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A LONGITUDINAL STUDY OF AN ATAXIC DYSARTHRIA

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Introduction

Although the literature pertaining to ataxic dysarthria has described the perceptual aspects of this speech disorder very often, the acoustic and physiological pathology relating to the perceptual characteristics have seldom been studied objectively. We studied a patient with ataxic dysarthria whose speech deficiency disappeared within a year. Fortunately, most of the therapy sessions were recorded, so the acoustic aspects of the patient's problems could be analyzed by comparing the patient's dysarthric speech with non-dysarthric speech by the same patient as well as by normal subjects in order to analyze his speech disorders.

Description of Subject

The patient was a 19 year-old male. While working in a store in April 1982, he suddenly collapsed and was incapable of any speech or movement. However, within a few days he recovered the movement of his arms and legs, and speech. Neurological examination revealed an ataxic gait, slightly poor execution on the finger-nose test and heel-knee test and dysarthric speech with an impression of drawling and explosiveness. A cranial nerve examination revealed a skewed deviation of the left eye indicating a left oculo-motor deficit. The patient's EEG showed slow and low voltage alpha waves within the normal range. The CT scan showed a wave-like high density area in the superior cerebellum. A cerebellar angiography was within the normal range, with a deviation from right to left. The medical diagnosis was an anterior inferior cerebellar artery infarction.

Assessment of Speech Pathology

An oral peripheral examination at one month after onset revealed that the shape and the basic function of the lips and soft palate were intact, though the patient reported that he had had salivation from the right corner of the mouth during the three weeks since his onset. No defect was found in the shape of the tongue, but there was some difficulty in reaching the corners of the mouth and the upper lip. It was also difficult for him to elevate the tongue to the requested points on the palate, as well as to sustain such elevation for a long time.

The patient's articulation was evaluated in the context of monosyllables, words and sentences. Articulatory deficiencies were observed in 27 out of 100 syllables during a monosyllable articulation test. Most of the errors were sound distortions. Syllables with /k/ and /g/ (e.g. /ka/ and /ga/) gave the impression that their place of articulation was further back than usual. /tʃ/, /ts/ and /dʒ/ were more similar to fricative sounds than to affricate sounds. The distortion of syllables with /s/ and /ç/ seemed to be due to insufficient frication. Omissions of sounds were observed in the context of contracted sounds (i.e. pa/pja, go/gjo). Substitution was limited to voicing of voiceless plosives /k/ and /p/ (in other contexts /t/ was also voiced). An overall observation of his monosyllable articulation suggested an under-shoot of the tongue elevation resulting in insufficient closure or narrowness and some inadequate laryngeal adjustment resulting in the voicing of voiceless plosives.

Forty errors were elicited on 85 words context. These included a) prolongation of vowels; b) insertion of a double consonant (gemination of a consonant); c) voicing or devoicing; and d) distortion of consonants. Fourteen out of 40 errors were due to the prolongation of short vowels. These errors were only observed in initial vowels, most of which were low vowels such as /a/ and /o/ (often in /a/ before bilabial sounds and in /o/ before linguo-alveolar and fricative sounds). The insertion of a geminate consonant, which is the phoneme /Q/ in Japanese, was perceived in 9 words. Most of the geminate consonant insertions occurred after short vowels or just before /k/ (7/9). The rest were observed before /ʃ/ and /ç/. In 3 utterances, voiceless sounds were inadequately voiced. These were /t/ and /tʃ/ in word-initial and /s/ in word-medial position. The devoicing of voiced sounds was observed in /g/ and /b/ in word-medial position. In the context of words, /s/, /ʃ/, /ç/ and /dz/ were again perceived to be distorted with an impression of weak frication. In addition, /r/ was distorted in every context. It sometimes sounded like /d/ or /dʒ/ in initial position, while omission or weakness, possibly due to incomplete contact of the tongue with the alveolar ridge, occurred in word-medial position. The speaking rate was not particularly slow compared to that of the speech pathologist after whom the patient repeated. However in the erroneous utterance of words the intensity pattern gave a deviant impression.

The patient's articulation breakdown was much clearer in the context of sentences. In the repetition of simple sentences, 43 out of 48 utterances showed some defects. In addition to all of the errors seen in the context of single word repetitions, an irregularity in speaking rate was also noticed. Some words were spoken much slower than others in a sentence. In the context of reading from books, his speech was characterized by a) an omission of vowels and consonants; b) the substitution of consonants and syllables; c) the distortion of consonants; and d) the addition of geminate consonants. Omission of vowels occurred after /k/, /t/, /d/ and /r/ (e.g. /ta/, /ke/ and /ru/), while omission was perceived often for medial position /r/ (e.g. koreano/ korerano), and a few times for /n/ and /s/ in the context of $a\left\{\begin{matrix}n\\s\end{matrix}\right\}a$. Substitutions included long vowels for short vowels, occasionally associated with omission of the following syllable; affricates for fricatives (tʃ /s, ʃ); devoicing plosive and affricate sounds (e.g. k/g); voicing of voiceless sounds (e.g. dz/s); and shortening of long vowels—though this did not occur as frequently as did the prolongation of short vowels. Those sounds which were distorted in single syllable repetitions were again distorted in the context of reading from a book. The insertion of a geminate consonant was observed quite often before /k/ in word repetition and additionally before /t/, /N/, /ts/ and /r/, though much less frequently. The omission of vowels and insertion of glottal stops gave a perceptual impression of staccato. The speaking rate was not slow, but excess stress on /k/, /t/, /dz/ and /o/ in the initial position of words seemed to give an impression of a deviant intensity pattern.

Running speech was characterized by prolonged phonemes, the omission of vowels and the insertion of geminate consonants, resulting in faltering speech, and excess stress on initial syllables and acute pitch change at the beginning of utterances —all of which gave the impression of unusual intonation and explosiveness.

Within three months of the first assessment of the subject's speech, errors in monosyllables, words and simple sentences disappeared, while those which occurred in book reading and running speech lasted for about six months, although considerably decreased in frequency. Supersegmental aspects such as intensity and pitch pattern recovered faster than the articulation of certain sound combinations (e.g. repeated sounds such as /tatakau/).

In the final assessment, that is 8 months after onset, none of these errors were observed in any situation. The patient's speech was perceived as normal by two people who had not had any direct contact with him prior to treatment.

In order to describe objectively the nature of the subject's speech problems, a sound spectrographic analysis was made of the erroneous utterances, which were compared both with those recorded later at 4 months after onset and with those of normal subjects.

Intensity Pattern

An unusual intensity pattern was noticed in the subject's dysarthric speech. Spectrographic analysis of the erroneous utterances in the word repetition test revealed that the intensity patterns in the dysarthric speech at 1 month after onset differed from those which were perceived as normal at 4 months after onset. In bisyllabic words, the intensity contour for the first syllable was always larger (higher and wider) than that of the second syllable in the dysarthric speech. On the other hand, the intensity patterns at 4 months after onset showed the opposite tendency. That is, the contour of the second syllable was larger than that of the first one. This pattern is consistent with that of normal subjects (Fig. 1).

In the dysarthric speech recorded at one month after onset, the intensity contour of trisyllabic words also showed the superiority of the first syllable. The intensity contour of the first syllable was higher, wider or higher and wider than that of the second or third syllable. Whereas at 4 months after onset the intensity patterns of the same words showed each syllable sharing about the same height and width as the second and the third syllables which were superior to the first syllable (Fig. 2a & b).

In quadrisyllabic words, no clear intensity pattern was observed among any of the quadrisyllables. However, at 4 months after onset it was noticed that the intensity contours tended to have more peaks corresponding to the number of syllables in the correct articulation by the patient and the normal subjects than in the dysarthric speech. For example, the intensity contours of "hjakuen," show only 2 peaks, one for the first syllable and the other for the other syllables with about the same width (Fig. 3).

Excess stress on the first syllable may be related to the prolongation of the initial vowels, both of which give the impression of an explosive initiation of speech.

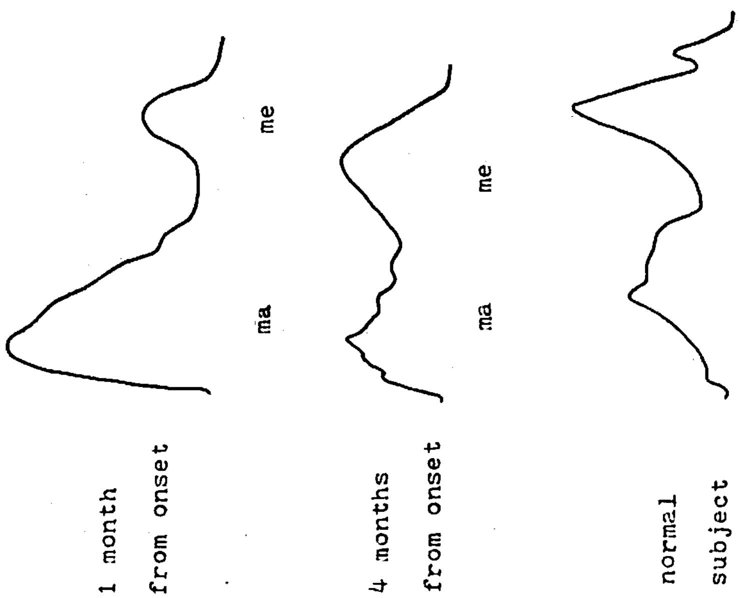


Fig. 1 *Examples of the intensity pattern for bisyllabic words.*

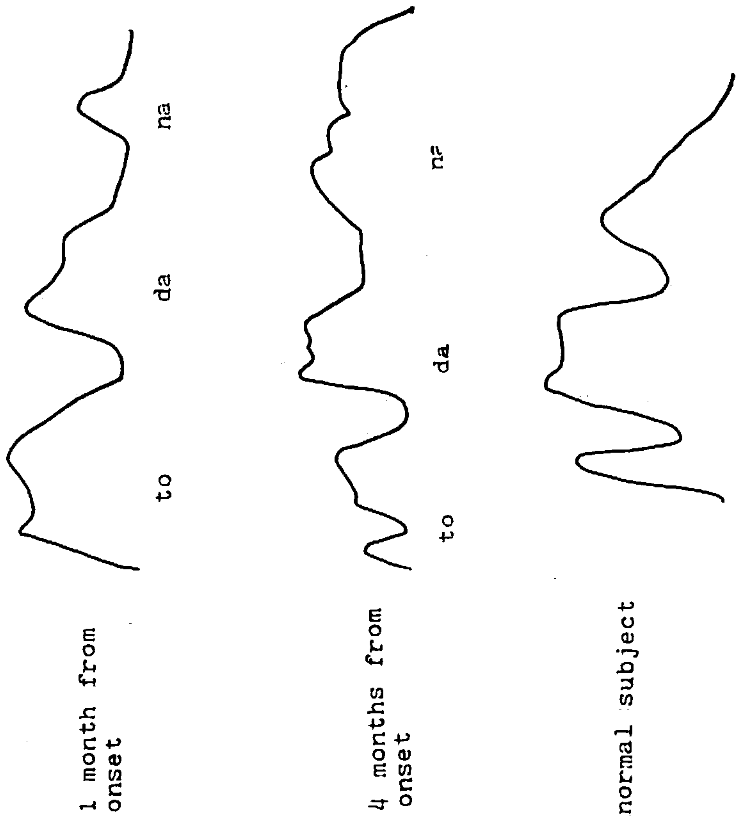


Fig. 2a *Examples of the intensity patterns for trisyllabic words.*

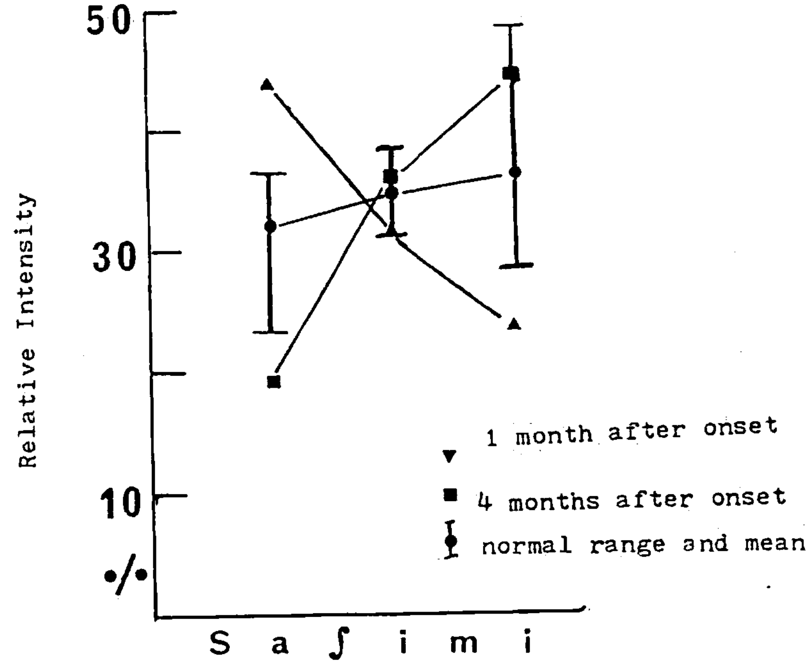


Fig. 2b *Relative intensity in the word "sashimi" for the dysarthric at 1, 4 and 7 months from onset in comparison to normal subjects.*

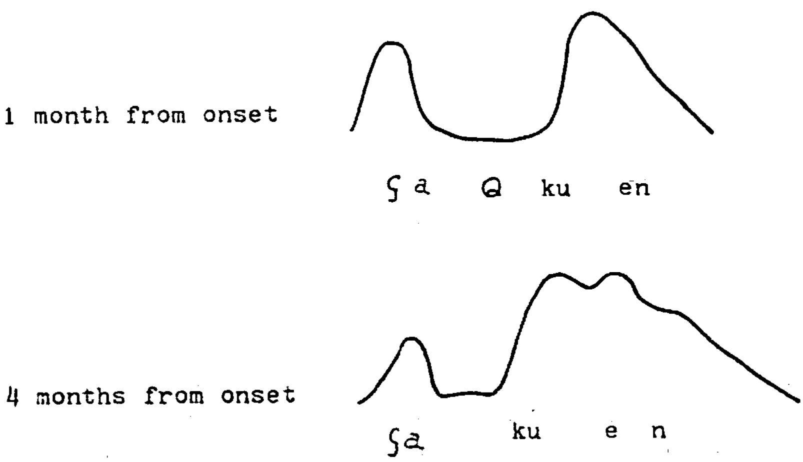


Fig. 3 *Examples of the intensity patterns for quandrasyllabic words.*

Formant Pattern

One month after onset, spectrograms of /k/ and /g/ in monosyllable repetition were characterized by the omission of vowel formants either partially or totally and by the substitution of fricatives for stops. The frication noise spread over and sometimes replaced an entire syllable. This is consistent with the perceptual impression that /k/ and /g/ were like pharyngeal closures and that often fricatives were substituted for stops. Cineradiographic study (Kent et al. 1975) has confirmed an uvular or pharyngeal closure in the articulation of /k/ by ataxic dysarthric individuals. Kent et al. interpreted this as the result of a musculature insufficiency for the large displacement of the tongue mass. In the context of coarticulation, the distortion of /g/ and /k/, the omission of vowels after /k/ (which is actually a fricative), and the substitution of /k/ for /g/ were all often observed. These impressions are supported by the spectrographs.

Spectrograms of these sounds were also made at 4 months after onset (i.e. 3 months after the first assessment). In contrast to the first assessment, formants were seen in all of the syllables and the stop (i.e. spike plus blank) was normal in syllables with /k/, except /ki/ which is usually a fricative-like sound in normal speech.

In the context of monosyllables, a spreading of the frication noise on the formants instead of the spike was also observed in /ta/ and /da/. A lack of separation between the frication noise and the formants was generally seen in syllables with /s/ (with the exception of /se/) and /ts/. However, at 4 months after onset the spectrograms of these sounds showed a clear separation between the frication noise (the spike in /ta/ and /da/) and the formants. The spreading frication noise seems to be explained by the slow movement of the tongue which led to insufficient closure, or by a slow release after constriction. Also, it should be acknowledged that the patient substituted affricates for fricatives (i.e. tʃ/ʃ, ts/s) in the context of words and sentences, which may be explained better by hypermetrie rather than by slow movements. The irregularity in the nature of the patient's speech could be characterized by distortions in /s/, /ç/, /ʃ/ and /dʒ/ due to weak frication in some cases, and by the omission of vowels possibly due to an exaggeration of the preceding consonants or the substitution of affricates for fricatives in other cases.

Duration

Some of the deficiencies in the patient's utterances seemed to relate to durational features. The prolongation of short vowels and the insertion of the geminate consonant /Q/ can be included as examples. In the word repetition test at 1 month after onset, 35% of the errors were due to the substitution of long vowels for short ones. The spectrograms of these erroneous utterances revealed that the duration of the prolonged vowel was nearly twice as long as that of the corresponding vowels at 4 months after onset in most instances (i.e. a mean of 180% longer within a range of 160% to 260%). Table 1 shows the segment durations for the word 'zabuton.' The data indicate that the initial vowel, V_1, in dysarthric speech is considerably longer than those of correct utterances by the patient or by normal subjects (e.g. more than 3 S.D.). On the other hand, the total duration of the dysarthric speech is within 2 S.D. In most of the utterances, the duration of the vowel (V_2) following

Table 1 *Relative segment durations in the word "zabuton" for the dysarthric patient at 1 and 4 months from onset compared to normal subjects (based on 9 Ss. x 2 = 18 utterances)*

	dz	a	b	u	stop gap	t	o	N (%)	Total Dur. (msec.)
1 month	4	*36	8	*0	19	3	15	15	503.2
	4	*37	9	*0	21	4	*9	15	525.4
4 months	7	19	11	14	14	3	13	21	540.2
Normal (mean)	9.2	16.1	9.1	14.9	14.2	2.9	16.4	18.7	623.1
(S.D.)	3.5	3.4	1.9	4.4	3.4	8.9	2.3	3.9	65.8

*> ± 2 S.D.

Table 2 *Segment durations in the word "hanetsuki" for the dysarthric patient and a normal subject. When repeated twice by the patient, one was correct while the other was erroneous. All values are in msec.*

(msec.)

	h	a	n	e	ts		w	k	i	Total
correct	59.2	81.4	103.6	81.4	96.2	125.8	133.2	22.2	51.8	747.4
erroneous	66.6	148.0	222.0	0.0	88.8	66.6	133.2	51.8	0.0	777.0
normal	59.2	59.2	74.0	125.8	74.0	88.8	88.8	74.0	96.2	740.0

a prolonged vowel (V_1) was shortened.

During the test, the words were repeated twice in succession. In most instances, the patient made errors on both utterances. But there were a few cases where one utterance was perceived as distorted due to a prolongation of the vowel, whereas the other was perceptually correct. Table 2 contains the segment durations for the words 'hanetsuki' as an example. Notice that the duration of /a/ in the defective utterance is double that of the correct utterance, while in the former, /i/ is devoiced —resulting in about the same total duration for both utterances (i.e. 100 and 101). Such inconsistency in misarticulation has been described as a common characteristic of ataxic dysarthria, and mere "slow movement" can not account for this pathology.

The addition of /Q/, a geminate consonant, was perceived in 9 out of 40 errors on the word repetition test. Spectrographic analysis indicates that the duration of the closure period (stop gap) for /k/, /ʃ/ and /ç/ in the dysarthric speech were more than twice as long as that in the correct speech at 4 months after onset (mean 210%; range from 156% to 333%). Although prolongation of the stop gap does not increase the total duration of the utterances, no specific means of compensation was found. Segment durations for the words 'sashimi' are contained in Table 3. The data indicate that the duration of the closure period for /k/ in the dysarthric speech was longer than that for the normal subjects, exceeding it by more than 3 or 4 S.D., whereas the duration at 4 months after onset was within the normal range (within 1 S.D.). Although no silent period was observed between /a/ and /ʃ/ in the spectrograms of the normal subjects or those of the patient's utterances at 4 months after onset, there is a blank of 13% and 14% of the total duration in the dysarthric speech at 1 month after onset.

Since the duration of the long vowels and the stop gaps for /Q/ preceding voiceless plosives and affricates appears to have been more than twice as long as its shorter counterpart, the perceptual impression that short vowels were substituted for by long ones and that /Q/ was inserted before /k/ is not unnatural. The prolongation of vowels and addition of geminate consonants, however, seem to have affected the suprasegmental aspects rather than the segmental aspects perceptually in most cases.

In the sentence context a marked variation in the speaking rate was noticed in some cases. Its perceptual consequence was jerky and faltering. Spectrograms were made on 5 sentences from a simple sentence recitation test to determine the variation in the speaking rate within a sentence. Table 4 contains relative phrase durations (%) and mean syllable durations for the sample sentence "sorini zabuton o hiku." The data indicate that the speaking rate (i.e. mean syllable duration) of the dysarthric speech varied considerably in comparison with that of the patient at 4 months after onset and the normal subject. He tended to be slower in certain kinds of coarticulation, which will be mentioned later, but attempted to maintain a faster rate in others.

Since intermittence of speech was noticed in the context of reading books and running speech, 2 sentences were taken from the utterances in the context of reading a book for spectrographic analysis. Table 5 contains the durations of the voiceless consonants, blanks (including stop gaps) within a phrase and silent periods between phrases of the sentence 'soreigai ha:be: ni ketsuisurukotoga arudaro:ka"

Table 3 *Relative segment durations in the word "sashimi" for the dysarthric patient at 1 and 4 months from onset compared to normal subjects (based on 9 Ss. x 2 = 18 utterances)*

	s	a	blank	ʃ	i	m	i(%)	Total Dur. (msec.)
1 month	7	*25	*13	11	7	*25	12	495.8
	7	*30	*14	15	*5	18	12	547.6
4 months	8	12	0	24	17	12	28	562.4
normal (mean)	16.2	13.7	0	14.4	19.6	15.8	19.7	590.5
(S.D.)	4.6	2.1	0	3.4	6.4	3.1	3.2	54.4

* > ± 2 S.D.

Table 4 *Relative phrase durations in the sentence "sorini zabuton o hiku" for the dysarthric patient at 1 and 4 months from onset as well as for a normal subject*

		sorini	zabuton o	hiku (%)
1 month	phrase dur.	33.3	30.4	7.3
	mean syllable dur.	11.0	6.0	3.7
4 months	phrase dur.	27.4	37.2	20.5
	mean syllable dur.	9.1	7.4	10.2
normal	pharse dur.	24.9	43.2	19.7
	mean syllable dur.	8.3	8.6	9.7

Table 5 *Durations for voiceless consonants, stop gaps and silent periods between phrases in the sentence "soreigai haa bee ni ketsuisurukotoga arudarooka." All values are in msec.*

	1 month	7 months
Voiceless consonants	447.7	414.4
Stop gaps & blanks	791.8	214.6
Silent periods between phrases	1050.8	436.6
Total durations of voiceless periods	2290.3	1065.6
Total durations of the sentence	4014.5	4432.6

in the dysarthric speech and that of the same patient 7 months after onset.

The data indicate that the total duration of the voiceless period in the dysarthric speech is more than half of the total duration of the sentense. The discrepancy between 1 month and 7 months after onset is most noticeable in the duration of blanks within the phrase. This is due to the devoicing of the vowels and voiced consonants and longer stop gaps, one of which was perceived as an insertion of /Q/. The longer silent period between phrases did not affect the utterances so much as longer stop gaps or blanks within a phrase, but still gave the impression of short phrases or chopped speech. Devoicing or longer stop gaps also affected the intensity pattern, with acute changes from low to high.

Recovery Process

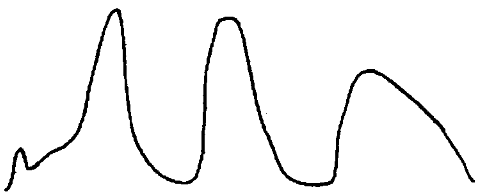
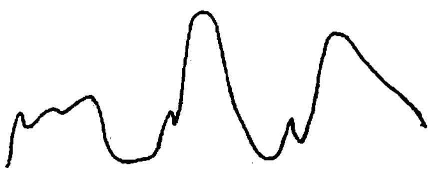
When he was asked to read from a book at three different rates, he showed more control over his speech at a slow rate than at a fast rate, although he made errors in certain combinations of sounds even at a slow rate. These combinations were 1) repetition of the same syllable with /t/, /k/ and /ts/ as in kakaranai, tatakai and tsutsuku; 2) repetition of the same consonant with /r/, /t/, /k/ and /s/, such as in rareru, tateru, kaku and sasetsu; and 3) similarity in place of articulation of /r/, /t/, /d/, /k/, /g/, /ʃ/, /tʃ/ and /ts/, such as in naranai, gakete, kisetsu and chizu. Some of these errors disappeared within a few months while others lasted longer. Repetition of the same syllable seemed more difficult and the patient tended to articulate these sounds more slowly than others. A staccato impression in these sounds lasted for about 6 months. Table 6 shows example of changes in the durational and intensity patterns of these words over time.

Since repeating the same syllable was particularly difficult for the patient, samples from a diadochokinetic test were studied. The nonsense syllables /pa/, /ta/ and /ka/ were each repeated for 1 minute by the patient at his fastest rate of speech. The first and the last 10 seconds of the recorded samples were processed following the procedure of Tatsumi et al. (1979) for comparison with data for normal subjects. Computed were: a) the mean of the syllable duration; b) the standard deviation of the syllable duration; and c) the standard deviation of the relative values of the maximum voice intensity.

Fig. 4 shows the mean syllable durations of the patient for /pa/, /ta/ and /ka/ at 1 month, 4 months and 7 months after the onset of the disease. The data for the normal subjects were taken from Tatsumi et al. (1978) for comparison. Overall, a gradual decrease in the mean of the syllable duration on the syllable repetition was observed over time.

The values of /pa/ at 7 months were within the higher limit of the normal range while those of /ta/ or /ka/ were not. The numbers of repetition per second for the syllable /pa/ in the first 10 seconds were 3.47, 4.4 and 5.2 at 1 month, 4 months and 6 months after onset respectively; 3.1, 4.0 and 4.3 for the syllable /ta/; and 3.2, 4.0 and 4.1 for the syllable /ka/. These values were much smaller than those for normal subjects: 6.78 for /pa/, 7.36 for /ta/ and 6.68 for /ka/. The discrepancy between /pa/ (lips) and /ta/ and /ka/ (tongue) both in the values of the repetition rate and its recovery process suggests the possibility of a difference in lip and tongue involvement. That is, the patient's tongue movement might have been somewhat

Table 6 *Recovery process of the word "tatakai"*

Syllable Durations and Blanks	Intensity Patterns
1 month from onset ta ta kai Total 22 0 31 17 30 % 473.6 msec	 t h a: k ai
1.5 months from onset ta ta kai Total 25 16 16 15 27 % 495.8 msec	 t a: t a k ai
4 months from onset ta ta kai Total 20 20 17 17 27 % 444.0 msec	 t a t a k ai
6 month from onset ta ta kai Total 18 12 20 15 35 % 444.0 msec	 t a t a k ai

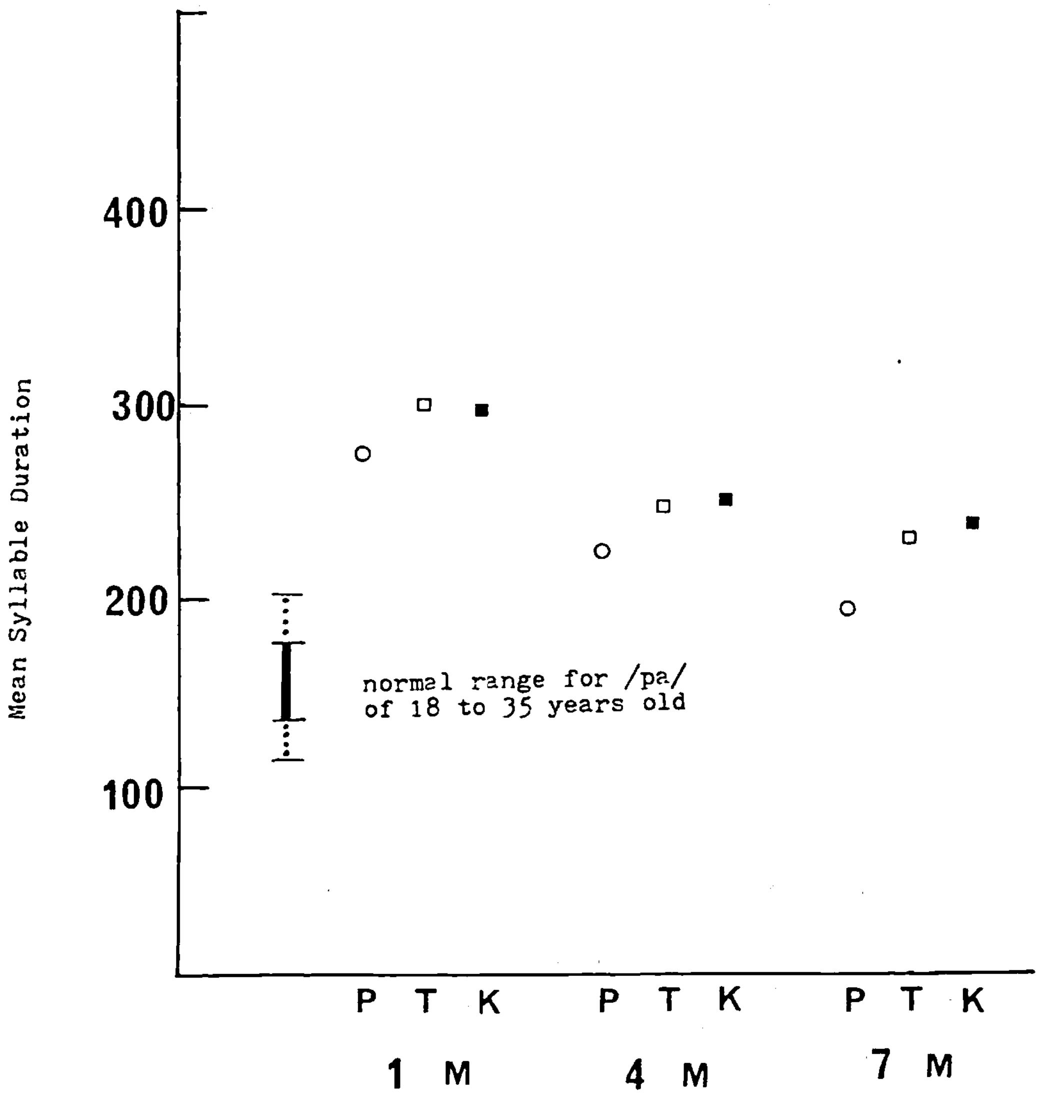


Fig. 4 *Mean syllable duration in monosyllable repetition for the dysarthric patient at 1, 4 and 7 months from onset compared to normal subjects.*

more disturbed than that of the lip.

It should be noted that the total duration of each sample was strikingly shorter at 1 month after onset than at 4 months and 7 months after onset. At 1 month after onset, except for the first sample (6 seconds), samples lasted for only 2 seconds or less, whereas the patient seemed to be able to sustain phonation for 10 seconds easily even in the last 15 seconds of repetitions at 4 and 7 months after onset.

Fig. 5 shows the standard deviation of the syllable durations in the repetition of the syllables /pa/, /ta/ and /ka/. The data for 1 month after onset are based on samples which had more than 20 repetitions of each syllable. Notice that all of the S.D.'s of the syllable durations decreased considerably within 4 months after onset, indicating a complete recovery from the irregularity in the rate of the syllable repetitions.

The change in the standard deviation for voice intensity is shown in Fig. 6. Again, all of the S.D.'s fell within the normal range within 3 months after onset, which indicated a recovery from the irregularity in the voice intensity. The devoicing in the repetition of the syllable /ka/ contributes to the small S.D. value at 1 month after onset.

Compared with samples from the first 10 seconds of repetitions, those of the last 10 seconds showed considerable reduction in the rate and total duration of the syllables /pa/ and /ka/, but those of the syllable /ta/ were nearly the same or better in some instances. These results are consistent with the perceptual impression obtained in the therapy sessions that the irregularity of the intensity and rate, especially the explosiveness, disappeared quickly and that the articulatory deficits decreased gradually. It appears that when the patient tried to control the irregularity of the suprasegmental features his speech became rather monotonous and slow. However, after a few months his suprasegmental aspects were perceived as normal, though some articulatory breakdown remained.

Discussion

The deviant dimensions of the patient's speech can be summarized as follow.

a) Distorted sounds possibly due to
   1. misplacement of tongue contact (i.e. in /k/ and /g/)
   2. insufficient closure or narrowness (e.g. in /tʃ/ and /s/).
b) Substitution of sounds possibly due to
   1. over-shooting of the tongue movement for fricatives (e.g. tʃ/ʃ)
   2. inadequate laryngeal adjustment resulting in voicing errors (e.g. k/g and g/k)
   3. prolongation of short vowels (e.g. a:/a and o:/o).
c) Omission of sounds possibly due to
   1. insufficient tongue contact (e.g. in /r/ and /n/).
d) Insertion of the geminate consonant /Q/ resulting in
   1. prolongation of the stop gap (e.g. Qk/ k).
e) Deviant intensity pattern which could be described as an explosive initiation of speech.
f) Irregularity in the speaking rate within sentences mainly because of a selective reduction in rate in certain sound combinations.

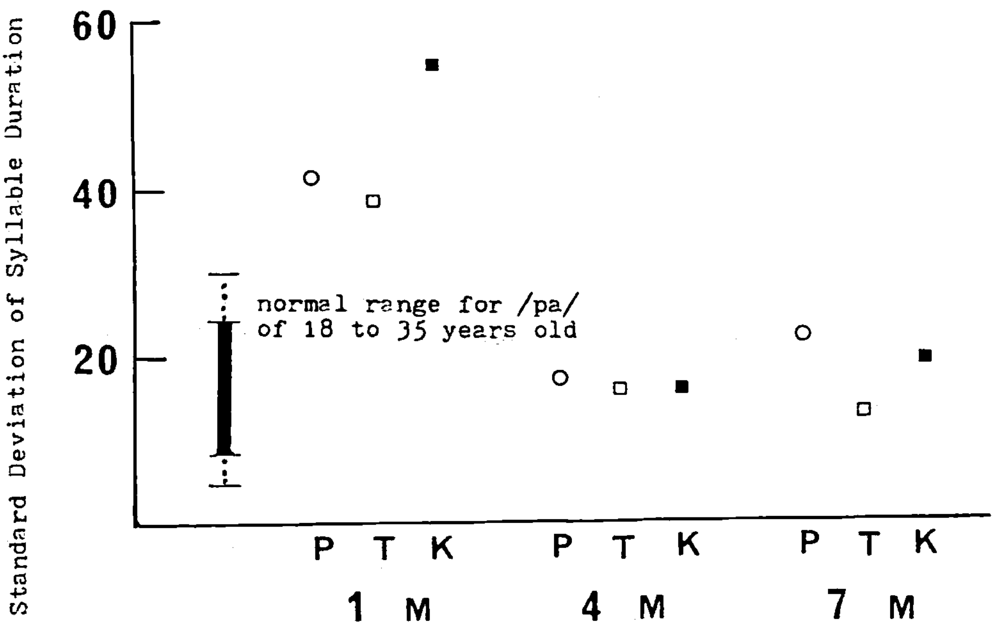


Fig. 5 *Standard deviations of syllable duration in monosyllable repetition for the dysarthric patient at 1, 4 and 7 months from onset compared to normal subjects.*

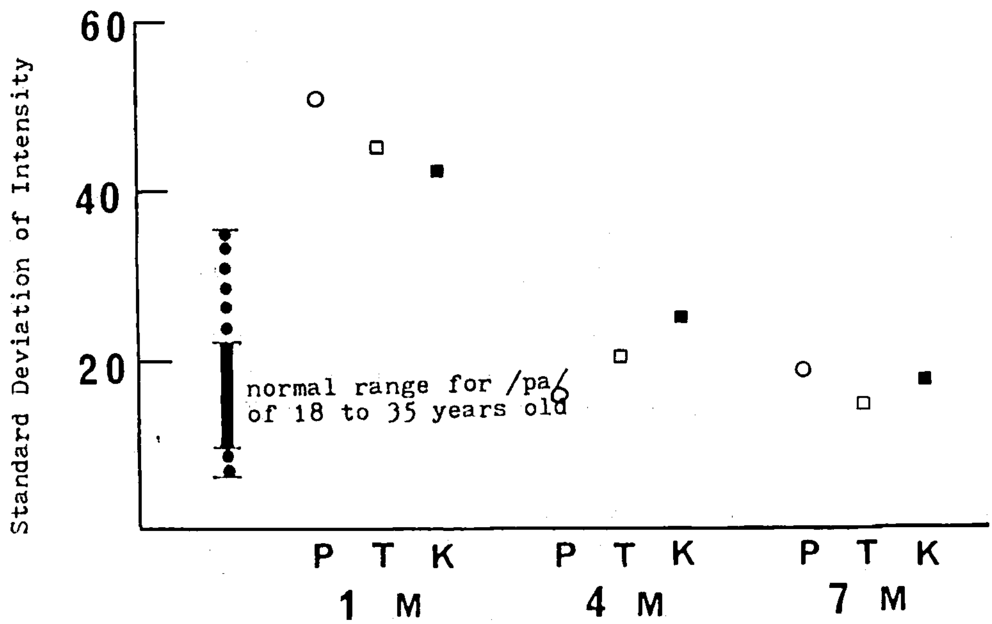


Fig. 6 *Standard deviations of intensity in monosyllable repetition for the dysarthric patient at 1, 4 and 7 months from onset compared to normal subjects.*

Kent et al. (1975) have suggested "generalized hypotonia" as a primary factor in ataxic dysarthria. Among the above dimensions, the slow transition which could result in the prolongation of short vowels and stop gaps and a delay in the voice onset time (which resulted in the devoicing of voiced consonants) might be explained by such a hypotonia because of a delay in the generation of the patient's muscular forces. A reduced rate of muscular contraction and a reduced range of some movements due to hypotonia may account for the insufficient closure, or narrowness, and insufficient contact. However, in order to explain the rest of the symptoms, such as the over-shooting of the tongue movement and the explosive initiation of speech, the concept of hypermetria which is common in general action by ataxic individuals may have to be introduced. Although Kent et al. (1975) have interpreted the misplacement of the tongue contact in /k/ and /g/ (i.e. substitution of pharyngeal closure for a velar closure) as a result of hypotonia (that is. a reduced range of tongue movements), it could also be described as an example of hypermetria.

Second, Kent et al. (1979) have reported that their subjects with ataxic dysarthria convey an impression of regularity derived from a tendency toward uniform syllable durations mainly due to the lengthening of unstressed vowels, lax vowels and consonants in clusters. They suggested that this might be accounted for by the patient's storing less motor control information. For example, the dysarthric individual may prepare motor programs for only one syllable instead of preparing programs for several syllables, and therefore each syllable might become a unit into itself. In our patient, however, the prolongation of short vowels did not result in uniform syllable duration, but rather led to a disproportion of syllable durations. Moreover, an inconsistency in the articulatory breakdown (i.e. when he uttered the same word twice one was correct while the other was erroneous) suggests irregularity. The results for the repetition of monosyllables revealed an irregularity in intensity and duration. Hirose et al. (1978) concluded in their study using an X-ray microbeam system that the range and velocity of the movement, as well as the intervals, are considerably inconsistent in atxic subjects.

Third, an irregularity in the speaking rate within a sentence was due to a selectively reduced rate for the articulatory movements in certain combinations of sounds. In addition, in the articulatory tests some sounds or combination of sounds elicited more errors than others. These could suggest a difference in involvement among the articulators and among different kinds of movements. The patient tended to show more deficit of control for tongue movement than for that of the lips, and more in the elevation of the tongue than in antero-posterior movement.

Fourth, the disproportion of syllable duration due to the prolongation of short vowels and as a compensatory shortening of following vowels possibly indicates the patient's insistance on a preplanned duration for a word by inadequate readjustment, instead of revising it to proportional syllable duration by increasing the total duration. This phenomenon was also observed in the variation in the speaking rate within sentences. Therefore, some of the patient's speech disorders may be due to inadequate compensation. In the therapy sessions around 2 months after onset, it was noticed that the patient tried to prevent explosiveness and articulatory breakdown by sustaining the approximately constant intensity and pitch, as well as a slow rate, which resulted in the impression of monotonous and slow speech. However, he gradually returned to a natural intonation and speaking rate within a few months. Hence, the monotone and the slow rate of his speech could be explained better as the result of a compensation rather than an impairment per se.

Finally, a few inferences toward speech therapy technique can be drawn from the present analysis. First, the speaking rate of such a patient should be reduced so that he might articulate each syllable more accurately as well as control suprasegmental features more easily. Second, at the same time, the sound combinations which are determined to be more difficult for the patient than others should be articulated repeatedly at first at a slow rate, and then gradually faster, until he can articulate fast and precise movements. Third, since the dimensions on diadochokinetic tests seem to provide a sensitive index of speech production ability, these tests should be used periodically in therapy sessions for assessment.

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