

# 音楽が拓く認知症予防の未来



## 音会の実証研究


Transforming text to music using artificial intelligence improves the frontal lobe function of normal older adults

AIを用いたテキストから音楽への変換が通常の高齢者の前頭葉機能を向上させる



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# Transforming text to music using artificial intelligence improves the frontal lobe function of normal older adults

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## Abstract

**Introduction:** Recent advances in artificial intelligence (AI) have been substantial. We investigated the effectiveness of an online meeting in which normal older adults (*otokai*) used a music-generative AI that transforms text to music (Music Trinity Generative Algorithm-Human Refined [MusicTGA-HR]).

**Methods:** One hundred eighteen community-dwelling, cognitively normal older adults were recruited through the internet (64 men, 54 women; mean age:  $69.4 \pm 4.4$  years). Using MusicTGA-HR, the participants chose music that they thought was the most suitable to a given theme. We established 11 classes of 7–10 members and one instructor each. Each class held an online meeting once a week, and each participant presented the music they chose. The other participants and the instructor then commented on the music. Neuropsychological assessments were performed before and after the intervention for 6 months, and the results before and after the intervention were statistically analyzed.

**Results:** The category and letter word fluencies (WFs) were significantly improved (category WF:  $p = .003$ ; letter WF:  $p = .036$ ), and the time of the Trail-Making Test-B was also significantly shortened ( $p = .039$ ). The Brain Assessment, an online cognitive test we developed, showed significant improvement in the memory of numbers ( $p < .001$ ).

**Conclusion:** The online meeting of the *otokai*, which used music-generative AI, improved the frontal lobe function and memory of independent normal older adults.

## KEYWORDS

artificial intelligence, composition, music, Music Trinity Generative Algorithm-Human Refined, *otokai*

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## 1 | INTRODUCTION

The number of people with dementia is rising rapidly with the increase in longevity. Approximately 46.8 million people worldwide are estimated to be living with dementia, and 9.9 million new cases of dementia are diagnosed every year (Strøm et al., 2016). According to Alzheimer's Disease International (Prince et al., 2015), these numbers will nearly double every 20 years to an estimated 74.7 million in 2030 and 131.5 million in 2050, with a large proportion of those individuals living in Asia (Satoh et al., 2020). Recent studies have demonstrated that through adequate intervention, including the control of lifestyle parameters, such as those related to hypertension, physical exercise, or intellectual activities, the occurrence of dementia can be prevented to some degree (Barnes & Yaffe, 2011; Livingston et al., 2017; Satoh et al., 2014/2017/2020; Tabei et al., 2017).

Today in the field of neurology, the effectiveness of the music therapy is established in following neurological diseases or symptoms: dementia (Moreno-Morales et al., 2020; van der Steen et al., 2018), Parkinson's disease (Zhang et al., 2017; Zhou et al., 2021), stroke (Magee et al., 2017; Van Crielinge et al., 2019), aphasia (García-Casares et al., 2022; Liu et al., 2022), and unilateral spatial neglect (Long et al., 2023). It is well-known that music interventions have a significant effect on stress reduction (de Witte et al., 2020/2022), and the effectiveness of music therapy was reported about the behavioral and psychological symptoms of dementia (BPSD) (Dyer et al., 2018; Ueda et al., 2013). Later, the effectiveness to cognitive function of older adults with dementia was also reported (Dorris et al., 2021; Ito et al., 2022; Moreno-Morales et al., 2020). Recently, the relationships between kinds of music activities and the effects to health and well-being have been reported (Dingle et al., 2021). They showed the effectiveness of receptive and intentional music listening to main reduction, shared music listening to the enhancement of social connections in older adults, music listening and carer singing to agitation of people with dementia, group singing, playing a musical instrument, and dance and movement with music programs to the improvement of cognitive health and well-being, and rapping, songwriting, and composition to the well-being of marginalized people. Musical activities, such as playing instruments and music composition, require long-term specialized training that generally begins in childhood. It is quite challenging for normal older individuals to start to compose musical pieces if they have not had prior musical training. Therefore, these individuals are more likely to participate in musical activities such as listening to music and singing songs. Recently, the development of artificial intelligence (AI) has led to substantial advancements in many fields. For example, Chat Generative Pre-trained Transformer (ChatGPT) allows a user to input words or text and generate appropriate responses to inquiries or questions. In image generation AI, such as Stable Diffusion Online (<https://stablediffusionai.org/#home>) or Bing Image Creator (<https://www.bing.com/create>), novel images can be created using input text. The musical version of such the generative AI is Music Trinity Generative Algorithm-Human Refined (MusicTGA-HR; <https://www.amadeuscode.com/music-tga-hr>). MusicTGA-HR has

decomposed data for musical components, including melody, rhythm, harmony, timbre, instruments, instrumentation, and style. By combining these features and relating them to corresponding input text, we can obtain an almost unlimited selection of high-preference music. Making music, namely, composition, requires in-depth learning and training which often starts during childhood. However, MusicTGA-HR enables musically naïve persons to choose the most suitable music for their image or concept. Many YouTubers use MusicTGA-HR as background music for their videos, and more than 44,000 musical pieces are generated each month worldwide using this platform.

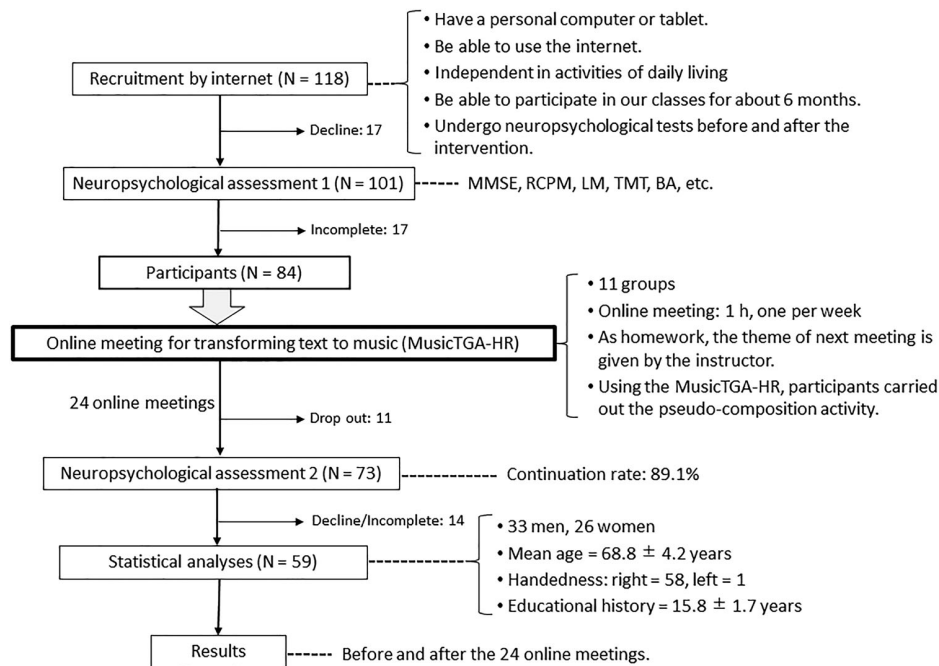
Various mental activities, including drawing, ceramic art, dressmaking, and cooking, are used for the cognitive stimulation training, a type of nonpharmacological intervention aimed at improving the quality of life of older individuals (Societas Neurologica Japonica, 2017). In Japan, another type of cognitive stimulation training involves the *haiku*, the shortest fixed form poem in the world. In meetings called *kukai*, participants write *haikus* for a given theme and present it in front of the other members of the meeting. Then, the instructor makes some comments on each *haiku*. Originally, the *kukai* was held in-person; however, after the outbreak of coronavirus disease-2019 (COVID-19), in-person meetings became difficult. Therefore, online *kukais* are now often held using videoconference systems. Based on this background, we hypothesized that MusicTGA-HR may have applications as a non-pharmacological therapy for improvement of the cognitive function of older adults. Using MusicTGA-HR, individuals can choose music that they think is most suitable for a given theme. At online meetings, each participant presents the music they chose, and the other participants state their impressions of that music. The instructor will also comment on the music. According to the term *kukai*, which is used for meetings to discuss *haiku*, as mentioned above, we named this type of musical meeting *otokai*. In Japanese, "oto" and "kai" mean music/sound and meeting, respectively; therefore, *otokai* means a meeting of music/sound.

The aim of this study was to investigate the effectiveness of the *otokai* for improving the cognitive functions of community-dwelling, normal older individuals. Using a videoconference system, we held the *otokai* for 6 months and carried out cognitive assessments before and after the intervention period. The primary outcome was changes in neuropsychological batteries before and after the intervention period. We expect that our results may have applications in dementia prevention, which is currently one of the most important and pressing problems in the world.

## 2 | MATERIALS AND METHODS

### 2.1 | Subjects

The number of subjects was decided based on our previous study (Tabei et al., 2023). In this study, we investigated the effectiveness of the online physical exercise with music accompaniment for older adults. One hundred and fourteen subjects participated in the online exercise class for 6 months, and before and after the intervention period, neu-



**FIGURE 1** Diagram of the flow of this study. BA, Brain Assessment; LM, logical memory; MMSE, Mini-Mental State Examination; MusicTGA-HR, Music Trinity Generative Algorithm-Human Refined; N, number; RCPM, Raven's Colored Progressive Matrices; TMT, Trail Making Test.

ropsychological examinations were performed. Finally, the results of 75 subjects were used for statistical analysis, and we found the significant improvement on the N-back task which belonged to a frontal lobe function. So, in the present study, we planned to establish 10 groups of 12 participants each, for a total of 120 participants (Figure 1). We recruited participants through the internet. Because our intervention was carried out through the internet, we expected that the recruited participants would have the skill for digital devices (Sato et al., 2023). We announced this study by sending direct emails to approximately one million adults who had a SAISON credit card, issued by the parent company of the Research Institute of Brain Activation. The inclusion criteria for participants were as follows: (a) over 65 years old, (b) psychologically healthy, (c) good eyesight, (d) able to hear instructions clearly, (e) able to function independently in most aspects of life, (f) have a personal computer or tablet, (g) able to use digital devices, (h) able to participate in our classes for approximately 6 months, and (i) agreed with the performance of a neuropsychological examination before and after the intervention period (Sato et al., 2023). Applicants were excluded if they met any of the following exclusion criteria: (a) apparent history of cerebrovascular attack; (b) presence of chronic exhausting disease, such as malignancy or infection; (c) presence of severe cardiac, respiratory, and/or renal disabilities; (d) use of drugs that might adversely affect cognition (antidepressants and antipsychotics); (e) previous diagnosis of dementia; or (f) unable to use digital devices (Sato et al., 2023). One hundred eighteen participants were recruited on a first-come basis (64 men, 54 women; mean age:  $69.4 \pm 4.4$  years; Figure 1).

## 2.2 | Online meeting for transforming text to music using AI (*otokai*)

The instructors were professional musicians who also held private licenses as musical trainers with the YAMAHA Music Foundation. The author JO is the head and the mentor of YAMAHA's musical trainers, and he selected the *otokai* trainer who is, he thought, adequate for this study, based on their achievement and suitability. Prior to the beginning of the study, the exercise of the *otokai* instructors was performed online, dividing them into two groups. First, the author MS lectured the aim and the background of this study. Then, the methods of the *otokai* were explained by the author MS and JO as mentioned below. Lastly, the author KT and AY showed how to operate the MusicTGA-HR. Namely, we taught the instructors about the purpose and contents of the study, the way of holding *otokais*, the positive feedback of comments to each subject, as well as the operating procedures of MusicTGA-HR. Total time of the exercise was almost 2 h. The instructor can question to the authors at any time after the exercise. After excluding individuals who declined to participate, we established 11 classes of 7–10 members and one instructor each. Each participant got the operation manual of MusicTGA-HR online, and, almost a week before starting the intervention, the participants of each group were explained online about the aim of this study, procedure of online meeting, and how to operate MusicTGA-HR by the author JO, AY, and the instructor of the group. Each meeting was held as follows. First, the theme of the next online meeting was set and communicated via email to each member. Using MusicTGA-HR, the participant then chose

**TABLE 1** The theme of each meeting of *otokai*.

Section	Meeting No.	Theme
1. Concrete pictures	1	Mt. Fuji
	2	A train
	3	A dinosaur
	4	Carps in a pond
2. Scenes of human activities	5	Fireworks
	6	Festivals
	7	Playing a piano
	8	Running in a marathon
3. Famous sentences	9	A poem by Issa Kobayashi
	10	A proverb
	11	A saying by a famous historical person
	12	A poem by Shuntaro Tanigawa
4. Concrete short movies	13	A sleeping kitten
	14	Seashore with large waves
	15	A toy showing the turning of a Ferris wheel
	16	A walking tiger
5. Abstract pictures	17	A figure of a Mandelbrot set
	18	A painting by Wassily Kandinsky
	19	A painting by Wassily Kandinsky
	20	A movie with shining lights
6. Autobiographical materials	21	Pictures and movies chosen by participants
	22	
	23	
	24	

the music they thought was most suitable to given the theme. The file of the music could be recorded in the PC/tablet of each participant. Second, in each online meeting, each member presented their music and explained the reason why they chose it. The instructor commented on the music and encouraged other members to also comment on the music. Third, the instructor presented the music they chose and recorded in their PC in advance in the same way as the members. Finally, the instructor described the theme for the next meeting, and the meeting ended. Based on the term *kukai*, we named this type of meeting *otokai*. For the online meeting, a videoconference system (Zoom, Zoom Video Communications, Inc.) was used. Online meetings of *otokai* were held once a week and were 1 h long. In total, 24 online meetings were held over the course of 6 months.

The theme gradually became more difficult, moving from concrete to abstract (Table 1). The themes for the last four meetings (from the 21st to 24th meeting) were autobiographical materials; the participants chose their own pictures or movies, which showed things they were proud of (e.g., a journey abroad, prizes their children had won, and their hobbies).

### 2.3 | Neuropsychological assessments

Neuropsychological assessments were performed online within 2 weeks before starting and after ending the intervention. Each assessment required almost 1 h and was carried out at one occasion. Subjects were not paid. For neuropsychological assessments, the tests were nearly identical to those used in the Mihama-Kiho Project, which investigated the effects of physical exercise with music accompaniment in normal and cognitively impaired older adults (Sato et al., 2014/2017/2020/2023; Tabei et al., 2017/2023). To quantify intellectual function, the Mini-Mental State Examination (MMSE) (Folstein et al., 1975) and the Japanese version of the Raven's Colored Progressive Matrices (RCPM) (Raven, 1995) were administered. We were going to exclude the subject who revealed the abnormal score of the MMSE, but all participants showed normal scores (24–30). RCPM not only provides a score but also measures the performance time, which reflects the psychomotor speed of the participant. Memory was evaluated using logical memory I and II of the Rivermead Behavioral Memory Test (Wilson et al., 1985), which consists of immediate and

delayed recall of a short story. Assessment of constructional ability was based on the method described by Strub and Black (2000). A cube was shown to the examinees, and they were asked to draw it. Their drawing was scored by assigning one of four possible grades (0: poor, 1: fair, 2: good, and 3: excellent). The Mie Constructional Apraxia Scale (MCAS) was also used to assess constructional visuospatial ability (Satoh et al., 2016). The MCAS is designed to assess constructional disabilities by evaluating not only the shape of a drawn Necker-cube but also the drawing process. Higher scores are indicative of worse symptoms. Additional details are available in our previous paper (Satoh et al., 2016). Frontal function was assessed by two types of tasks: word fluency (WF) and Trail-Making Test A and B (TMT-A/B). The WF test consisted of two domains: category and letters. For the categorical WF, participants were asked to name as many animals as possible in 1 min. For the letter WF, for each of four phonemes (*ka*, *sa*, *ta*, and *te*), the participants were asked to name objects that have that phoneme at the beginning of the word (Dohi et al., 1992). We used the average scores of these four phonemes for statistical analyses. It is generally accepted that the cognitive processing of categorical and letter WFs is somewhat different; categorical WF is more reflective of memory function than letter WF (Satoh et al., 2017). These neuropsychological assessments were administered before and after the intervention for 6 months.

We also used an online cognitive test that we recently developed, named Brain Assessment (BA) (Satoh et al., 2021a, 2021b, 2022). The BA covers five fields: number memory, word memory, mental rotation, working memory (N-back test), and judgment task. The cardinal features of the BA include five different versions to avoid habituation, conciseness (30 min), an automated scoring system, easy access on a website, and basic data based on a large population of 5000 participants with a wide age range of 40–89 years. More details are given in our previous papers (Satoh et al., 2021a, 2021b, 2022).

## 2.4 | Statistical analyses

Statistical analyses were performed based on selection of appropriate tests from a statistics textbook (Tsushima, 2007). For neuropsychological tests, including the BA, statistical analyses were performed as follows: changes before and after the 6-month intervention period were analyzed. The Shapiro–Wilk test was used to evaluate normality. If the result was parametric, a paired *t* test was used; otherwise the Wilcoxon signed–rank test was used. We regarded the result as significant if the *p* value was less than 0.05. We also calculated the effect sizes. All statistical analyses were performed using IBM SPSS Statistics 27 software.

## 3 | RESULTS

During the 6-month intervention period, 11 individuals dropped out of the study due to schedule conflicts, the meetings being different from their expectations, health problems, or needing to provide nurs-

ing care for their spouses. The continuation rate for 6 months was 89.1%. Figure 2 shows the mean number of minutes participants spent accessing the website, the mean number of words searched on their PCs/tablets, and the number of musical pieces to which each individual listened within a week. These numbers were automatically recorded by the MusicTGA-HR system. For each theme, individuals spent approximately 100–120 min on the intervention each week. They searched for approximately 40 words and listened to 100 musical pieces each week. Although the theme became more difficult over time, the number of words searched and the number of musical pieces the participants listened to remained almost constant (from meetings 5–20). However, for the last four meetings (meetings 21–24), the time spent accessing the website decreased. These changes suggested that the participants already had a specific image in mind when they selected their autobiographical materials.

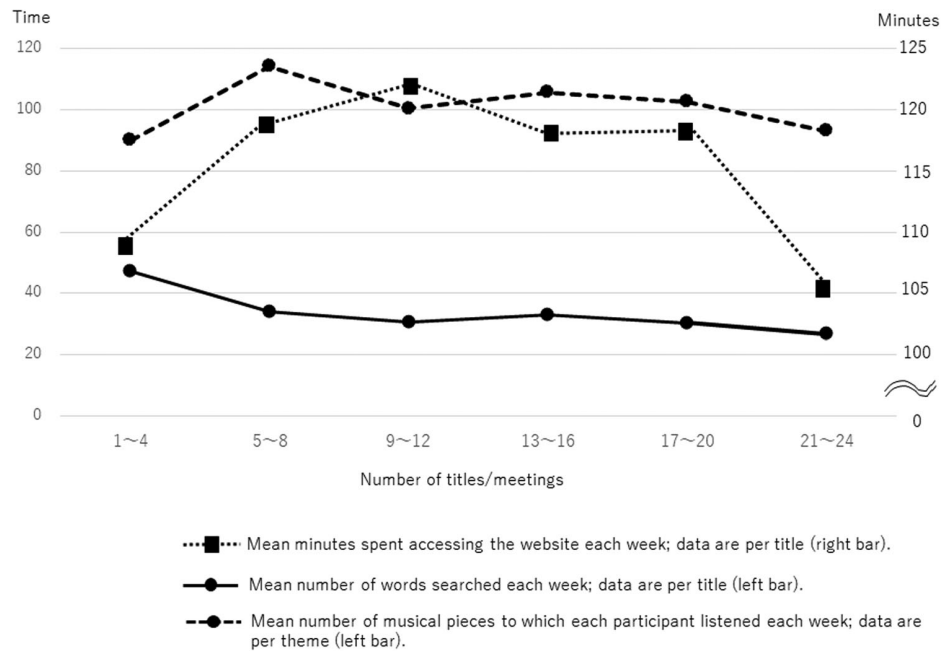
The total number of participants who were eligible to take neuropsychological examinations after the intervention was 73 (Figure 1). Because 14 participants declined or did not fully complete the examination, the results of 59 participants (33 men, 26 women; mean age:  $68.8 \pm 4.2$  years; education history:  $15.8 \pm 1.7$  years) were analyzed.

The results of neuropsychological examinations are shown in Table 2. The category and letter WFs were significantly improved after the 6-month intervention (category WF:  $p = .003$ ; letter WF:  $p = .036$ ; Table 2). The time of the TMT-B was also significantly shortened ( $p = .039$ ). As for the BA, a significant improvement was observed in terms of the memory of numbers ( $p < .001$ ; Table 2). From these results, we concluded that the intervention with the online meeting using MusicTGA-HR to convert text to music improved frontal lobe function and memory.

## 4 | DISCUSSION

In this study, we carried out an intervention in cognitively normal older adults via online meetings using AI that transformed text to music (MusicTGA-HR). This activity was named *otokai*, meaning the meeting of music/sound. According to a preset theme, participants chose music made by the AI, selecting musical pieces that were most suitable to their image and preferences. Professional musicians acted as instructors and provided positive feedback on the music. The meetings were held once a week for 6 months and were 1 h long each. The continuation rate was 89.1%. Neuropsychological assessments revealed that frontal lobe function and memory were significantly improved after 6 months.

Music perception involves complex brain functions underlying acoustic analysis, auditory memory, auditory scene analysis, and processing of musical syntax and semantics, and potentially affects emotion, influences the automatic nervous system, the hormonal and immune systems, and activates (pre)motor representations (Koelsch & Siebel, 2005). Many brain regions participate in the music perception: neocortical regions, insula, cingulate cortex, primary and secondary somatosensory cortex, premotor cortex, frontal operculum, and auditory cortex (Koelsch et al., 2021). It was suggested that music



**FIGURE 2** The mean minutes spent accessing the website, mean numbers of words searched on their PCs/tablets, and mean number of musical pieces to which each participant listened each week.

**TABLE 2** Results of neuropsychological batteries and Brain Assessment (BA) following the intervention using the Music Trinity Generative Algorithm-Human Refined (MusicTGA-HR) for 6 months.

		Before	After	Effect size	<i>p</i> Value
<b>Intellect</b>	<b>MMSE</b>	29.0 ± 1.0	29.0 ± 1.0	0	.49
	<b>RCPM</b>				
	Score	32.3 ± 2.4	32.7 ± 2.2	0.17	.39
	Time	234 ± 41	230 ± 53	0.08	.097
<b>Memory</b>	<b>LM-I</b>	13.5 ± 3.3	13.8 ± 3.5	0.09	.44
	<b>LM-II</b>	12.7 ± 3.3	13.0 ± 3.4	0.09	.39
<b>Visuospatial</b>	<b>Necker</b>				
	Score	2.9 ± 0.2	3.0 ± 0.1	0.58	.32
	Time	20.6 ± 8.3	20.9 ± 9.5	0.03	.64
	<b>Construction</b>	17.6 ± 0.6	17.6 ± 0.6	0.33	.74
<b>Frontal function</b>	<b>WF</b>				
	Category	16.0 ± 3.8	17.8 ± 4.3	0.44	<b>.003</b>
	Letters	14.0 ± 2.9	14.8 ± 2.5	0.29	<b>.036</b>
	<b>TMT-A</b>	94 ± 46	97 ± 55	0.06	.96
	<b>TMT-B</b>	110 ± 52	98 ± 54	0.23	<b>.039</b>
<b>Brain Assessment (BA)</b>					
<b>Memory</b>	Numbers	55.6 ± 14.0	60.0 ± 14.8	0.31	<b>&lt;.001</b>
	Words	52.9 ± 9.9	54.0 ± 9.8	0.11	.13
<b>Visuospatial</b>	MRT	52.1 ± 12.1	51.6 ± 13.6	0.04	.58
<b>Working memory</b>	N-back test	58.1 ± 14.4	58.6 ± 16.2	0.03	.57
<b>General intellect</b>	Judgment	53.8 ± 15.6	54.8 ± 16.3	0.06	.30
<b>Total score</b>		54.4 ± 10.0	55.5 ± 10.4	0.11	.082

Note: Bold letters indicate statistical significance.

LM, logical memory; MMSE, Mini-Mental State Examination; RCPM, Raven's Colored Progressive Matrices; TMT, Trail Making Test; WF, word fluency.

training-related pathway plasticity facilitated the right hemisphere ventral stream information transfer that connects the middle temporal lobe with the inferior frontal cortex via the extreme capsule, supporting an improved sound-to-meaning mapping in music (Oechslin et al., 2018). Brain network connectivity can change after receptive music-based intervention in cognitively unimpaired older adults: comparing pre- and post-intervention showed significant increase in functional connectivity between auditory regions and medial prefrontal cortex (Quinci et al., 2022). We can say that the frontal lobes participate in the formation of music perception.

Notably, in the *otokai* in this study, the proportion of male participants was higher than that of other in-person nonpharmacological interventions. For example, for the current study, 55.9% of participants were men, whereas in an in-person intervention with physical exercise combined with music accompaniment previously reported by our group (the Mihama-Kiho project), the percentage of male participants was only 20% (Sato et al., 2014). Due to the COVID-19 outbreak, we carried out the same intervention using a videoconference system (Sato et al., 2023; Tabei et al., 2023), and the percentage increased to approximately 50% (Sato et al., 2023). Interestingly, a questionnaire administered to study participants showed that more than half would not have participated in the physical exercise plus music accompaniment class if it had been held in-person. Their main reasons were the risk of COVID-19 infection, trouble with getting to the exercise site, and discomfort in interactions with others (Sato et al., 2023). In many regions in Japan, older men tend to have decreased social activity, and this problem has yet to be solved (Morinaga et al., 2018). However, the online *otokai* may facilitate participation by older men in nonpharmacological interventions, increasing the percentage of male participants compared with in-person classes.

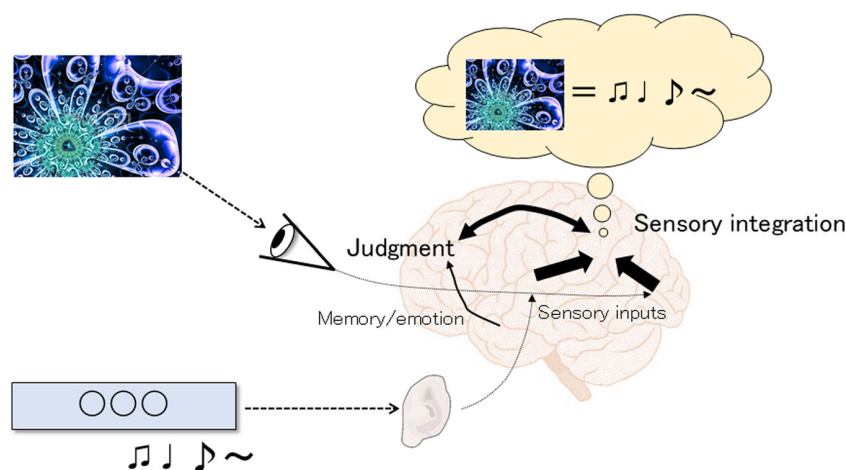
The *otokai* also showed a relatively high continuation rate (89.1% over the 6-month intervention). To the best of our knowledge, the continuation rate for nonpharmacological interventions in older adults ranges from 65% to 100% for interventions lasting 3–6 months (Gajewski & Falkenstein, 2012; Kraus-Sorio et al., 2022; Suzuki et al., 2014). Therefore, the continuation rate obtained in this study is sufficient and consistent with those of similar studies. Our novel approach using AI for music composition and the gradual increase in difficulty may have helped keep participants engaged.

The most important characteristic of the *otokai* was the significant improvements observed in frontal lobe function and memory after the 6-month intervention. As shown in Figure 3, the participant viewed the figure, which was the Mandelbrot set used as the theme for the 17th meeting in this study. This visual stimulus was perceived at the occipital lobe, and then, when the participant listened to music using MusicTGA-HR, the information was processed via the temporal lobes. The inferior portion of the parietal lobe, particularly the angular gyrus, is the integration site for multiple sensory information. The information for the figure and music may be integrated, and the frontal lobe then functions to judge whether the two pieces of sensory information conform to each other. The participants compared the music composed by MusicTGA-HR and the given theme almost one hundred times a week.

This process might stimulate their cognitive function. During online meetings, the instructor would ask each participant to describe personal experiences related to the theme. In cases in which a familiar object, such as Mt. Fuji, was the visual stimulus, episodic and semantic memory, involving emotions related to personal experiences, may be evoked. By repeating these processes for 6 months, we hoped to improve frontal lobe function and memory.

We also compared the results of neuropsychological assessments between male and female subjects. The age and education level were almost the same between them (age,  $p = .90$ ; education level,  $p = .68$ ) (Table A1). As for the neuropsychological tests, the changes of the scores of the MMSE and RCPM were significantly better in female compared to male subjects (MMSE,  $p = .007$ ; RCPM,  $p = .029$ ) (Table A2). After the intervention, the scores slightly worsen in male ( $p = .050$ ), but those of female subjects slightly improved ( $p = .16$ ). As long as we know, there is no report which showed significant gender differences in nonpharmacological interventions to dementia. The present results might suggest that the effects of nonpharmacological interventions are different depending on the gender. It is a very interesting problem, and remains to be investigated in the future.

The current study had several limitations. First, the number of participants who were included in the statistical analyses was not so large ( $n = 59$ ). Thus, additional studies with more participants may be needed in order to confirm the results. Second, the intervention period was 6 months. Longer interventions may give different results and the data of sustainability of cognitive improvements. Third, the instructors were professional musicians, and therefore, it may be necessary to train more musicians in order to expand the *otokai* to other locations worldwide. Fourth, there was no control group in the present study. It is possible that the conversational nature of the *otokai* may have improved participants' verbal fluency. We are now planning to carry out the comparison of cognitive changes between *otokai* and another nonpharmacological intervention group in order to strengthen the causality of the findings. Lastly, the participants in the *otokai* need information technology literacy. We expect that the use of the internet does not represent a barrier for today's older population to participate in the *otokai* (Sato et al., 2023). According to the Annual Report on the Ageing Society 2021 published by the Cabinet Office in Japan (Annual Report on the Ageing Society, 2021), approximately 74% and 58% of septuagenarians and octogenarians, respectively, utilize the internet, and the rates have increased almost two- to three-fold compared with the results from 2010 (septuagenarians: 39.2%, octogenarians: 20.3%) (Annual Report on the Ageing Society, 2010). The Communication Usage Trend Survey (2020) performed by the Japanese Ministry of Internal Affairs and Communications showed that 53.9% of people over 65 years old use the internet (men: 64.4%, women: 45.7%). Because utilization of the internet by older adults is increasing yearly, we expect that more older adults will be able to participate in the *otokai* more easily in the future. In order to introduce the tech-savvy individuals to *otokai*, in-person activity will be needed by conquering the problem of shortage of the number of instructors.



**FIGURE 3** The cognitive processing in the brain that might occur during the intervention used in the current study. The figure shows the so-called Mandelbrot set, which was used at the 17th *otokai*.

In the *otokai*, men accounted for more than half of all participants. This supports the observation that men tend to be more willing to participate in nonpharmacological activities if they are held online, not in-person. Moreover, the *otokai* can be held in place of in-person activities despite restrictions due to health concerns, such as the outbreak of COVID-19, and can also be used for inhabitants of remote and islands areas. Therefore, this approach may be useful in countries in which the aging population is growing.

#### AUTHOR CONTRIBUTIONS

**Masayuki Satoh:** Conceptualization; methodology; investigation; formal analysis; supervision; project administration; visualization; writing—original draft; writing—review and editing; resources; data curation. **Jun Inoue:** Conceptualization; methodology; investigation; supervision; project administration; resources. **Jun-ichi Ogawa:** Conceptualization; methodology; investigation; project administration; resources. **Ken-ichi Tabei:** Conceptualization; methodology; investigation; project administration; resources; data curation. **Chi-aki Kamikawa:** Methodology; data curation; investigation; project administration. **Makiko Abe:** Conceptualization; methodology; data curation; investigation; project administration; resources. **Ayaka Yoshizawa:** Methodology; data curation; investigation; project administration. **Gyo Kitagawa:** Conceptualization; methodology; investigation; project administration; resources. **Yosinori Ota:** Conceptualization; methodology; investigation; project administration; resources.

#### ACKNOWLEDGMENTS

We would like to thank Haruka Hosomichi and Yumi Inoue for their kind contributions to this study.

#### FUNDING

The Department of Dementia and Neuropsychology, Advanced Institute of Industrial Technology, Tokyo Metropolitan Public University Corporation was established using donations provided by the Research Institute of Brain Activation.

#### CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

#### DATA AVAILABILITY STATEMENT

All data analyzed during this study are included in this article. Further enquiries can be directed to the corresponding author.

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#### PEER REVIEW

The peer review history for this article is available at <https://publons.com/publon/10.1002/brb3.70007>

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**How to cite this article:** Satoh, M., Inoue, J., Ogawa, J., Tabei, K., Kamikawa, C., Abe, M., Yoshizawa, A., Kitagawa, G., & Ota, Y. (2024). Transforming text to music using artificial intelligence improves the frontal lobe function of normal older adults. *Brain and Behavior*, 14, e70007. <https://doi.org/10.1002/brb3.70007>

## APPENDIX

**TABLE A1** Comparison of characteristics between male and female subjects.

		Male	Female	p Value
Age	Mean	69.0	69.0	.90
	s.d.	4.5	3.9	
Edu.	Mean	15.8	15.6	.68
	s.d.	1.3	2.2	

Edu., education; s.d., standard deviation.

**TABLE A2** Comparison of the results of neuropsychological tests between male and female subjects.

Tests	Male			Female			p Value (Dif: male vs. female)
	Before	After	Dif	Before	After	Dif	
<b>MMSE</b>							
Mean	29.2	28.7	−0.5	28.9	29.3	0.4	.007
s.d.	1.1	1.1		1.3	1.0		
p-value (before vs. after)	.050			.16			
<b>RCPM_score</b>							
Mean	32.6	32.3	−0.3	32.3	33.2	0.9	.029
s.d.	2.7	2.4		2.1	1.9		
p-value (before vs. after)	.63			.11			
<b>RCPM_time</b>							

(Continues)

TABLE A2 (Continued)

Tests	Male			Female			<i>p</i> Value (Dif: male vs. female)
	Before	After	Dif	Before	After	Dif	
Mean	230	217	−13	238	246	8	.11
s.d.	45	40		37	63		
<i>p</i> -value (before vs. after)	.23			.61			
<b>LM-I</b>							
Mean	12.5	13.5	1	14.6	14.2	−0.4	.095
s.d.	10.2	11.8		3.1	3.7		
<i>p</i> -value (before vs. after)	.26			.65			
<b>LM-II</b>							
Mean	12.0	12.7	0.7	13.5	13.4	−0.1	.24
s.d.	3.3	3.8		3.3	2.9		
<i>p</i> -value (before vs. after)	.43			.86			
<b>Necker_score</b>							
Mean	2.9	3.0	0.1	3.0	3.0	0	.36
s.d.	0.25	0		0.19	0.19		
<i>p</i> -value (before vs. after)	.16			1.0			
<b>Necker_time</b>							
Mean	18.2	19.0	0.8	23.4	23.1	−0.3	.64
s.d.	6.3	8.3		9.6	10.4		
<i>p</i> -value (before vs. after)	.66			.91			
<b>Construction</b>							
Mean	17.6	17.6	0	17.7	17.6	−0.1	.48
s.d.	0.6	0.6		0.6	0.6		
<i>p</i> -value (before vs. after)	.84			.47			
<b>WF_category</b>							
Mean	15.5	17.7	2.2	16.6	18.0	1.4	.47
s.d.	3.4	3.4		4.2	5.2		
<i>p</i> -value (before vs. after)	.012			.29			
<b>WF_letters</b>							
Mean	10.5	10.8	0.3	11.1	11.3	0.2	.87
s.d.	2.6	3.0		3.9	3.6		
<i>p</i> -value (before vs. after)	.71			.89			
<b>TMT-A</b>							
Mean	96.5	95.8	−0.7	90.4	98.1	7.7	.53

(Continues)

**TABLE A2** (Continued)

Tests	Male			Female			<i>p</i> Value (Dif: male vs. female)
	Before	After	Dif	Before	After	Dif	
s.d.	42.7	50.9		51.2	59.4		
<i>p</i> -value (before vs. after)	.95			.62			
<b>TMT-B</b>							
Mean	116	108	−8	104	86	−18	.57
s.d.	45	55		60	51		
<i>p</i> -value (before vs. after)	.52			.25			

Note: Bold letters indicate statistical significance. Dif, difference; MMSE, Mini-Mental State Examination, RCPM, Raven's Colored Progressive Matrices; s.d., standard deviation; TMT, Trail-Making Test; vs., versus; WF, word fluency.

人工知能を用いたテキストから音楽への変換が通常の高齢者の前頭葉機能を向上させる  
佐藤正之、井上純、小川純一、田部井賢一、神川ちあき、阿部真貴子、吉澤彩佳、  
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初回公開日：2024年9月5日

<https://doi.org/10.1002/brb3.70007>

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## 要旨

### はじめに

人工知能(AI)の進展は目覚ましいものがあります。本研究では、テキストを音楽に変換するAI「Music Trinity Generative Algorithm-Human Refined(MusicTGA-HR)」を使用したオンライン会議を通じて、通常の高齢者(音会)に対するその効果を調査しました。

### 方法

平均年齢  $69.4 \pm 4.4$  歳の地域在住の認知的に健康な高齢者 118 名(男性 64 名、女性 54 名)をインターネットで募集しました。参加者は MusicTGA-HR を使用して、テーマに最もふさわしいと思われる音楽を選択しました。7~10 人のメンバーと 1 人の指導者で構成される 11 クラスを設け、各クラスで週 1 回オンライン会議を実施しました。参加者はそれぞれ選んだ音楽を発表し、他の参加者や指導者からコメントを受けました。介入前後で神経心理学的評価を実施し、6 か月間の介入による効果を統計的に分析しました。

### 結果

カテゴリーと文字流暢性(WF)が有意に改善され(カテゴリー-WF:  $p = .003$ ; 文字 WF:  $p = .036$ )、Trail-Making Test-B の時間も有意に短縮されました( $p = .039$ )。また、オンライン認知テスト「Brain Assessment」で数字記憶が有意に改善されました( $p < .001$ )。

### 結論

MusicTGA-HR を使用した音会は、独立した生活を送る健康な高齢者の前頭葉機能と記憶力を改善しました。

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## 1. はじめに

高齢化に伴い、認知症の罹患数は急速に増加しています。現在、世界中で約 4680 万人が認知症を患っていると推定され、毎年 990 万人の新規症例が診断されています

(Strøm ら, 2016)。アルツハイマー病国際会議 (Prince ら, 2015) によると、これらの数字は 20 年ごとにほぼ倍増し、2030 年には 7470 万人、2050 年には 1 億 3150 万人に達すると見込まれています。アジアでは特に多くの認知症患者が見られるとされています (Satoh ら, 2020)。近年の研究では、高血圧や身体運動、知的活動といった生活習慣の管理を含む適切な介入によって、認知症の発症をある程度予防できることが示されています (Barnes & Yaffe, 2011; Livingston ら, 2017; Satoh ら, 2014/2017/2020; Tabei ら, 2017)。

現在、神経学の分野では、音楽療法が認知症 (Moreno-Morales ら, 2020; van der Steen ら, 2018)、パーキンソン病 (Zhang ら, 2017; Zhou ら, 2021)、脳卒中 (Magee ら, 2017; Van Criekinge ら, 2019)、失語症 (García-Casares ら, 2022; Liu ら, 2022)、および片側空間無視 (Long ら, 2023) に効果があると確立されています。また、音楽介入はストレス軽減に有意な効果を持つことがよく知られており (de Witte ら, 2020/2022)、認知症の行動および心理症状 (BPSD) に対する効果も報告されています (Dyer ら, 2018; Ueda ら, 2013)。その後、認知症を患う高齢者の認知機能に対する効果も報告されています (Dorris ら, 2021; Ito ら, 2022; Moreno-Morales ら, 2020)。

最近では、音楽活動の種類と健康およびウェルビーイングへの効果との関係についての研究が報告されています (Dingle ら, 2021)。音楽鑑賞や楽器演奏、音楽制作には長期的かつ専門的な訓練が必要ですが、AI の発展により、これらの活動に初心者でも参加できる新しい可能性が生まれています。

最近の人工知能 (AI) の発展により、さまざまな分野で大きな進歩が遂げられています。例えば、ChatGPT のような生成型 AI は、入力された単語やテキストに基づいて適切な回答を生成することが可能です。画像生成 AI (例: Stable Diffusion Online や Bing Image Creator) では、入力されたテキストから新しい画像を作り出すことができます。これらの AI 技術の音楽版ともいえるのが「Music Trinity Generative Algorithm-Human Refined (MusicTGA-HR)」です (<https://www.amadeuscode.com/musicTGA-hr>)。MusicTGA-HR は、メロディ、リズム、ハーモニー、音色、楽器構成、スタイルなどの音楽要素を分解したデータを基に、対応するテキスト入力をもとにしたほぼ無限の選択肢の音楽を生成することができます。この技術により、専門的な音楽訓練を受けて

いない人でも、自分のイメージやコンセプトに最適な音楽を選択できるようになりました。この技術は YouTuber の間でも広く利用されており、毎月世界中で 44,000 以上の音楽作品が生成されています。

一方で、高齢者向けの非薬物的介入としては、絵画、陶芸、裁縫、料理などの様々な活動が認知刺激トレーニングとして使用されています（日本神経学会, 2017）。日本では俳句を用いた認知刺激トレーニングが行われており、参加者がテーマに沿って俳句を作成し、それを他のメンバーの前で発表します。この活動は「句会」と呼ばれ、もともとは対面で行われていましたが、新型コロナウイルス感染症（COVID-19）の流行により、オンライン形式で開催されるようになりました。この背景から、私たちは MusicTGA-HR を認知機能改善のための非薬物療法として応用できる可能性があるかと仮定しました。MusicTGA-HR を使用すれば、個人がテーマに最適だと思う音楽を選ぶことができます。そして、オンライン会議でその音楽を発表し、他の参加者や指導者がその音楽についての感想を述べます。この活動を、俳句の「句会」に倣い、「音会」と名付けました。「音会」とは日本語で「音楽/音」と「会議」を意味します。

この研究の目的は、地域在住の健康な高齢者の認知機能改善を目的とした「音会」の有効性を調査することです。ビデオ会議システムを用いて 6 か月間音会を実施し、介入期間前後で認知評価を行いました。本研究の主要な成果は、介入期間前後の神経心理学的評価の変化です。本研究の結果が、世界的に重要かつ緊急の課題である認知症予防に応用されることを期待しています。

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## 2. 材料と方法

### 2.1 対象者

本研究では、事前研究に基づいて対象者数を決定しました（Tabei ら, 2023）。以前の研究では、音楽を伴うオンライン運動クラスに 114 名が参加し、そのうち 75 名のデータを用いて解析を行った結果、前頭葉機能に関連する N-back 課題で有意な改善が見られました。本研究では、1 グループ 12 名の計 10 グループ（合計 120 名）を計画しました（図 1）。インターネットを通じて対象者を募集し、デジタルデバイスを使用できるスキルがあることを前提に参加者を選びました。最終的に、先着順で 118 名（男性 64 名、女性 54 名、平均年齢  $69.4 \pm 4.4$  歳）が対象となりました。

### 選定基準

- 65 歳以上
- 精神的に健康
- 視力良好
- 指示が明確に聞き取れる
- 独立して日常生活を送る能力がある
- 個人用 PC またはタブレットを所有
- デジタルデバイスを操作可能
- 6 か月間のクラスに参加可能
- 介入前後の神経心理学的評価を実施可能

#### **除外基準**

- 明らかな脳血管障害の既往歴
- 慢性的な消耗性疾患（悪性腫瘍、感染症など）の存在
- 心疾患、呼吸器疾患、腎障害の重症例
- 認知に悪影響を与える薬剤（抗うつ薬、抗精神病薬）の使用
- 認知症の診断歴
- デジタルデバイスが使用できない

#### **2.2 テキストから音楽への変換を用いたオンライン会議（音会）**

音会の指導者は、ヤマハ音楽振興会で音楽トレーナーの資格を持つプロの音楽家でした。著者の一人（JO）はヤマハの音楽トレーナーの責任者であり、この研究に適した指導者をその実績と適性に基づいて選びました。本研究開始前に、音会の指導者を対象としたオンライン講習を2つのグループに分けて実施しました。講習では、以下の内容を指導しました：

1. 著者（MS）による研究の目的と背景の講義
2. MS と JO による音会の方法説明
3. 著者（KT と AY）による MusicTGA-HR の操作説明

合計で約 2 時間の講習が行われ、指導者は講習後も随時著者に質問可能としました。参加を辞退した者を除き、7~10 名のメンバーと 1 名の指導者から成る 11 クラスが編成されました。各参加者には MusicTGA-HR の操作マニュアルがオンラインで提供され、介入開始 1 週間前には著者 (JO、AY) および指導者による研究の目的、オンライン会議の手順、MusicTGA-HR の操作方法の説明会が行われました。

### 音会の実施手順

1. 次回会議のテーマが事前にメールで通知される。
2. 参加者は MusicTGA-HR を使用し、テーマに最も適した音楽を選択する。この音楽ファイルは PC やタブレットに保存可能。
3. 会議では、各参加者が選んだ音楽を発表し、その理由を説明する。指導者その他のメンバーがコメントを行う。
4. 指導者も選択した音楽を発表し、同様に解説。
5. 次回のテーマを指導者が伝達し、会議を終了。

会議には Zoom (Zoom Video Communications, Inc.) が使用され、1 時間の会議が週 1 回、6 か月間にわたり合計 24 回開催されました。テーマは具体的なものから抽象的なものへと段階的に難易度が上がりました (表 1)。最後の 4 回 (第 21~24 回) のテーマは自叙伝的な内容であり、参加者が自身の写真や動画 (例: 海外旅行、子供が受賞した賞、自分の趣味など) を使用しました。

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**表 1. 音会の各回のテーマ**

セクション	会議番号	テーマ
1. 具体的な画像	1	富士山
	2	列車
	3	恐竜
	4	池の中の鯉

セクション	会議番号	テーマ
2. 人間活動の風景	5	花火
	6	祭り
	7	ピアノを弾く
	8	マラソンを走る
3. 有名な文	9	小林一茶の俳句
	10	諺
	11	歴史的人物の名言
	12	谷川俊太郎の詩
4. 具体的な短編映像	13	寝ている子猫
	14	大波の打ち寄せる海岸
	15	回転する観覧車を映した玩具
	16	歩く虎
5. 抽象的な画像	17	マンデルブロ集合の図
	18	ワシリー・カンディンスキーの絵
	19	ワシリー・カンディンスキーの絵
	20	光るライトの映像
6. 自叙伝的な素材	21	参加者が選んだ写真や動画
	22	
	23	
	24	

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## 2.3 神経心理学的評価

介入開始 2 週間前および終了 2 週間以内に、オンラインで神経心理学的評価を実施しました。評価は約 1 時間で完了し、1 回のセッションで行いました。評価には主に以下の項目が含まれました：

- **知的機能:** Mini-Mental State Examination (MMSE)、Raven's Colored Progressive Matrices (RCPM)
- **記憶:** Logical Memory (即時再生と遅延再生)
- **構成能力:** ネットワークキューブ描画 (形状と描画プロセスの評価)
- **前頭葉機能:** Word Fluency (WF)、Trail-Making Test (TMT)

さらに、最近開発されたオンライン認知テスト「Brain Assessment (BA)」を使用して、数値記憶、語彙記憶、精神回転、作業記憶 (N-back テスト)、判断課題を評価しました。これらのテストは事前・事後で比較され、統計解析が行われました。

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## 3. 結果

6 か月間の介入期間中、11 名がスケジュールの都合、健康上の問題、または期待と異なる理由で脱落しました。最終的な継続率は 89.1% でした。神経心理学的検査を完全に実施した参加者は 73 名で、うち 59 名のデータ (男性 33 名、女性 26 名) が統計解析に使用されました。

### 主な結果

- カテゴリー-WF と文字 WF が有意に改善 ( $p = .003$ ,  $p = .036$ )。
- TMT-B の時間が短縮 ( $p = .039$ )。
- Brain Assessment の数値記憶が有意に向上 ( $p < .001$ )。

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## 4. 議論

本研究では、人工知能 (AI) を用いてテキストから音楽を生成するシステム (MusicTGA-HR) を使用したオンライン会議 (音会) を、認知的に健康な高齢者を対象

に実施しました。この活動では、あらかじめ設定されたテーマに基づいて AI が作成した音楽を参加者が選択し、その選択理由を発表しました。指導者であるプロの音楽家は、音楽に対して肯定的なフィードバックを提供しました。音会は週 1 回、1 時間の形式で 6 か月間実施され、継続率は 89.1%でした。神経心理学的評価の結果、6 か月間の介入後に前頭葉機能と記憶力が有意に改善されたことが示されました。

### 音楽と脳の関係

音楽の知覚は、音響解析、聴覚記憶、音楽文法と意味の処理、感情への影響、自律神経系、ホルモンおよび免疫系の活性化など、複雑な脳機能を伴います (Koelsch & Siebel, 2005)。音楽知覚に関与する脳領域には、一次および二次聴覚野、前運動野、前頭弁蓋部、島皮質、帯状皮質、感覚皮質などが含まれます (Koelsch ら, 2021)。音楽訓練は、右半球の腹側経路における情報伝達を促進し、音と意味のマッピングを改善する可能性があること示唆されています (Oechslin ら, 2018)。また、健常な高齢者における音楽ベースの介入後に脳のネットワーク接続が変化することが報告されています (Quinci ら, 2022)。これらの知見から、音楽知覚には前頭葉が重要な役割を果たすと考えられます。

### 男性の参加率の高さ

本研究では、音会への男性参加率が 55.9%と比較的高く、対面形式の非薬物療法と比較して特筆すべき点でした。たとえば、私たちが以前に実施した音楽を伴う運動クラス (Mihama-Kiho プロジェクト) では、男性参加率は 20%に過ぎませんでした (Satoh ら, 2014)。COVID-19 の影響で同様の介入をオンライン形式で行った際には、男性参加率が約 50%に増加しました (Satoh ら, 2023)。アンケート結果によると、多くの男性参加者が対面形式では参加しなかった理由として、感染リスク、会場への移動の困難さ、他者との交流への不快感を挙げています (Satoh ら, 2023)。このように、オンライン形式の音会は高齢男性が非薬物療法に参加するきっかけを提供しうるものです。

### 継続率の高さ

音会の継続率は 6 か月間で 89.1%と比較的高い水準を示しました。非薬物療法の継続率は一般的に 65%から 100%の範囲であることが知られており (Gajewski & Falkenstein, 2012; Kraus-Sorio ら, 2022; Suzuki ら, 2014)、本研究の継続率は他の研究と同等か、それを上回る水準です。AI を活用した新しいアプローチやテーマの段階的な難易度の上昇が、参加者の関心を維持する助けとなった可能性があります。

## 前頭葉機能と記憶力の改善

音会の最大の特徴は、介入後に前頭葉機能と記憶力が有意に改善された点です。たとえば、第 17 回音会のテーマで使用した「マンデルブロ集合」の図は、参加者の脳内で以下のように処理されたと考えられます（図 3 参照）。

1. 視覚的刺激が後頭葉で知覚される。
2. MusicTGA-HR を用いて選択された音楽が聴覚野で処理される。
3. 感覚情報が頭頂葉下部（特に角回）で統合される。
4. 前頭葉がこれらの感覚情報が一致するかどうかを判断する。

参加者は毎週約 100 回、このようなプロセスを繰り返しました。また、オンライン会議では、指導者がテーマに関連する個人的な経験を述べるよう求めました。このように、エピソード記憶や意味記憶が呼び起こされることで、前頭葉機能が刺激された可能性があります。このプロセスを 6 か月間繰り返すことで、認知機能の改善が期待できると考えられます。

## 性別による効果の違い

性別間で認知評価結果を比較したところ、MMSE や RCPM において女性のほうが男性よりも成績が良い傾向が見られました（MMSE:  $p = .007$ ; RCPM:  $p = .029$ ）。これは非薬物療法による効果が性別で異なる可能性を示唆しており、今後さらなる研究が必要です。

## 制約

本研究にはいくつかの制約があります。

1. 解析に使用された参加者数（ $n = 59$ ）が少ない。
  2. 介入期間が 6 か月と限定的であり、より長期間の効果を検証する必要がある。
  3. 指導者がプロの音楽家であり、他の地域で普及させるには指導者の育成が必要。
  4. 対照群がないため、結果の因果関係をより強固にするための研究が求められる。
  5. 参加者は情報技術（IT）リテラシーを必要とするため、デジタルデバイスの使用に不慣れな高齢者への対応が課題となる。
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## 5. 結論

音会は、前頭葉機能および記憶力を改善する非薬物療法として非常に有望であることが示されました。特に、オンライン形式であるため、COVID-19のような健康リスクや交通アクセスの制約がある状況でも実施可能であり、男性の参加率向上にも寄与します。このアプローチは、遠隔地や離島に住む高齢者への適用も期待され、高齢化が進む社会での認知症予防に新たな可能性を提供するものです。

