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Original Article

The involvement of mora segmentation skills in the auditory comprehension process of aphasic patients

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ABSTRACT
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Purpose: This study was conducted to assess the involvement of mora segmentation skills in the auditory comprehension process of aphasic patients.
Methods: Several tests, such as an auditory word comprehension test, a mora segmentation test (using meaningful and meaningless words), speech discrimination test, and verbal short-term memory test, were conducted in 28 patients with aphasia, owing to left hemisphere brain damage, who had agreed to participate in the study.
Results: There was no significant relationship between mora segmentation skills for meaningful words and auditory comprehension ($F = 0.72$, $p = 0.407$). When mora types were analyzed separately for comparative purposes, a significant relationship between auditory comprehension and mora segmentation skills for meaningful words, including only a single-kana sound, was observed ($F = 7.50$, $p < 0.05$). However, such a relationship was not observed with words that include the sound of kana "n." There was no significant difference between meaningful words and meaningless words in terms of the relationship between mora segmentation skills and auditory comprehension (total correct answers for meaningless words: $F = 0.03$, $p = 0.857$; meaningless words containing only single-kana sounds: $F = 4.40$, $p < 0.05$).
Conclusions: The results suggest that phoneme segmentation assists phonological perception during the process of auditory word comprehension. Furthermore, it is conceivable that the segmentation unit involved in this process is a syllable, rather than a mora; however, this possibility requires further study.
Key words: aphasia, mora segmentation skill, auditory comprehension, phonological perception

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Introduction

It has previously been reported that the ability to discriminate speech [1], the understanding of the meaning of words, or syntactic comprehension [2], and verbal short-term memory [3] are involved in the impairments of auditory comprehension that are due to aphasia. Meanwhile, in "Mora and Syllable Rhythm Training," Doseki [4, 5] states that segmenting a word into syllables and perceiving the number of syllables is an effective way for patients with auditory comprehension impairment, owing to Wernicke's aphasia, to improve their ability to discriminate sounds. This suggests that separating words into syllables may be involved in auditory comprehension.

Separating words into syllables, or phoneme segmentation, refers to the breakdown of words into units called phonemes or syllables [6]. These segmentation units also include morae. A mora is a unit based on isochronous length, and is the basic rhythmic unit of the Japanese language. On the other hand, syllables are sound blocks that are centered on vowel sounds [7−9]. The common unit used by morae and syllables is a single-kana sound, whereas the unit that differs is special morae. Single-kana sounds are syllables represented by one kana character, excluding the sound of “n” and the assimilated sound of “tsu” (e.g., since the word “ringo” contains the sound “n,” a special mora, it is a three-mora, two-syllable word—the number of morae and syllables do not match. The word “kani,” which contains only single-kana sounds, has the same number of morae and syllables, that is, two).

“The phoneme segmentation skills of aphasic patients are measured by the expression of spoken language, as well as by the extent to which they display conscious phonological command in processing kana characters, such as reading and writing. Furthermore, it has been believed that impairment of these capabilities leads to the development of phonemic paraphasia and impaired kana character processing [10]. Previous studies have reported a difference between aphasia and healthy subjects with regard to mora segmentation skills [11], mora segmentation training for spoken language expression [12] and the relationship between kana character processing and phoneme segmentation [13, 14]; however, no study has previously investigated the relationship between phoneme segmentation skill and auditory comprehension.

Phonetic study, which is a different field, has also considered how phonological units are used in perceiving the Japanese language [15−17], whereas investigators working in the area of language development have evaluated phoneme segmentation skills, in relation to the process of reading and writing kana characters. However, no reports from either of these study specialties have discussed whether phoneme segmentation is involved in understanding spoken language [18−22].

It has generally been accepted that phoneme segmentation skills are a prerequisite for expressing speech language and processing kana characters [12−14]; however, the manner in which phoneme segmentation is involved in the process of auditory comprehension in aphasia has not yet been clarified. This research focuses on mora segmentation skills and attempts to examine their involvement in the process of auditory word comprehension among aphasics.

Methods

Study participants

This study was conducted in aphasics with left-brain hemisphere damage, all of whom gave their consent to participate. All participants were inpatients or outpatients at one of the 11 facilities (nine hospitals, two nursing homes for the elderly) located in five prefectures (Miyagi, Iwate, Yamagata, Hyogo, and Okinawa). A standard test for aphasia, the “II Auditory Comprehension” of the Western Aphasia Battery (WAB) [23], was conducted for all participants in order to eliminate those with severely impaired auditory comprehension, that is, patients who scored 3 and below out of 10 points. Those who scored 9 and below out of 37 points on the Raven’s Coloured Progressive Matrices (RCPM) [24] (the higher the score, the higher the intelligence) and those with hearing loss that clearly interferes with everyday communication were also excluded. The remaining 28 patients (Aged 49−88 years, average age 63.2, standard deviation 9.4) were included in the study (Table 1).

Table 1. Characteristics of research participants

Gender	Male	20 (71%)
	Female	8 (29%)
Disorder	Left cerebral infarction	20 (69%)
	Left cerebral hemorrhage	8 (31%)
Aphasia type	Amnesic	10 (38%)
	Broca	6 (23%)
	Wernicke	9 (26%)
	Conduction	3 (11%)
Age	63.2 ± 9.4 years old	
RCPM	26.6 ± 7.2 points	
Spoken Language Comprehension	7.1 ± 6.8 points	

Gender, disorder, and aphasia type show frequencies of occurrence, whereas figures in parentheses indicate the proportions.
The figures under age, RCPM (Raven’s Coloured Progressive Matrices), and spoken language comprehension show the average ± standard deviation.

Evaluation method

Evaluation procedure

All participants took four tests, which were individually administered by the author or the patient's speech therapist, in either a language training room or a private room with sound insulation. These tests were administered in the following order: (1) auditory comprehension test, (2) mora segmentation skills test (meaningful and meaningless words), (3) speech discrimination skill test, and (4) verbal short-term memory test. Tests (1) and (4) were provided orally by the test administrator. The test contents for (2) and (3) were pre-recorded by a male native Japanese speaker using a microphone and saved on a personal computer as Windows Media Player files. The recorded voice was played on a small speaker connected to the personal computer and placed in front of each study participant, approximately 50 cm away. The volume was preset at 80 dB, which is slightly louder than ordinary conversation, and was adjusted prior to the test to suit each individual.

Evaluation Items

(1) Auditory comprehension test

The number of correct answers given in the "B. Auditory Word Recognition" section of "II Auditory Comprehension" from the Japanese version of WAB [23, 25], previously employed in the participant selection procedure, was used. The study participants each selected a specific item from six pictures of items according to the examiner's instruction. In order to evaluate word comprehension, the number of correct answers was converted to points (ranging from 0 to 41) by excluding test words that are numbers, one-kana character words, or words with right/left adjectives, such as "right ear" and "left knee."

(2) Mora segmentation skills test

The testing method for mora segmentation of words introduced by Watamori and colleagues (1984) in "Speech Therapy Manual" [26] was utilized to test mora segmentation skills. Test words were selected from the test vocabularies listed in the Sophia Analysis of Language in Aphasia (SALA) aphasia test [27]. A total of 42 highly familiar, meaningful words containing 2 to 4 morae and the same type of 42 meaningless words were selected. In order to determine the skill, mora or syllable segmentation is involved in auditory comprehension; each category included 21 words that included only a single-kana sound (e.g., "ebi," "uchiwa") and 21 words that included the sound of kana "n," a special mora (e.g., "genkan," "kazan"). The number of special morae was not restricted to one per word. To test, the examiner allowed the participant to hear the word, and then asked the individual to state how many sounds each word contained. A card with a picture of four circles (hollow, black circles) was placed in front of the participant, and he/she responded by pointing at these circles to indicate the number of sounds detected. The size of each circle was 3.5 × 3.5 cm, and they were placed at intervals of 3 cm. Scoring was based on the total number of correct answers (ranging from 0 to 42 points). Errors were counted on the basis of omission, substitution, addition, and reallocation of morae.

(3) Speech discrimination skill test

Of the auditory dissimilarity discrimination tests included in the SALA Aphasia test (2-mora meaningless words, 2-mora meaningful words) [27], the 2-mora meaningless word test was used. A total of 30 questions included 18 sets of identical meaningless words and 12 sets of words that were different. To test, the participant listened to the audio voice and was instructed to indicate "same" if the two words heard by the participant were the same, and "different" if the two words heard were different. To respond, the individual pointed to the card that said "same" or "different." The number of correct answers constituted the score (which ranged from 0 to 30 points).

(4) Verbal short-term memory test

The forward digit span tests included in the Japanese version of Wechsler memory scale [28] was used. The number of morae in the words used in the tests previously described was taken into consideration to create a total of eight tasks; the participants were asked to repeat each of the 1 to 4 digits twice. The score was calculated on the basis of each task being worth 0.5 points (with the total score range being 0 to 4.0 points).

Statistical analysis

(1) The relationship between auditory comprehension and other evaluation criteria

A correlation coefficient was calculated in order to evaluate the relationship between auditory comprehension and mora segmentation skills, speech discrimination skills, and verbal short-term memory.

(2) The relationship between auditory comprehension and mora segmentation skill

In order to clarify the relationship between auditory comprehension and mora segmentation skills, a −1.96 standard deviation from the average number of correct answers given by healthy individuals was set as the cut-off value for the mora segmentation skills test (meaningful words), speech discrimination skills test, and verbal short-term memory test. On the basis of this cut-off value, the aphasics were divided into two groups: the high-performance group, if the score was equal to or higher than the cut-off value, and the low-performance group, if the score was lower than the cut-off value (cut-off values: mora segmentation skills

= 41.2, speech discrimination skills = 29.6, verbal short-term memory = 3.0). Unpublished data by Shimizu et al. [29] was referred to for a comparative performance by healthy individuals. Furthermore, using auditory comprehension as a dependent variable, mora segmentation skills (meaningful words) as an independent variable, and speech discrimination skills and verbal short-term memory as moderator variables, the Analysis of Covariance (ANOVA) was performed. The same analysis was also performed for meaningless words (cut-off value: mora segmentation skill = 40.6).

(3) Assessment of phonological units involved in auditory comprehension

In order to examine the phonological units that are involved in auditory comprehension, mora segmentation skills (meaningful words) for words that only include single-kana sounds and for words that include the "n" sound were separated, and ANOVA was performed in a similar manner to that conducted in (2) (cut-off value: single-kana sound only = 19.1, with "n" sound = 18.7). Similarly, ANOVA was performed for mora segmentation skills for meaningless words (cut-off value: single-kana sound only = 18.2, with "n" sound = 16.3).

Furthermore, to examine the differences between the average numbers of correct words that include only single-kana sounds and the ones that include the "n" sound, t-tests were performed for both meaningful and meaningless words. In addition, in order to assess how errors are made, an analysis was conducted on the results obtained from those participants whose performance on mora segmentation of words that include the "n" sound was lower than the average, despite a higher than average performance on auditory comprehension and mora segmentation of words that only include single-kana sounds.

Statistical analysis software

The analysis was done using SPSS Ver.18 (SPSS Japan Inc., Tokyo). Significance levels of less than 5% were considered statistically significant.

Table 2. Relationship between auditory comprehension and other evaluated variables

	Auditory Comprehension
Mora segmentation skills	
Total number of correct answers	0.54**
Words that only include single-kana sound	0.60**
Words that include "n" sound	0.45*
Speech discrimination skills	0.38
Verbal short-term memory	0.63**

The figures indicate Pearson correlation coefficient.
*, $p < 0.05$; **, $p < 0.01$

Results

The relationship between auditory comprehension and other evaluated variables

Table 2 shows the relationship between auditory comprehension and other evaluated variables. Of the mora segmentation skills, the total number of correct answers, number of correct answers for words that only include single-kana sounds, and for words that include the "n" sound, all showed a significant relationship with auditory comprehension (mora segmentation skill: total correct answer: r = 0.54, correct answers for words with single-kana sound only: r = 0.60, words with "n" sound: r = 0.45). Speech discrimination skill did not show a relationship with auditory comprehension; however, a strong relationship was observed between the latter and verbal short-term memory (r = 0.63).

Relationship between auditory comprehension and mora segmentation skills

The results of ANOVA using mora segmentation skills as an independent variable are shown in Table 3 (meaningful words) and Table 4 (meaningless words). Neither of these tables indicated that mora segmentation skills have a major effect on or interactions with auditory comprehension (meaningful words: F = 0.72, p = 0.407, meaningless words: F = 0.03, p = 0.857).

Table 3. Auditory comprehension and mora segmentation skill (meaningful words) relationships based on total number of correct answers

Dependent variable: auditory comprehension		
	F	**p**
Mora segmentation skills	0.72	0.407
Speech discrimination skills	0.01	0.929
Verbal short-term memory	0.92	0.348

Speech discrimination skills and verbal short-term memory were set as moderator variables (ANOVA).

Table 4. Auditory comprehension and mora segmentation skills (meaningless words) relationships based on total number of correct answers

Dependent variable: auditory comprehension		
	F	p
Mora segmentation skills	0.03	0.857
Speech discrimination skills	0.00	0.961
Verbal short-term memory	2.39	0.137

Speech discrimination skills and verbal short-term memory were set as moderator variables (ANOVA).

Table 5. Evaluation of phonological units involved in auditory comprehension (meaningful words)

Dependent variable: auditory comprehension					
	F	p		F	p
Mora segmentation skill (words with single-kana sounds only)	7.50	0.013	**Mora segmentation skill (words with "n" sound)**	1.08	0.310
Speech discrimination skill	0.01	0.942	**Speech discrimination skill**	0.01	0.924
Verbal short-term memory	0.30	0.588	**Verbal short-term memory**	0.49	0.490

Speech discrimination skill and verbal short-term memory were set as moderator variables (ANOVA).

Table 6. Evaluation of phonological units involved in auditory comprehension (meaningless words)

Dependent variable: auditory comprehension					
	F	p		F	p
Mora segmentation skill (words with single-kana sounds only)	4.40	0.049	**Mora segmentation skill (words with "n" sound)**	0.03	0.862
Speech discrimination skill	0.00	0.983	**Speech discrimination skill**	0.00	0.962
Verbal short-term memory	2.08	0.164	**Verbal short-term memory**	1.83	0.191

Speech discrimination skill and verbal short-term memory were set as moderator variables (ANOVA).

Assessment of phonological units involved in auditory comprehension

Analyzing mora segmentation skills (meaningful words) by phoneme type revealed that words including only single-kana sounds had a highly significant effect on auditory comprehension ($F = 7.50$, $p < 0.05$), although this was not true of words that included the "n" sound (Table 5). The same results were found with mora segmentation skills for meaningless words: words that only include single-kana sounds had a highly significant effect ($F = 4.40$, $p < 0.05$), which was not true of the words that included an "n" sound (Table 6).

Figure 1 shows the average number of correct answers given by phoneme type. No significant difference was found between words that included only single-kana sounds and words that included the "n" sound in meaningful words; however, with regard to meaningless words, the average number of correct answers given was significantly lower for words that included the "n" sound.

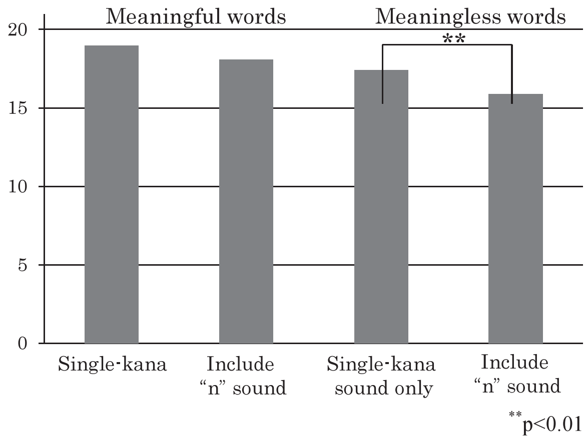

Figure 1. Comparison of average number of correct mora segmentation answers by phoneme type

Table 7. Mora segmentation errors by phoneme type

Meaningless words	"n" sound		single-kana sound		
	# of correct answers	Error type	# of correct answers	Error type	Aphasia type
Case 17	12/21	Omission 9	21/21		Conduction
Case 18	13/21	Omission 8	19/21	Omission 2	Conduction
Case 19	16/21	Omission 4, Addition 1	20/21	Omission 1	Broca
Meaningful words					
Case 14	17/21	Omission 2 NR2	19/21	Omission 2	Amnesic

The cases listed here are those in which the participants scored higher than the average on auditory comprehension and mora segmentation for words that include only single-kana sounds, but scored lower than the average on mora segmentation for words that include "n."
Figures under Error type by phoneme type indicate the number of errors. "Omission" and "Addition" indicate omission or addition of mora, respectively. NR indicates non-response.

Table 7 shows the analysis of mora segmentation error type by phonological unit. In one case, omissions were observed with both meaningful words that include only single-kana sounds and meaningful words that included the "n" sound. With regard to meaningless words, there were three cases wherein there were more omissions for words that contained the "n" sound compared with those that contained only single-kana sounds.

Discussion

The relationship between phoneme segmentation skills and auditory comprehension

The present study assessed the involvement of mora segmentation skills in the process of auditory comprehension in people with aphasia. The results indicated that a significant relationship exists between auditory comprehension and mora segmentation skills for words that included only single-kana sounds. This suggests that the ability to segment a word into some type of phonological unit helps aphasic adults with phonological perception.

Previous studies have reported that infants switch to the phonological units used in their native language during the process of language development. For example, one study showed that when statements were presented aurally, infants learning French listened to statements that contained syllables that they had previously learned for a significantly longer time than the time that they spent listening to those statements that did not comprise such familiar syllables [30]. With regard to infants learning Japanese, it was reported that 8-month old infants listen to words containing special mora, such as "chunta" and "monmo," which we frequently hear infants say, for a significantly longer time than words that do not contain special mora, such as "chuguta" and "mokomo" [31]. Since infants develop the phonological perception of their native language at approximately 10 months of age [32], these studies suggest that segmentation of words into some type of phonological units in the early stage of language development is key to phonological perception.

The present study indicated that the segmentation of words into some type of phonological units might also be helpful in phonological perception among aphasic adults.

Phonological units in phoneme segmentation related to auditory comprehension

The present study showed that auditory comprehension was related to mora segmentation skills for words that included only single-kana sounds, but not for the words that included the "n" sound. It seems possible that the phonological unit for phoneme segmentation involved in auditory comprehension is a syllable.

Our results also suggest that the "n" sound is difficult to recognize, and that the phonological unit used by aphasics in auditory comprehension may be a syllable: (1) the number of correct answers in the mora segmentation skills test for meaningless words was lower when the "n" sound was included, as opposed to the words that included only single-kana sounds, and (2) the three participants who scored higher than the average in auditory comprehension and mora segmentation for words that only included single-kana sounds made numerous errors in omitting the sound of "n."

In "Mora and Syllable Rhythm Training," Doseki [4, 5] presented two methods for evaluating auditory comprehension. The phonological unit for the first of these, the "method for accurately perceiving the number of syllables," is a syllable, and not a mora. This method emphasizes the correct recognition of the number of syllables in preference to identifying speech sounds. For example, a one-syllable word "ah" is to be recognized as a one-syllable word "ah" and not recognized as a two-syllable word "ah-a" or "a-a." Its segment unit is also a syllable. For example, this method allows the patient to hear the word "kakkontou" and separate it into syllables rather than morae. Our results seem to support the validity of this method of emphasizing segmentation using syllables as its unit.

In the second method, the "method to capture the difference between a single-kana sound and special mora" [5], patients hear, for example, "kata kata kantan" for the word "kantan," alternating the meaningless word "kata" and the meaningful word "kantan," while being presented with the phrase in syllables rather than morae, and chanting it without breaking the "syllable rhythm" [5], so that the "n" sound in "kantan" can be captured. Since Doseki's method separates special morae from single-kana sounds by using syllabic rhythm, it seems to emphasize mora segmentation with respect to special mora.

Our results support this method in terms of having a segmentation unit involved in auditory comprehension as a syllable. In addition, our results, which suggest the difficulty that aphasics have in recognizing the "n" sound, provide a certain level of evidence in support of the method that separates the "n" sound from single-kana sounds in order to promote the recognition of the "n" sound. However, if the phonological unit involved in auditory comprehension among aphasics is a syllable, then it is unlikely that the ability to segment into morae immediately leads to auditory comprehension.

Our investigation and a previous study by Hayashi [31] concurred that any individual word is segmented into some type of phonological unit; however, they were not in concordance with regard to the specific type of this phonological unit. It has been reported that the speech rhythm used during infancy is mora; however, it is generally understood that phonological awareness develops around school age to enable mora-based phoneme usage [20]. Mora segmentation may be a skill that is more related to kana character processing than phonological perception in adults.

The present study is limited in that the number of correct answers given in the mora segmentation skill test was different, according to the phonological type of meaningful and meaningless words. It seems that as compared to meaningless words, meaningful words were easier to breakdown because their kana characters were easier to recall; therefore, future studies should give some consideration to how this issue must be addressed and circumvented. In addition, the present study only tested mora segmentation skills and the only special mora included in test words was the "n" sound; therefore, further analyses are necessary to test syllable segmentation skills or mora segmentation skills that include other special morae, such as assimilated and prolonged sounds

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