

Relationship between musical and linguistic abilities in patients with aphasia

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Abstract

This retrospective study aimed to investigate the relationship between musical and linguistic abilities in patients with aphasia. We reviewed the clinical records of 32 stroke patients with aphasia admitted to subacute rehabilitation units between May 2014 and August 2018. We analyzed the results of melody and rhythm reproduction tests and subtests of auditory comprehension and speech sections in the Standard Language Test of Aphasia (SLTA) collected upon admission and discharge. The Spearman rank correlation coefficient (r_s) was used to analyze the correlation between 1) the increase in melody reproduction test scores and SLTA auditory comprehension subtest scores, 2) the increase in melody reproduction test scores and SLTA speech subtest scores, 3) the increase in rhythm reproduction test scores and SLTA auditory comprehension subtest scores, and 4) the increase in rhythm reproduction test scores and SLTA speech subtest scores. There were significant positive correlations between melody reproduction and auditory comprehension subtest scores on the SLTA: “word comprehension” ($n = 14$, $r_s = 0.57$, $p < 0.05$) and “following verbal instructions” ($n = 31$, $r_s = 0.42$, $p < 0.05$). An SLTA speech subtest score—action naming—was positively correlated with rhythm reproduction ($n = 31$, $r_s = 0.44$, $p < 0.05$). This study implies that melody reproduction ability is related to auditory comprehension and that rhythm reproduction ability is related to speech production in patients with aphasia after experiencing a stroke.

Key words :aphasia, music, stroke, rehabilitation

Introduction

The use of music in rehabilitation therapy has been increasing, and its effectiveness has been reported in several studies^{1–3}. In particular, the effects of music on aphasia rehabilitation have been widely studied and recognized^{1,4–10}. When using music as rehabilitation therapy, it is important to utilize musical components on the human body and cognition¹. Melodic intonation therapy (MIT) uses music components

and is widely recognized and used as a rehabilitation technique for aphasia^{1,4–9}. Many studies have shown MIT elements—melody and rhythm—contribute to speech production^{4–8,11}. MIT was developed based on the observation that patients with aphasia can often sing. This therapy is used to improve the speech production of non-fluent aphasic patients. During MIT, words or phrases are practiced with emphasized intonation and rhythmic tapping and gradually transferred to normal speech prosody¹⁰.

In addition to its effectiveness on speech production, some studies have reported that auditory comprehension of patients with Broca’s and Wernicke’s aphasia improved after MIT^{9,12}. These results suggest the possibility that melody and rhythm may influence auditory comprehension of language. Behavioral and neurological studies with healthy subjects favor this possibility. For example, Cason *et al.*¹³ showed that rhythmic priming enhanced speech perception, and Sidiras *et al.*¹⁴ reported that preceding

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synchronized beats enhanced spoken word recognition. Additionally, a part of the superior temporal gyrus, the planum temporale corresponding to the core of Wernicke's area, has a role in language and music and is instrumental in processing humming¹⁵ and different melody dimensions¹⁶.

Previous studies focused on musical melody and rhythm and investigated those relationships with speech production and auditory comprehension. However, the relationships between musical abilities and auditory comprehension have not been clarified, particularly in patients with aphasia. To use musical components (melody and rhythm) more effectively in speech and language rehabilitation for aphasia, it is important to examine these components' relationships to auditory comprehension and speech production.

Focusing on melody and rhythm as musical abilities, and on auditory comprehension and speech production as linguistic abilities, the current study aimed to investigate the relationship between improvements in musical abilities and linguistic abilities in patients with aphasia.

Materials and methods

1. Patients

In this retrospective study, we reviewed the clinical records of stroke patients with aphasia admitted to subacute rehabilitation units at Tokyo Chidori Hospital (Tokyo, Japan) and Yoshieikai Hospital (Osaka, Japan) between May 2014 and August 2018. Data of 32 stroke patients (11 females and 21 males, mean age = 66.9 years, range = 47–85) in the subacute phase (mean days post-onset = 38.8, standard deviation [SD] = 20.4) were available for this study. Out of 32 patients, 28 were non-fluent, two were fluent, and two had global aphasia. The

average hospital stay length was 106.6 days (SD = 35.5). Most of the patients received MIT during hospitalization; however, the degree and frequency of MIT varied from patient to patient. Some patients had rhythmic and intonation exercises without practicing words or phrases simultaneously, and others had singing exercises but not MIT.

This study was approved by the Tokyo Chidori Hospital (Permit Number: 20181120) and Yoshieikai Hospital (Permit Number: 20181207) ethics examination committees and conducted in accordance with the Declaration of Helsinki. The requirement of informed consent was waived. Instead, the patients were provided with the opportunity to opt-out after posting the purpose and method of this research.

2. Evaluation items

1) Evaluation of musical abilities

Melody and rhythm reproduction tests were created based on the Seashore Tests of Musical Ability¹⁷ and Montreal Battery of Evaluation of Amusia¹⁸. The tests correspond with those of Rosslau *et al.*¹⁹ and Grube *et al.*²⁰. We explained the procedures verbally to the patients and made sure that they understood the procedures by doing examples. For the melody reproduction test, patients listened to a melody hummed by a therapist and reproduced it by humming. For the rhythm reproduction test, patients listened to a rhythm tapped by a therapist and reproduced it by hand tapping. Both tests were scored based on the percentage of correct answers. The score difference between each subject's admission time and discharge time was taken as the improvement score. Figure 1 shows the items included in the melody and rhythm reproduction tests.

Melody reproduction test items (humming)

- ① do -
- ② do - mi -
- ③ do - so -
- ④ so - do -
- ⑤ re - do -
- ⑥ do - mi - do -
- ⑦ do re mi fa so fa mi re do
- ⑧ mi - do do re -
- ⑨ do do so fa so -
- ⑩ do mi do so so mi

Rhythm reproduction test items (tapping)

- ①
- ②
- ③
- ④
- ⑤
- ⑥
- ⑦
- ⑧
- ⑨
- ⑩

Both tests were scored based on the percentage of correct answers.

Fig. 1. Items used in the melody and rhythm reproduction tests

2) Evaluation of linguistic abilities

Standard Language Test of Aphasia (SLTA)²¹ is a widely administered aphasia test in Japan. The sections used in this study were auditory comprehension and speech. Subtests of auditory comprehension include word comprehension, sentence comprehension, following verbal instructions, and kana [Japanese syllabary] comprehension. Speech subtests included picture naming, word repetition, action naming, picture story description, sentence repetition, and animal category fluency. Each subtest was scored based on the percentage of correct answers. The increase in each subtest score was based on the difference between the scores on admission and discharge. Table 1 lists the subtests of auditory comprehension and speech sections in SLTA.

3. Data analysis

We excluded the data of subjects who had perfect scores on admission for each test. Mean scores \pm SD (%) on admission and discharge, and mean increase \pm SD (%) of music tests and SLTA auditory comprehension and speech subtests are listed in Table 2.

4. Statistics

The Spearman rank correlation coefficient (r_s) was calculated to analyze the correlation between 1) the increase in melody reproduction test scores and the increase in SLTA auditory comprehension subtest scores, 2) the increase in melody reproduction test scores and the increase in SLTA speech subtest scores, 3) the increase in rhythm reproduction test scores and the increase in SLTA auditory comprehension subtest scores, and 4) the increase in rhythm reproduction test scores and the increase in SLTA speech subtest scores. The Kruskal-Wallis test was performed to assess the differences between the tests in terms of the mean increase. Statistical analyses were performed using EZR version 1.35 (Saitama Medical Center, Jichi Medical University, Saitama, Japan). P values $<$ 0.05 were considered statistically significant.

Results

1. Mean scores on admission and discharge, and mean increases of musical tests and SLTA auditory comprehension and speech subtests

As shown in Table 2, except for word comprehension

Table 1. List and description of subtests of auditory comprehension and speech sections in the Standard Language Test of Aphasia (SLTA).

Section	Subtests	Description	Number of questions
Auditory comprehension	Word comprehension	Pointing to the correct picture card of an item (e.g., egg, horse) verbally presented by the examiner.	10
	Sentence comprehension	Pointing to the correct picture card of an action (e.g., "A student gets a certificate from the teacher.") verbally presented by the examiner.	10
	Following verbal instruction	Token test using ten objects (e.g., key, pen, coin).	10
	Kana comprehension	Pointing to the correct kana [Japanese syllabary] verbally presented by the examiner.	10
Speech	Picture naming	Naming an item on a picture card (e.g., book, pencil, dog, clock, mountain).	20
	Word repetition	Repeating a word after the examiner.	10
	Action naming	Naming an action on a picture card (e.g., sleeping, reading, swimming).	10
	Picture story description	Telling a story about a four-panel comic strip; scored according to the level of sentence perfection and number of key words used.	1
	Sentence repetition	Repeating a sentence with two to six words after the examiner.	5
	Animal category fluency	Listing animal names verbally in one minute; listing 15 names gets a full score.	1

Each subtest was scored based on the percentage of correct answers.

Table 2. Mean scores on admission and discharge, and mean increase of music tests and SLTA auditory comprehension and speech subtests.

		n	Mean score \pm SD on admission (%)	Mean score \pm SD on discharge (%)	Mean increase \pm SD (%)
Music tests	Melody reproduction	31	40.32 \pm 27.75	60.97 \pm 28.33	20.65 \pm 24.35
	Rhythm reproduction	28	38.57 \pm 24.15	57.14 \pm 20.88	18.57 \pm 20.13
SLTA auditory comprehension subtests	Word comprehension	14	67.14 \pm 24.94	90.71 \pm 14.39	23.57 \pm 24.99
	Sentence comprehension	28	56.07 \pm 26.44	75.71 \pm 22.01	19.64 \pm 27.82
	Following verbal instruction	32	17.81 \pm 24.19	39.69 \pm 34.87	21.88 \pm 31.36
	Kana comprehension	27	47.78 \pm 32.03	70.00 \pm 28.28	22.22 \pm 31.66
SLTA speech subtests	Picture naming	31	32.26 \pm 30.13	53.23 \pm 35.20	20.97 \pm 17.86
	Word repetition	20	62.00 \pm 33.97	82.50 \pm 35.37	20.50 \pm 21.64
	Action naming	32	35.00 \pm 31.72	61.25 \pm 36.08	26.25 \pm 25.62
	Picture story description	32	19.38 \pm 27.58	38.13 \pm 31.05	18.75 \pm 30.87
	Sentence repetition	29	29.66 \pm 27.58	42.07 \pm 31.78	12.41 \pm 27.99
	Animal category fluency	32	6.04 \pm 10.21	24.38 \pm 28.72	17.86 \pm 27.62

SD, standard deviation

n, number of included patients after excluding data of patients who had perfect scores on admission

Table 3. Results of the Spearman rank correlation coefficient (r_s) between the increase in musical test scores (melody and rhythm reproduction) and the increase in SLTA subtest scores of auditory comprehension and speech.

	Auditory comprehension				Speech					
	Word comprehension	Sentence comprehension	Following verbal instructions	Kana comprehension	Picture naming	Word repetition	Action naming	Picture story description	Sentence repetition	Animal category fluency
Melody reproduction	0.569* (n = 14)	0.244 (n = 28)	0.42* (n = 31)	0.25 (n = 27)	0.0295 (n = 30)	0.0136 (n = 20)	0.287 (n = 31)	0.186 (n = 31)	0.0437 (n = 29)	-0.0893 (n = 31)
Rhythm reproduction	0.503 (n = 11)	0.0177 (n = 25)	0.0564 (n = 28)	0.00469 (n = 24)	0.312 (n = 28)	0.211 (n = 17)	0.443* (n = 28)	0.235 (n = 28)	0.00269 (n = 26)	0.0912 (n = 28)

* $p < 0.05$

and word repetition subtests, the data excluded from the analysis were small (0–5). Compared to other tests, word comprehension and word repetition subtests also had higher mean scores at admission; however, the mean increase was not significantly different among all tests.

2. Results of the Spearman rank correlation coefficient (r_s) between the increase in musical test scores (melody and rhythm reproduction) and the increase in SLTA subtest scores of auditory comprehension and speech

Table 3 shows the results of the Spearman rank

correlation coefficient between the increase in musical test scores (melody and rhythm reproduction tests) and the increase in SLTA subtest scores of auditory comprehension and speech. There were significant positive correlations between melody reproduction and auditory comprehension subtests of “word comprehension” ($n = 14$, $r_s = 0.57$) (Figure 2A) and “following verbal instructions” ($n = 31$, $r_s = 0.42$) (Figure 2B). A speech subtest—action naming—was positively correlated with rhythm reproduction ($n = 31$, $r_s = 0.44$) (Figure 2C).

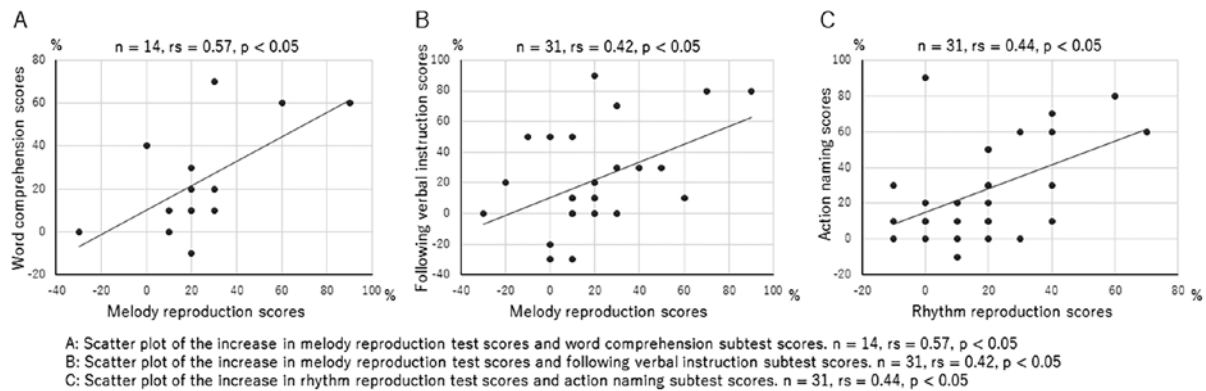


Fig. 2. Significant positive correlations between melody reproduction test scores and the scores of the auditory comprehension subtests for “word comprehension” (A) and “following verbal instructions” (B), and the correlation between rhythm reproduction test scores and the score for a speech subtest—the action naming test (C).

Discussion

The current study investigated the relationship between musical and linguistic abilities of patients with aphasia. We analyzed results of melody and rhythm reproduction tests as musical abilities, and subtests of auditory comprehension and speech sections in the SLTA as linguistic abilities. The score difference between the hospital admission time and discharge time of each subject was taken as the improvement score. The correlation was then analyzed between the improvement scores of melody reproduction and auditory comprehension, melody reproduction and speech production, rhythm reproduction and auditory comprehension, and rhythm reproduction and speech production. We found significant correlations between the improvement score of melody reproduction and the improvement score of auditory comprehension and between the improvement score of rhythm reproduction and the improvement score of speech.

Regarding the relationship between melody and linguistic comprehension abilities, previous studies reported the relationship in terms of analytical ability, syntactic processing, and semantic processing^{16, 22–25}. In brain research on melody and language, Kunert *et al.*²² showed that musical and linguistic syntax processing were shared in the left inferior frontal gyrus. Furthermore, Yu *et al.*²³ investigated the association of brain function at the localized and network levels using resting functional magnetic resonance imaging (fMRI) and reported that melody analysis and semantic processing of language were shared in the precentral gyrus and the superior temporal gyrus. The current results were consistent

with these previous reports. Our study added new knowledge about the relationship between improvements in musical and linguistic abilities in patients with aphasia after stroke to earlier studies on healthy subjects.

In researching the relationship between rhythm and speech, studies have been conducted in patients with aphasia and healthy subjects. Rosslau *et al.*¹⁹ reported decreased abilities in rhythm processing in patients with aphasia. Grube *et al.*²⁰ showed associations between rhythm processing and speech capabilities in patients with progressive aphasia. In clinical studies, many researchers have shown the effects of MIT, mainly focusing on the contribution of MIT’s elements—melody and rhythm—to speech production^{4, 5, 8}. The current results supported these previous studies that reported the association between rhythm and speech production.

In our study, patient melody and rhythm reproduction abilities upon hospital admission varied from patient to patient, much like auditory comprehension and speech production variations. Regardless of the variability, there were correlations between improvements in linguistic and musical abilities. Our results suggest that the therapeutic use of music may be effective for all severity levels of aphasia. Based on the current results showing a correlation between melody and auditory comprehension and between rhythm and speech, melody and rhythm could be used to improve auditory comprehension and speech abilities in patients with aphasia of various severity levels. A patient’s musical background may impact the effectiveness of rehabilitation therapy that incorporates music. However, we did not inquire about the patients’ musical background in this study, and we

did not find any previous literature regarding the influence of musical experience in patients with aphasia on the effectiveness of music rehabilitation therapy. It will be interesting to examine this issue in future studies. We believe that this study could be an important first step for future research.

This study had some limitations. These included the limited correlation between certain SLTA subtests and auditory comprehension and speech, and the limited number of correlational levels. With SLTA auditory comprehension subtests, significant correlations were limited to two subtests—word comprehension and following verbal instructions—with melody reproduction ability. In terms of the SLTA speech section, the related subtest was limited to “action naming” with rhythm reproduction ability. Iwata *et al.*²⁶ reported that initial scores for comprehension were higher than speech production scores, and comprehension scores improved faster than speech production scores. Improvement rates varied among SLTA subtests; for example, the word comprehension score improved more than the sentence comprehension score, and improvement scores of the animal category fluency and the sentence repetition were low compared to other subtests. In the current study, the mean increase was not significantly different among all the tests, although the mean increases for word comprehension (23.57) and action naming (26.25) tended to be higher than other subtests. Initial mean scores for auditory comprehension subtests were higher than speech subtests. The initial mean score for animal category fluency was particularly low among the tests. Regarding the present results, it might be possible that the combinations of initial test scores, improvement scores, and the degree of difficulties were related. To identify the factors involved in the limitations, further examinations are necessary. Regarding the current study’s correlational levels, the significant correlation values were moderate, with correlation coefficients between 0.4 and 0.6^{27,28}. To interpret the correlational levels, we must consider other factors such as age, sex, lesion site, type of aphasia, time from onset, other cognitive impairments, and the rehabilitation provided in terms of content, frequency, and duration.

Our small sample size was another limitation. Data from 32 stroke patients were available for this study. Then, we excluded the data of subjects who had perfect scores on admission for each test. We cannot deny the possibility that the small sample size was the reason for the non-significant

correlation between rhythm reproduction and “word comprehension” even though the correlation coefficient was 0.503. Further studies with more subjects are required to confirm whether our small sample size significantly influenced this result.

Furthermore, this study investigated the correlation coefficient between musical elements and language modalities of patients with aphasia, but not causal relationships. Based on the current results, in future studies, it is necessary to develop therapeutic use of musical elements in rehabilitation programs for aphasia and test the effectiveness of these programs, particularly in the therapeutic use of melody for auditory comprehension improvements.

In conclusion, this study showed a significant correlation between melody reproduction ability and auditory comprehension and between rhythm reproduction ability and speech production in patients with aphasia. The current results, along with results from previous reports, will contribute to developing the therapeutic use of music for the treatment of aphasia.

Conflict of interest disclosure

The authors declare no conflicts of interest.

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