Moonshot R&D MILLENNIA* Program

*Multifaceted investigation challenge for new normal initiatives program

“Empowering vitality and creativity in the global society through emotional inspiration and co-creation in music”

Initiative Report

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Missionary Team "Nishimoto MS Music Project”

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I. CONCEPT OF PROPOSED MS GOAL

1. Proposed MS goal

1.1 Title of the proposed MS goals

"By 2050, we will realize a human society full of vitality and creativity through the emotional inspiration and co-creation in music.”

1.2 Vision of society in 2050

Figure 1: Logo of the MS Music Inspiration and Co-Creation Project (conceptual diagram of the ideal society). *The two trunks of "emotional inspiration" and "co-creation," represented by music score, are bearing the seven fruits in society 2050.*

Since ancient times, humans have felt the expansion of time and space in music. The integration of time and space is called "harmony" in musical terms. In ancient Greece, it was believed that "music not only harmonizes the universe but also gives harmony to human beings and redeems their souls." Music was included in the curriculum of the Platonic Academy, so music was originally an inseparable fusion of art and science. However, in the process of development of art and science, they have come to be treated as separate things. We would like to realize a new society in which people shine with vitality and creativity and experience irreplaceable happiness through the "emotional inspiration" and "co-creation" evoked by music by uncovering the deep potential of music and using it in multiple and multifaceted ways.

In the society of 2050, the realization of existing MS goals will develop “Cybernetic Avatar (CA)” and AI robots that allows humans to participate in diverse social activities. In such a future society, however, the 20th-century model in which humans contribute to society through productive labor and gain a sense of purpose in life will not work. There is a danger that we will live in a society that is materially affluent but spiritually satisfying for only a few people. In the next 30 years, we can expect

more pandemics, natural disasters, terrorism, conflicts, and other events that will have a long-term and enormous negative impact on the mental health of humanity. Lack of spiritual enrichment may lead to conflicts among individuals, groups, and cultures, which may threaten the hopeful life of humanity.

To overcome these challenges, we must uncover the power of "emotional inspiration," which deeply and intensely moves people's hearts and 'Kansei' (sensibilities), and the power of "co-creation" which is defined to encourage both empathetic resonation and creativity. We shall also make the best use of these powers for the people's mental health, happiness, world peace and global sustainability. With the mechanism of music to inspire deep emotion and creativity, we envisage achieving zero depression, zero suicide, zero conflicts, mental and physical wellness, self-realization, happiness realization, and breakthrough to the universe. Our hope of human society in 2050 will be full of vitality and creativity (**Fig. 1**).

2. Targets in 2030, 2040, and 2050

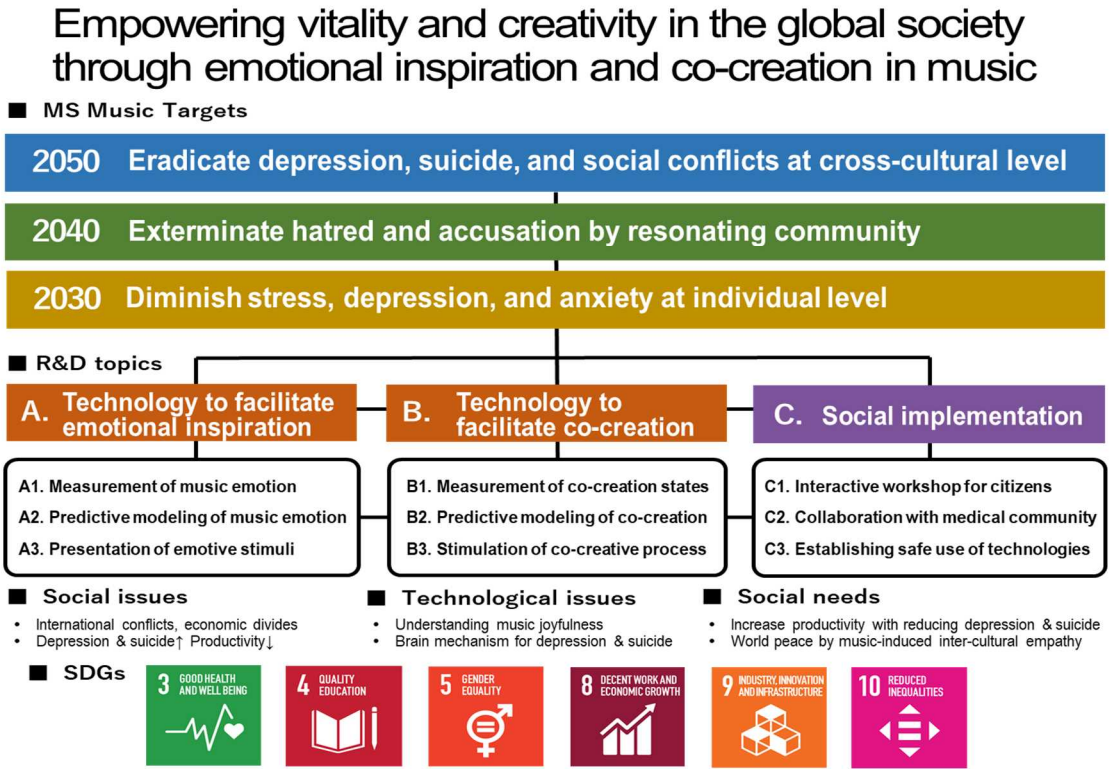

Figure 2: Overview of the relevant MS goals and the scenes in which they are achieved.

The MS goal is to establish, by 2050, a society full of vitality and creativity with zero depression, zero suicide, and zero conflict through cross-cultural emotional inspiration and co-creation. It will be achieved by the application of the technologies developed through the scientific validation of how music evokes *deep* emotion and co-creation ("Technology to facilitate emotional inspiration" and "Technology to facilitate co-creation", respectively) (**Fig. 2**). For backcasting the achievement in 2050, in 2030, we will reduce stress and depression of individuals by establishing emotional inspiration and co-creation of music.

As a first step to practically examine to what extent the above goals can be concretely realized, a "Moonshot (MS) Music Trial Workshop" with citizen experience participation was held on June 23, 2021, as an outcome of this research (**Fig. 3**).

Led by the team leader Nishimoto, the Illuminato Philharmonic Orchestra, Toshima City, Yamaha Corporation, audiences at the venue and at remotely connected locations, and researchers worked together to create a workshop to envision the style of music in 2050 (**Fig. 3A**). As a first step in elucidating the mechanisms by which music evokes emotional inspiration and co-creation, we experimented with an EEG quantification using the "excitement" visualization technology developed by team members Yamawaki and Machizawa (**Fig. 3B**). In addition, we conducted a visualization experiment of the mental movement of viewers in actual and remote spaces by applying the contactless autonomic quantification technology by monitoring facial skin and heartbeats with the “Ultra-Diversity Society Team” (led by Prof. Shima Okada) in MS Millennia Program (**Fig. 3C**). We also measured the physical movements of musicians using micro acceleration sensors to monitor and quantify synchronization among players with the “Psyche Navigation System Team" (led by Prof. Seiji Kumagai) in the MS Millennia Program. With the shared vision of "emotional inspiration and co-creation", the researchers crossing the boundaries across the teams in the MS Millenia program, performers, government, industry, and citizens could interconnect between the actual and remote spaces and unite to co-create would be credited as the first step toward the realization of the MS goal.

Figure 3: Moonshot Music Trial Workshop*. Demonstration by Tomomi Nishimoto with conducting and hand clapping (A). EEG measurement experiment using high-precision visualization technology of "excitement" (B). Visualization experiment of viewer's mental movement at the actual and remote locations using EEG, heartbeat, and facial image measurement analysis technology (C).*

3. Background of MS Goal and social significance

3.1. Why now?

In recent years, the number of patients suffering from depression and other mood disorders has doubled, rising to about 1 million per year (White Paper on Health, Labor and Welfare, 2012). The number of suicides among young people (15-39 years old), who will support the future as the birthrate continues to decline, has not improved and is the leading cause of death, with suicide accounting for more than 50% of all deaths among males in their 20s (Ministry of Health, Labor and Welfare, 2019). The percentage of people suffering from high stress in the workplace exceeds the majority (58%, Ministry of Health, Labor and Welfare data, 2018). As the birthrate continues to decline, there is a national crisis of depression among workers and an increase in the number of suicides, and urgent measures are needed.

The COVID-19 pandemic caused to increase in the number of adults showing symptoms of depression, which is a major factor for suicide, more than threefold compared to the pre-pandemic period (3.6 times in the U.S., 2.2 times in Japan, and twice in the U.K., OECD, 2021). It also slashed enormous social benefits (>79 trillion yen) due to the rapid increase in depression and suicide (United Nations, 2020; JSCP data, 2021). In Japan, the economic damage caused by the absence from work due to depression and suicide is estimated to be about 2.7 trillion yen (Ministry of Health, Labor and Welfare, 2010). A survey on the actual state of affairs (Hiroshima City, 2020) revealed severe concerns: "I feel depressed more often (39.1% of males, 55.5% of women)," "My depression increases the more my economic situation suffers, and the less I have friends or someone to talk to," and "I have so much trouble and stress that I want to die (5.8% of males, 13.5% of females). As such, concerns about the deterioration of mental health from non-direct, secondary effects of the pandemic is warned (Bourgeault et al., 2020). In light of these social situations, the need is requested to urgently develop scientific technologies that can contribute to the maintenance and improvement of our mental health (Union of Brain Science Associations in Japan (former principal: Shigeto Yamawaki) Urgent Proposal, 2020).

On the other hand, a recent study investigated which of the many leisure activities (a total of 43 leisure activities including music, social networking, cooking, drinking, watching movies, and exercising) have a positive effect on coping with psychological distress. It has been shown that music was people picked music most often as the best activity to cope with psychological distress (Mas-Herrero et al., 2020). Listening to music, playing music, singing, dancing to music, going to the park to play the guitar with friends, etc., were all used as a way to cope with psychological distress under the COVID-19 pandemic, and those who engaged in musical activities for more time were shown to have lower levels of depression symptoms. In our report, we conducted a questionnaire survey on the relationship between music and the daily lives of citizens, and it was found that the majority of citizens listen to music to feel safe and relaxed, to be energized and happy, to be motivated and focused and that they need music in their daily lives and for their happiness. The majority of citizens listen to music to feel safe and relaxed, feel energized and happy, and feel motivated and focused.

Furthermore, there are many global problems such as the destruction of nature, environmental

pollution, and abnormal weather. To establish and maintain a sustainable global environment, we need to resolve separation, fight and conflicts among groups and cultures and bring all the people of the world together. It is imperative to realize a society that fosters respect for people, animals, nature and the earth, thoughtfulness, compassion, and happiness, rather than self-centered and selfish thoughts and attitudes. For the actual achievement of the Sustainable Development Goals (SDGs), it is pivotal to present *inspiring* stories and visions that will make people voluntarily take action for the entire planet.

3.2. Social significance

The social significance of achieving this MS goal is to achieve zero- depression and suicide through the musical inspiration and joy of co-creation, to solve the decline in the working population and productivity rapidly, and to make a peaceful and sustainable global society with zero conflicts through inspiring co-creation beyond cultures.

Since time immemorial, music has been a universal part of our daily lives, transcending time, borders, and cultures. Although music exists as a natural part of humanity's daily life, we do not have a sound scientific understanding of where the music came from, where it is going, and its origin and future. In order to achieve this MS goal, the people of the world should sincerely confront the music and arts that exist around them and explore their essence, which should lead to a deep and strong sense of the other in oneself and the self in others and society, respect for the dignity of each other's life, fostering empathy and a sense of unity, and creating a bright future together.

Music can nonverbally express human nature, such as joy, anger, sorrow, and various emotions, ideals, religious beliefs, learning from history and mythology, sensual fascination, and immoral regret. In other words, musical expression skillfully transforms information that may cause logical conflicts, contradictions, and frictions in the verbal expression into information that generates abstract sympathy. By elucidating the process of co-creation and the mechanism of abstraction of emotional information that naturally takes place in musical acts, and by utilizing the benefits of these processes as science and technology for the well-being of humanity, we can resolve conflicts among all individuals, groups, and cultures, and realize world peace and sustainable society.

3.3. Outline of society-wide actions

First, in order to achieve the MS goals, it is necessary for performers and researchers to cooperate and work together. One of the main features of our missionary team is that the performers and researchers are working together as a team to conduct research with appreciation and love of music. The discussions and study sessions within the team have revealed that the performers wish to deepen their understanding of music and contribute to the happiness of humanity through scientific research and that the researchers wish to break through the closed music research and contribute to the happiness of the world by collaborating with the performers to clarify the fundamental impact of music. The promotion of this MS goal would integrate art and academia and make an arts and sciences nation. This project is an effort to cultivate humanity's vitality and creativity to confront the various global-scale difficulties and problems that may arise in future society.

Second, what is necessary to achieve the said MS goal is to create a bright future together with the next generation of youth who will be responsible for the future in 2050. To demonstrate the feasibility, we held a workshop, "Tomomi Nishimoto Moonshot Music Inspiration Co-Creation Project Workshop 2021," attended by 763 elementary, junior high, and high school students from a total of 10 schools. Imagining the future in 2030, 2040 and 2050, we created paints, calligraphy, music and writings that would be loaded on a Golden Record for each decade. (The Golden Record is a collection of the earth's cultures at the time in which the Voyager, the space probe launched back in 1977 to explore the outer Solar System.) As a result of the workshop, we were able to co-create a dreamy image of the future society of 2050 with the next generation of youth who will be responsible for the future (**Fig. 4**).

Figure 4: Works to be included in the "Golden Record of 2050" drawn at the workshop for elementary, middle and high school students (examples of elementary school students' works). *(A) "Anywhere smartphone". (B) "Earphones for all living things". (C) "Music & Fish Headphone Set". (D) "Magic clothes that can go to space, and space and earth speakers". (E) 'MUSIC clay'. (F) 'Music note badge'. (G) 'Song cookies'. (Kokoro) 'UMB ~Universe Music Building~'. (I) 'Axiom'.*

The third point is a collaborative effort with medical professionals. We conducted a hearing survey to share our vision and hold opportunities to discuss with: Shinya Yamanaka, Director of the Kyoto University iPS Cell Research Institute, Keisuke Goda, Professor of the University of Tokyo, and professors from the Moonshot Millennia Program Research Team (Ultra-Diversity Society Team, Post-Antropocene Team, Digital Biosphere Future Co-Creation Team, and Street Medical City Team), Ryota Kanai, MS Target 1 PM and president of Araya Inc, Shigeto Yamawaki, Specially Appointed

Professor, Center for Brain, Mind and KANSEI Sciences Research, Hiroshima University, and Maro Machizawa, Specially Appointed Associate Professor, Center for Brain, Mind and KANSEI Sciences Research, Hiroshima University. Among them, we realized that Yamawaki and Machizawa are working on a project, Mental Health Digital Transformation (DX), which aims to maintain and improve the mental health of humanity by integrating brain science, AI and digital technologies. Their scopes and our MS goals share the same vision and beliefs to achieve people's mental wellness and happiness by applying Kansei Science. Both Yamawaki and Machizawa have officially joined the team in the process of promoting this research because of a fair share of the goal with our missionary team. It is expected that further collaboration with medical professionals will be promoted in the future.

Fourth is to take care that the technologies of evoking emotional inspiration, harmony, and synchrony through musical art are not misused socially. Technology that moves people's hearts deeply and strongly and strengthens their connections may potentially lead to brainwashing technology for people if it is misused. For example, looking at music historically, there are examples of the political use of music in the Greek era, the religious use by the church in the European Middle Ages, the use as propaganda in the modern era, and the use of music to unite the inner group to eliminate the outer group, such as military songs. It is necessary to collaborate with experts in ethics, law, history, and philosophy for the safe use of synchronized emotion-evoking technologies.

4. Changes in industry and society

Music is an art of connection. The achievement of this goal may lead to a change in social and industrial structure that integrates regional and hierarchical divisions and effectively brings together the wisdom of all humankind by extending the connection through the emotional inspiration and co-creation of music to the entire globe. Art is also a spiritually productive activity. The industries in which humans are engaged are expected to change to an industrial structure that supports artistic creation and thereby creates ties between humans. By achieving this goal, human productivity in the 21st century will be embodied as spirituality, and the realization of a society full of vitality and creativity with zero depression, zero suicide, and zero conflict will lead the world from division to peace, from destruction to sustainability, and bring stable peace to the global community.

II. STATISTICAL ANALYSIS

1. Scientific, technological, and social issues, and necessary actions

To date, it is still unclear why and how music arouses people's emotion and make people synchronize. Without solving the mechanism underlying the power of music, the goals of the MS cannot be achieved. To do so, one of the social issues is to integrate art and academia. To achieve this MS goal, musical art and science and technology must be truly integrated. To realize the goal, music practitioners and researchers need to cooperate with each other to academically pursue the effects of music on our mental health and well-being together with medical professionals and the general public. While Japan's research on musical information processing is at a high level compared to the other countries, the music science that focuses on perception and cognition, brain, emotion and social behaviors, training and development, and medical applications lag behind compared to the other countries. It is necessary to actively promote the research fields on music perception and cognition, music and neurosciences, developmental music science, and medical music science by taking advantage of the strengths in music informatics in Japan. In addition, it is expected to unite all cultural backgrounds in the world through international cooperation to integrate art, science and technology for the happiness of humanity and world peace.

2. Overview of required R&D fields

In order to realize a human society full of vitality and creativity through the emotional inspiration and co-creation of music, it is necessary to (a) develop technology to facilitate emotional inspiration, (b) develop technology to facilitate co-creation, and (c) work toward social implementation (**Fig. 5)**.

The "development of technology to facilitate emotional inspiration" means the development of science and technology to reveal the scientific mechanism of why and how music arouses emotion in people and to apply it to society. To realize the development of "emotion-evoking technology," it is necessary to develop (A1) technology to objectively measure and quantify the emotion state (emotion measurement technology), (A2) mathematical modeling to predict the time-series transition of the emotional state and the moment of emotion evocation (emotion prediction technology), and (A3) technology to present sensory stimuli that extend the emotion experience (emotion enhancement technology). (A3) Technology for presenting sensory stimuli that extend the emotional experience (emotion enhancement technology).

The development of technology for stimulating co-creation is the development of science and technology for clarifying the scientific mechanism of why and how music stimulates people's co-creation and applying it to society. In order to realize the development of "technology to stimulate co-creation," it is necessary to develop (B1) technology to objectively measure and quantify the state in which people are inspired to create together (co-creation measurement technology), (B2) mathematical modeling to predict the dynamics of the process in which people are inspired to create together (co-creation prediction technology), and (B3) technology to facilitate and expand the process in which people empathize, are inspired and become creative. (B2) development of mathematical modeling to predict the dynamics of the process by which people become inspired and create together (co-creation

prediction technology), and (B3) development of technology to promote and extend the process by which people become empathetic, inspired, and creative (co-creation extension technology).

To achieve "social implementation" (C1), we need to promote "technology to evoke emotion" and "technology to evoke co-creation" in cooperation with the general public. In order to realize "social implementation," (C1) citizen science initiatives that promote "technology to arouse emotion" and "technology to arouse co-creation" in cooperation with the general public, as well as workshops and demonstrations in cooperation with the general public, are necessary. It is also necessary to collaborate with medical professionals to apply the results obtained in (C2) to the physical and mental health of people. In addition, (C3) ethical and legal arrangements are necessary for the safe and peaceful use of the results obtained.

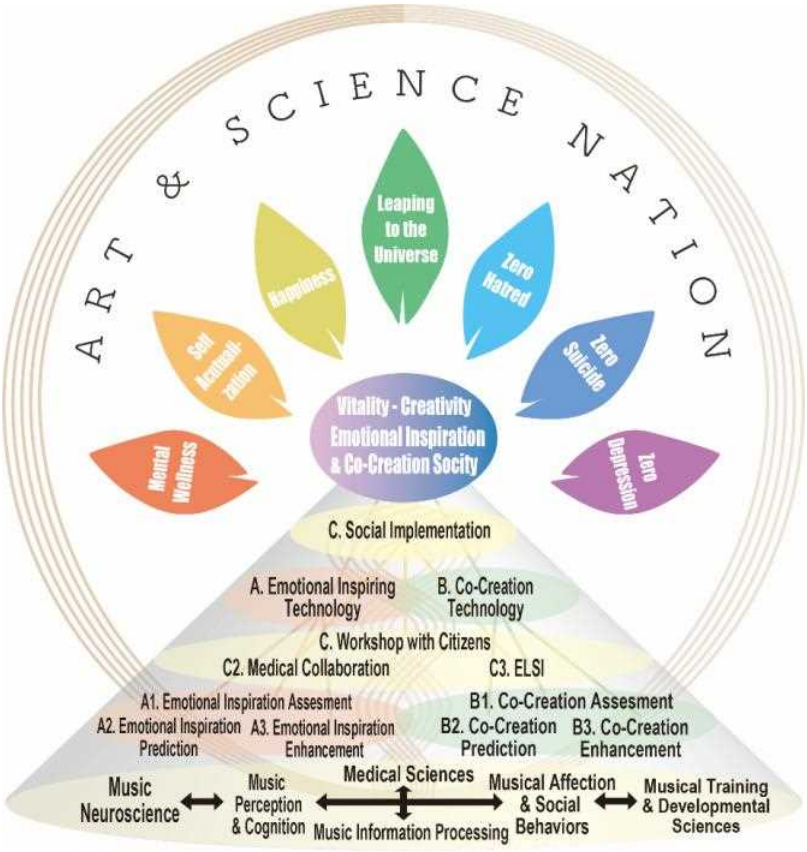

Figure 5: Structuring of MS Goal, related research field and technologies.

3. R&D trends in related fields, overseas trends, and Japan's strengths

We investigated the trends in science and technology research and development related to music. We extracted the top scientific and technological papers in order of the number of citations from the Web of Science article database using "music" as the keyword and analyzed their contents and international trends. We also conducted a broad literature survey to investigate the scientific and technological trends related to music.

First, with a selection criterion for the keywords in the titles and abstracts the top 5,000 most-cited papers on the Web of Science article database were extracted, and clustered into subfields using the co-occurrence frequencies between the keywords. As a result, there are six main research subfields determined in the field of music science.

Table 1: Six subfields obtained by keyword analysis of music science and technology papers.

Subfields	Topics
Music Perception and Cognition	Music perception and cognition
Music Neuroscience	Structural and functional neuroimaging studies related to music perception, cognition, and performance
Music Information Processing	Signal processing, music data search, and auto transcription technologies related to informatics
Musical Affection and Social Behaviors	Emotions and social behaviors evoked by music
Musical Training and Development	Development of musical ability and the effect of musical training on them
Music-related Medical Sciences	Clinical application of music, dysfunctions of musical abilities

For these six subfields, we examined the changes over time in the ratio of the number of papers in each field and found that the field of "Neuroscience" increased from the 1990s to the 2000s, while the field of "Affection and Social Behaviors" has increased since the 2010s (**Fig. 6**). Since the theme of this MS goal is the emotion and co-creation of music, it is noteworthy that music science on emotions and social behaviors has increased since the 2010s. This result suggests that music science focusing on emotion and social aspects has been increasing in recent years in the world.

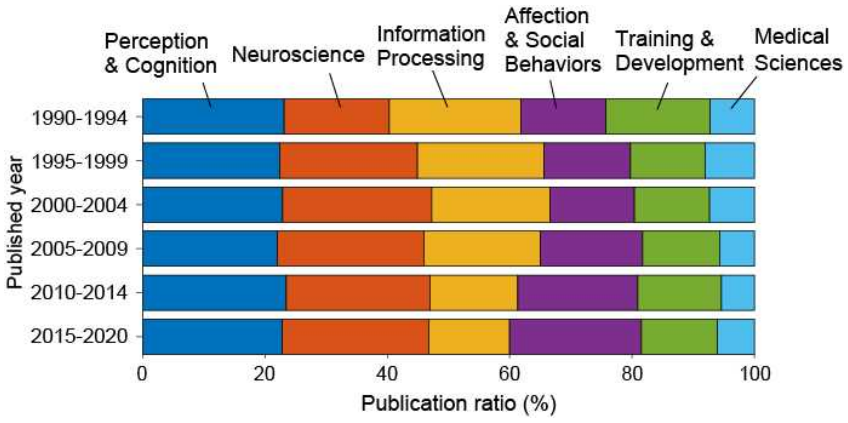

Figure 6: Research trends in music sciences as publication coverage across six subfields.

Next, we analyzed the trends in the number of publications in eight major countries (Japan, the U.S., China, the U.K., France, Germany, Canada, and Australia) for each of the six subfields in order to make an international comparison of the trends of research development in each subfield (**Fig. 7**). As a result, we found that the number of papers in each of the six subfields tended to increase as a whole. In the five fields of "Perception and Cognition," "Neuroscience," "Affection and Social Behaviors," "Training and Development," and "Medical Sciences," the U.S. maintains the top position. In the field of "Information Processing," China has shown remarkable growth, recently overtaking the U.S. for the top spot. Japan ranks last among the eight major countries in the five fields of "Perception and Cognition," "Neuroscience," "Affection and Social Behaviors," "Training and Development," and "Medical Sciences". On the other hand, in the field of "Information Processing," Japan ranks fourth after China, the U.S., and the U.K., which can be considered a strength of Japan. The challenge for Japan is to quickly develop the five fields of "Perception and Cognition," "Neuroscience," "Affection and Social Behaviors," "Training and Development," and "Medical Sciences," which are currently the lowest rankings, and link them with "Information Processing," which is one of Japan's strengths. Of particular concern is the fact that the field of "Medical Sciences" has been declining in recent years only in Japan, while other fields outside Japan have been growing in recent years. It is desirable to promote research on clinical applications of music science in cooperation with medical professionals as soon as possible.

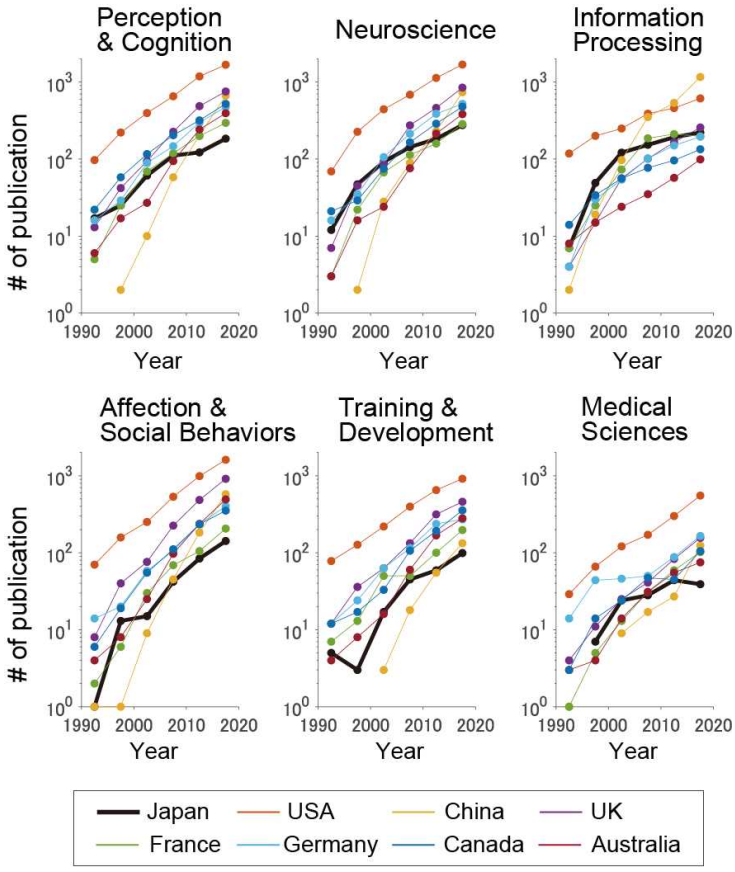

Figure 7: Number of papers published in eight countries in six subfields of music science.

Japan's music market size is the second largest in the world after the United States (IFPI, 2019). However, scientific research on the use of music for people's well-being appears to be critically lacking. We thought that a reason for the lack of progress in music science in Japan might be that the public may not need music science in the first place. Therefore, in order to investigate the necessity of music in daily life and the actual situation regarding the necessity of music science, a large-scale questionnaire survey was conducted in this research.

As a result of the questionnaire survey, 94% of the respondents answered "Positive" or "Strongly Positive" to the question "Is music necessary for daily life? (**Figure 8**).

In response to the question, "Is the music science necessary for society?" 86.8% of the respondents answered "Positive" or "Strongly Positive." This result suggests that the needs of the public and society for music science are relatively high. On the other hand, more than 60% of the respondents answered "Positive" or "Strongly Positive" to the questions "Is music science useful for daily life?", "Do you want to be involved in music science?" and "Should the music science be actively promoted in Japan/the world? The fact that the response need for music in daily life was 94%, while the need for music science was only 60%, suggests that the usefulness of music science has not been disseminated to the general public. The challenge is how to promote social acceptance of music science while communicating the significance of its usefulness to the general public.

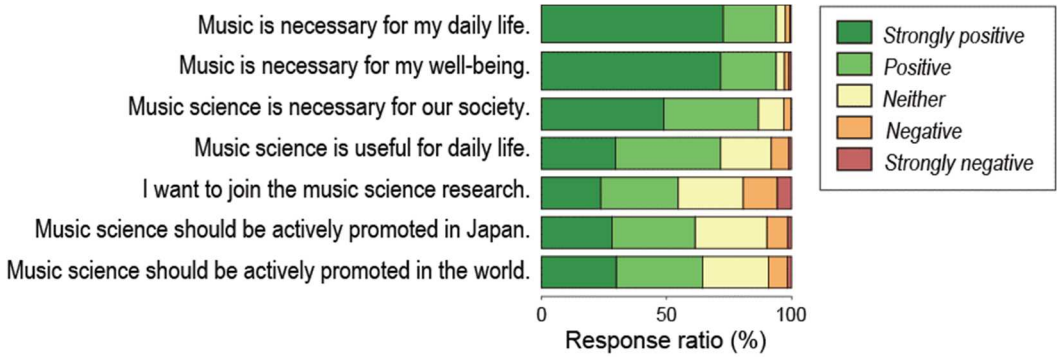

Figure 8: Questionnaire response on daily and social needs of music and music science.

In this study, we also conducted a music science workshop for university students and an academic symposium on music science with the aim of encouraging public participation in the usefulness of music science. A total of 80 people participated in the workshop for university students over four days, and about 300 people attended the joint academic symposium "Significance and Prospects of Music Science" held at the University of Tokyo, where the significance and prospects of music science were actively discussed in an open, citizen-participatory manner.

III. SCENARIO FOR REALIZATION

1. Essential R&D fields and research topics

i) Fields and areas where challenging development should be promoted

Please see Fig. 5 bottom showing an overview of fields and areas that challenging developments need to be promoted to achieve the MS goal.

From the results of the analysis (statistics and bird's eye view analysis), it is clear that Japan is strong in the field of information science of music but lags far behind other countries in the field of medical science of music. Japan should actively promote research and development on music science to utilize its strengths in the field of information science in the field of medical science.

The next priority areas for research and development are neuroscience, social-emotional science, developmental science, and cognitive science of music. In order to make full use of the strengths of the field of information science of music in the field of medical science, scientific research should be promoted to clarify the mechanisms of how music is perceived and recognized in the human brain, how it arouses emotion and empathy, and how the arousal of emotion and co-creation by music affects development, education, and society. We should promote scientific research to clarify the mechanism of how music evokes emotion and empathy and how music evokes emotion and co-creation affects development, education and society.

ii) Research issues to be addressed in achieving the goals

(A) Development of Technology to Facilitate Emotional Inspiration

(A1) Development of emotional measurement technology

Prior to developing technology to arouse emotional inspiration, it is first necessary to objectively quantify the state of "emotional inspiration (deeply being moved)". We, the missionary team, have already developed the measurement and quantification technology of the "anticipatory excitement meter (Brain-Emotion-Interface)" based on a Kansei multi-axis model of EEG signals (Machizawa, Yamawaki, et al., 2020). At the "MS Music Trial Workshop", we demonstrated real-time quantification of the emotionally inspired state of excitement (as quantified by the combination of valence, arousal, and expectation) during the live music concert. Emotional inspiration is hypothesized as an outcome of positively overwhelming ‘prediction error’ based on a contrasting positive prediction (the anticipatory excitement, Machizawa, Yamawaki et al. 2020; Patent 6590411 and JP 2019-202031, patent approved). Given these established primary technologies, it is reasonable to believe the development of the brain-emotion-interface to quantify emotional inspiration can be achieved.

(A2) Development of emotional forecasting technology

Kansei visualization technology can also be applied to the development of technology for predicting emotional inspiration. Just like a moment when we get goosebumps (or chills) by feeling aesthetic appreciation for being moved while listening to music, our emotional inspiration experiences can be mathematically and physiologically modelled as an information process between the brain and

interoceptive senses such that all perceived external stimuli (such as sound and vibration) by exteroception are processed by the neural system for interoception (i.e., heartbeat, respiration, skins, etc.). We will evaluate excitement (prediction) and emotional inspiration (prediction error) using a combination of multimodal high-precision wearable devices. In addition to EEG (wearable high-precision electroencephalograph & simple electroencephalograph), we will measure pupil, facial expression, facial blood flow, voice, body temperature, heart rate, pulse rate, blood pressure, vascular stiffness, and behavioral rhythm using wearable biological devices. Using IoT and cloud information and communication technologies, we will aim to revolutionize the DX of big data on the mind and body (brain and interoceptive senses) related to emotional inspiration. We will analyze these multimodal data related to emotional inspiration using applied mathematical models and AI and develop an individually customizable predictive model of emotional inspiration that is thought to vary across individuals by the peronal-type optimization technology (Patent Applications JP2019-202031 (granted) & US-2019-0357792-A1, Machizawa & Yamawaki, Sensibility Evaluation Apparatus, Sensibility Evaluation Method and Method for Configuring Multi-Axis Sensibility Model). At the "MS Music Trial Workshop" as well, we have successfully collected a fair variety of multi-modal data such as brain waves (EEGs), heartbeats, and facial blood flow of spectators in real and remote locations while listening to the live music.

(A3) Development of emotional enhancement technology

In order to maximize the power of emotional inspiration of music experience, we will also develop technologies to willfully deliver emotionally inspiring stimuli. For example, our team has developed technologies to amplify the thrilling tough sensation during sound listening by cold tactile stimulation and binaural sounds (Ishikawa, Fujii et al., 2019; Honda, Fujii et al., 2020). We have also developed technology to convert EEG signals to musical sounds (Hamano, Okanoya et al., 2013; Hamano, Ohmura, Okanoya et al., 2014) and has been developing the sonification of emotion with EEG responses. In parallel with the development of predictive models for emotional inspiration (A2), we are to invent technologies to optimally extend musical aesthetic experiences for anyone that adaptively optimize the delivery patterns (Patent Application 2017-139585, Machizawa & Yamawaki) to stimulate our five senses to trigger emotional inspiration.

(B) Development of Technology to Facilitate Co-creation

(B1) Development of co-creation measurement technology

A community of musicians will be measured their "honest signals" while performing pieces of music. By "honest signals," we mean unconscious movements, facial expressions, and physiological signals that are not accompanied by an intention. We will elucidate the mechanism underlying the synchronization phenomenon and causal relationship between these physiological measures and the aesthetic and technical evaluation of the performance itself. In addition, we will reveal hidden synchronization processes associated with creativity. At the "MS Music Trial Workshop", we have achieved to measure body movements of a group of musicians during the live performance using micro-accelerometers. We, the missionary team, also have evidence on motor control mechanisms of musicians (Fujii et al., 2009; 2010) and revealed the “honest synchronization” between music and body movements in infants (Fujii et al., 2014). By collaborating with performers and researchers, we

can assess the "honest signals" of the synchronized states and promote the development of co-creation technology.

(B2) Development of co-creation prediction technology

We develop a predictive model for evoking co-creation by acquiring big data of "honest signals" of a group of musicians in the process of performing a piece of music. We measure the pupils, facial expression, facial blood flow, voice, body temperature, heart rate, pulse, blood pressure, vascular stiffness, and behavioral rhythm of a group of musicians using wearable devices, together with the high-resolution wearable brain-interoception DX tools while musicians are performing. The analysis of each individual's "honest signals" and the aesthetic and technical evaluation data of a group of performers would lead to developing a predictive model of the co-creation at which moments creative ensembles can be facilitated.

(B3) Development of co-creation extension technology

We will also develop technologies that manipulate, facilitate, and extend the process by which people become empathetic, inspired, and creative. For example, we will elucidate and determine how the co-creation process occur by examining various signals and conditions during a group of musicians performing music. By discovering signals that promote or inhibit co-creation, we will be able to facilitate the creativity of the group. Since this technique would involve somewhat intervening for the creativity as a community, it is essential to initially examine parameters using computational models and simulations prior to an experimental intervention and take great care of ethical concerns for volunteers.

2. R&D goals, milestones and expected ripple effects in 2030, 2040, and 2050

In 2030:
(i) The goal to be achieved in 2030 is the reduction of stress and depression in *individuals* through musical emotional inspiration and co-creation (Fig. 2).
(ii) R&D milestones are to achieve the clinical and social application of (A) facilitatory emotional inspiration technology and (B) facilitatory co-creation technology for *individuals* suffering from stress and depression. Using the (A) facilitatory emotional inspiration technology, we will achieve to deliver multimodal stimuli that are optimized for reducing the stress and depression symptoms of each individual while monitoring and analyzing the brain-interoception dynamics of individuals suffering from stress and depression. In addition, using the (B) facilitatory co-creative technology, we will reduce the stress and depression of individuals in clinical and social settings.
(iii) As a ripple effect, the medical application of music in Japan will be rapidly expanded in 10 years.

In 2040:
(i) The goal to be achieved in 2040 is the suppression of hatred and the elimination of conflicts in *groups* through the inspiration and co-creation of music.
(ii) R&D milestones are: the applications of (A) facilitatory emotional inspiration technology and (B) facilitatory co-creation technology for the social community. In various groups, such as households, municipalities, companies, educational facilities, and medical facilities, (A) facilitatory emotional

inspiration technology and (B) facilitatory co-creation technology will be applied to suppress abstract hatred toward other groups and resolve conflicts. By changing the social-dynamic structure of the inner and outer groups through musical inspiration and co-creation, abstract hatred within the group is suppressed and conflicts are resolved.
(iii) As a ripple effect, the number of isolated individuals will decrease, leading to fewer suicides.

In 2050:
(i) The goals of 2050 are zero depression, zero suicide, and zero conflict through (A) facilitatory emotional inspiration technology and (B) facilitatory co-creation technology across *cultures*.
(ii) R&D milestones are to apply (A) facilitatory emotional inspiration technology and (B) facilitatory co-creation technology beyond the various *cultural* groups.
(iii) As a ripple effect, we believe that we can resolve conflicts and divisions among peoples and cultures, and achieve world peace through the two technologies by all human beings.

3. International collaborations

The key to achieving this MS goal is to promote research and development by effectively integrating Japan's strengths in the field of information science with the fields of medical science, neuroscience, cognitive science, emotional and social science, and developmental science. In the fields of music and medicine, neuroscience, perceptual and cognitive sciences, emotional and social sciences, and developmental sciences, the U.S. has the largest number of published papers. In fact, the U.S. National Institutes of Health (NIH) is actively promoting the use of music science as a national policy for physical and mental health, aiming to reduce healthcare costs. The NIH is promoting a $20 million project on health applications of music science titled "Sound Health" for five years starting in 2019 (NIH, 2019). If the NIH's "Sound Health" project and this MS goal are linked internationally, the field of health applications of music science could make dramatic progress in Japan.

On the other hand, one of the major problems in the world's music science research to date is that scientific research centered on Western countries, and the cultural diversity of Asia, Africa, and other parts of the world has not been taken into account (Jacoby et al., 2020). To close the gap, an international symposium "CLaME Event: Building sustainable global collaborative research networks" was held in February 2021 with music scientists from all over the world, including the United States, Portugal, Nigeria, India, Germany, England, New Zealand, South Africa, Spain, and Japan. Shinya Fujii, the sub-leader of this project also participated in the symposium and discussed the goals of achieving music science research that challenges cultural diversity into account (Savage, Fujii et al., 2021). To achieve the MS goal, it is essential to promote research and development in consideration of cultural diversity through international collaboration with countries of diverse cultural backgrounds all over the world.

4. Interdisciplinary and inter-sector collaborations

In order to achieve our goals, we shall: (1) collaborate with performers and researchers to conduct research; (2) involve varieties of citizens, including the next generation of young people who will be responsible for the future, to create a brighter future by sharing the same vision; (3) actively work in

cooperation with medical (psychiatric) professionals; and (4) develop ethics and laws for the peaceful use of technology that evokes co-creation of emotions, while appreciating the history of music. In addition, the social implementation shall be primarily taken into account. As a track record of this research, we have conducted public demonstrations and workshops, such as the "MS Music Trial Workshop." It is mandatory to continue these activities to gain social acceptance for the realization of the MS goal. It is expected that we will keep hosting interactive demonstrations and participatory workshops in cooperation with citizens for the social implementation of the technology to facilitate emotional inspiration. Such a social R&D platform will be the key for co-creation where everyone, as a global citizen, can experience the universality of global civilization and the brilliance of life. As a team leader, Nishimoto has also performed at the Vatican International Music Festival and Sennyu-ji Temple Sound Stage, where she has conveyed the emotional co-creation of music to move people's hearts (**Fig. 9**).

Figure 9: Examples of Co-Creation of Emotions through Music. (A) Vatican International Music Festival (B) Sennyu-ji Temple Sound Stage (©MBS).

5. ELSI (Ethical, Legal, and Social Issues)

This team's research is aiming to facilitate the power of music on humanity, such as regulating mood and emotion, promoting health, and promoting happiness and excitement. However, the influence of music may also work in a negative way. In the history of music, there are some uses of music that can be considered relatively negative, such as the political use of music in the Greek era, the religious use of music by the church in the European Middle Ages, and the use of music as propaganda in the modern era. There are also examples of positive uses of music, such as military songs that were used to unite the inner group in order to eliminate the outer group. Another interesting example was the legal ban on music and musical instruments in Trinidad and Tobago by the British government in the 19th century. This made it impossible for citizens to own musical instruments, so they created an instrument known as the steel pan, which gave birth to musical culture. The relationship between politics, citizens, and music has always been one of interaction and has been affected in many ways. Negative influences potentially caused by music need to be regulated to some extent with careful ethical and legal considerations because it is one of the cultural activities of human beings, and it may be necessary to allow it to have freedom. In addition, it is important to carefully establish ethics for informed consent for the protection of personal information and ethical concerns

because it is expected to use various sensory devices and collect data from individuals and groups. It is necessary to set rules in cooperation with experts in ethics, law, history, and philosophy for the safe and peaceful use of facilitatory emotional inspiration and co-creation technologies.

IV. CONCLUSION

In an aging society with a declining birthrate, a society where everyone can maintain and improve their physical and mental health through the power of music is not only provide benefits on medical and social security costs but also realize global happiness and promote the greatest value of humanity.

Our goal is to make a planet harmonized with our sensibilities and society — a collection of individuals with irreplaceable lives — co-creates inspirations using artistic, medical, and scientific music that is the shared heritage of humanity.

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