speaking rate slo.:slow speech
V:increase per vowel C:increase per consonant P:increase per intersyllabic pause

syllable for each sentence with their SD in the patients. Those of the normal subjects (average), and the example with a maximum or minimum SD are also included. As can be seen in Table 2, the average syllable duration of the patients tend to be shorter than those of the normal subjects, indicating that the utterances of the Broca's aphasia have more silent periods. All of the SDs in case 2 fall within normal limits. On the other hand, those of case 1 are greater than the normal subjects', indicating that durations tended to vary greatly from syllable to syllable.

Table 4 shows the segmental durations of the three normal subjects when they uttered 'are wa buta desu' in their usual way, with slow speech and syllabic speech. The data indicate that the SDs were least in syllabic speech. The speech pattern of case 1 is rather close to syllabic speech in terms of having intersyllabic pauses. However, besides larger SDs in syllable durations, case 1's syllable durations were longer and the intersyllabic pauses other than usual pauses (that is , those just after a phrase) were shorter than those of the normal subjects in syllabic speech.

In order to examine wnich part of segmental duration increases in slower speech, the utterances of 'atode itokoto iku'("I will go later with my cousin") --which includes many plosives, so that segmentation of duration is less complicated-- were measured for the duration of each category of vowel, closure and releasing periods in the five normal subjects. Table 5 shows the segmental durations of their utterances in usual and slow speech, and the percentile distribution of the increase in each segment compared with the segmental durations of case 2. There are three types of percentile distribution of the increase: a) mainly vowel duration increases (S6); b) mainly silent periods, and especially pauses, a increase(S9) and; c) both vowel and silent periods increase to a similar extent (S7, S8 and S10). These types seem to have little relation to the amount of the increase or the total duration of the utterances. The durational pattern of case 2 is similar to S9 in that both have quite long pauses after each phrase. However, the rest of the silent periods in case 2 accounts for the smaller durational distribution (%) than that of S9, indicating that case 2's vowels tended to be prolonged selectively.

Discussion

A slow speaking rate has been often mentioned in studies on the dysprosody of Broca's aphasia (Lebrun et al., 1973; Collins, Rosenbek, and Wertz, 1978). Kent and Rosenbek (1983) have suggested two major forms of this slow speaking rate: 'articulatory prolongation', which is defined as a lengthening of steady-state segments and intervening transitions, and 'syllable segregation', which is defined as temporary isolation or separation of syllables in a syllabic series. Our patients with Broca's aphasia also showed a great reduction in speaking rate.

The utterances of case 1 were characterized by the insertion of silent periods between the syllables, that is, syllable segregation. However, most of his silent periods occurred after a phrase (that is, pauses) while the lengthening of vowels contributed more to the increase in total durations when the pauses were excluded. The same was true in the utterances of case 2, where syllable segregation was less often observed than in case 1.

As a second step, however, the question must be raised whether there is any difference between syllable segregation and prolongation in patients with Broca's aphasia and that in normal subjects using a slow speaking rate in order to clarify the characteristics of their dysprosody. Our measurements normal subjects at slowed speech show that there are few syllable segregations except for pauses, and that variation in syllable duration tends to remain small. The shortening of the first syllable in a sentence, which is observed in most of the utterances in the usual speech of normal subjects, is maintained in about 50% of the utterances at a slow speaking rate. The durational pattern of case 2 is close to that of normal subjects at a slow speaking rate, since both have few additional intersyllabic silent periods, except for pauses. His SD for syllable durations is about the same as that of normal subjects, and a shortening of the first syllable is also observed. The only difference noticed was that his silent periods other than pauses were shorter than those of the normal subjects at a slow speaking rate, where both vowel durations and silent periods increased equally. This phenomenon was also observed in the utterances of case 1. The durational pattern of case 1, which was characterized by syllable segregation, was similar to the syllabic speech of the normal subjects. The SDs for the syllabic speech of the normal subjects was smaller than those in their usual or slow speech. However, the SDs of the syllable durations in the utterances of case 1 were quite large, indicating that his syllable duration varied from syllable to syllable. In addition, a prolongation of the first syllable also distorted the normal durational pattern in case 1. These results may not support the possibility that patients with Broca's aphasia preplan their slow speaking rate for compensations as Darley (1982) has suggested. The variation in durational abnormality seen in these two patients needs further inverstigation. In particular, intersyllabic pauses may not always be found in the utterances of Broca's aphasics (Lebrun et al., 1973). Although intersyllabic pauses are the most apparent form of scanning speech, other factors, such as the lack of a smooth or quick transition between syllables, may also be a reason for the perceived scanning. Segmental duration bears a more important role in Japanese than in stress languages, and further details need to be studied in order to clarify the effects of duration on prosody.

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