Provisional translation

[Moonshot Goal 9]

R&D Concept of “Realization of a mentally healthy and dynamic society by increasing peace of mind and vitality by 2050”

November 2021
Ministry of Education, Culture, Sports, Science and Technology (MEXT)

1. Moonshot Goals

Within the Moonshot Goals (decided on September 28th, 2021, by Plenary session of Council for Science, Technology and Innovation), the Ministry of Education, Culture, Sports, Science and Technology (“MEXT”), with Japan Science and Technology Agency (“JST”) as a research and development promotion agency, will undertake research and development activities for achieving of the following Goal.

<Moonshot Goal>

“Realization of a mentally healthy and dynamic society by increasing peace of mind and vitality by 2050”

- Realization of a society in which people have high individual mental stability with an active role in their own lives, and people can accurately understand their mental status and move towards their desired status through technology by 2050.

- Development of motivating technologies through extraction and measurement of elements that influence the human mind (present in culture, tradition, art, etc.) and elucidate the mechanism of mental influence by 2030. In addition, to undertake broad consideration of the issues in implementing these technologies in the community and thereby finding solutions to achieve wide uptake by the populace.

- Realization of a society that can widely accept and utilize diversity, using technology to enhance the empathy, stability, and creativity of groups, and to disseminate mental support services around the world by 2050.

- Development of science and technology that enhances human communication and sharing of emotions, and to develop mental support services that enhance the empathy, stability, and creativity of groups through collaboration with humanities and social sciences, by 2030.

2. Direction of research and development

Based on the outcomes of the Moonshot R&D MILLENNIA Program, direction of research and development at present is shown as follows.

(1) Area and field to promote challenging R&D

As information and other technologies have flourished in recent years, social issues related to the mental status have only become more severe. Whether it is depression, stress, anxiety, isolation or even suicide; violence, domestic violence and bullying; conflict, war and intolerance of diversity; these increasingly serious issues have been exposed for all to see by the COVID-19 pandemic.

In this context, the key to a mentally healthy and dynamic society is to apply science and technology matters including mutual understanding of mental status, kind communication and mutual harmony, so that we can all dream in the direction we wish. In particular, it is vital that we aim to apply science and technology to “good mental health: happiness”. “Increasing peace of mind” (returning from negative status) and “increasing vitality” (returning to positive status) are essential.

As we look to the shape of society in 2050, we must aim for “understanding of individual mental status and transitions” and “Support for the mental status in terms of interpersonal and intergroup communication”. The research areas for these targets, as seen in Figure 1, are “To know your own mental status”, “To know the mental status of your group and society”, “To know what is deeply connected to the mental status”, and “To know about mental status transitions and how to improve them”. Achieving the targets will require R&D that tries to fuse together the various related technological elements and research fields.

When it comes to the new technologies and assumptions related to the mind and mental status testing and deliberation on the relationship to society are required, and Ethical, Legal, and Social Issues (ELSI) must be addressed. Elsewhere, without neglecting full consideration of ELSI, a key deliverable will be the social application of the developed technologies via the conversion of research outcomes for industry and services.

As such, “Understanding of individual mental status and transitions,” “Mental status support in terms of interpersonal and intergroup communication” and ELSI are to be the challenging R&D fields.

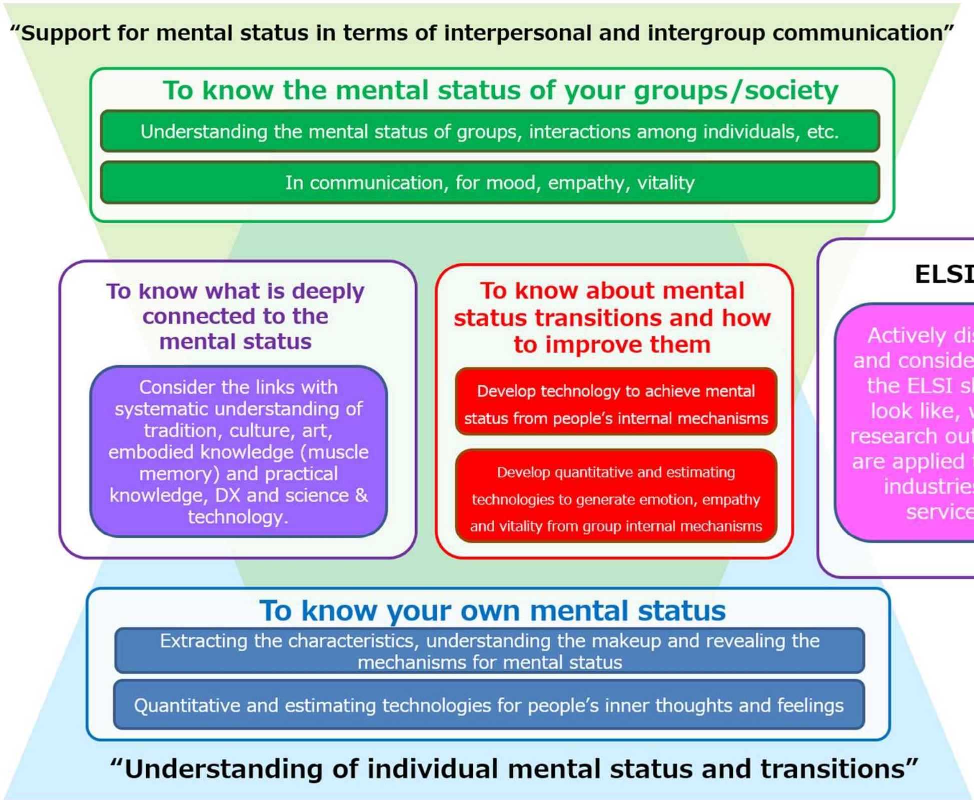

Fig. 1. Main R&D fields required for the Realization of a mentally healthy and dynamic society by increasing peace of mind and vitality

(2) Research subject for realization of Moonshot Goal

The image in Fig.1 is the area and field for challenging R&D to be promoted under the Moonshot Research & Development Program. R&D that contribute to the achievement of this Moonshot goal “realization of a mentally healthy and dynamic society by increasing peace of mind and vitality” should proceed. In order to have the most effective and efficient countermeasures, the most cutting-edge scientific trends shall be researched and used for R&D.

In concrete, such as the following research and development will be promoted.

<Overall>

The human mind is shapeless, and difficult to grasp objectively. Among the social sciences, research approaches to the mental status through verbalization are based on qualitative analysis, mostly in psychology, philosophy and sociology. In the natural sciences, the mind has been increasingly revealed through inductive and quantitative analysis. Systematic understanding of the mind requires multifaceted and multidimensional analysis applied both in reductive and inductive methods, with subjective and objective viewpoints, and in quantitative and qualitative perspectives. However, that progress has not been completely made so far, due to the gaps between scholarly disciplines in terms of perspectives and methods. Although in this context, the development of neuroscience and data science has already produced research with quantitative approaches to subjective data, bringing about major changes in research on the mind in recent years.

Moreover, under the science, technology and innovation policy of the Japanese government, a value-discovery perspective unique to the social sciences is supposed to vital in providing a guide to the resolution of challenges facing society. The complementary strengths of the social sciences and physical sciences are needed. We are in a situation where the research about mental status must be pursued with multidisciplinary knowledge based on the collaboration across academic fields.

No specific objective indicators exist at this point for this goal, i.e. peace of mind and vitality, so it cannot be expressed in quantitative terms. Therefore, shared quantitative indicators (based on qualitative values) related to mental vitality and peace of mind under the overall goal must be reflected in the future R&D directions. This will require the setting of a variety of indicators under constant and flexible review, bearing in mind the diversity of individuals when it comes to human emotion, sensibility and knowledge.

<Understanding of individual mental status and transitions>

By extracting the characteristics of the mind, we need to advance our understanding of its mechanisms, harnessing the scientific and technological knowledge at the cutting edge of various sciences – instrumentation and measurement, information science and life science, such as neuroscience – with breakthrough methods and ways of thinking.

Moreover, as the mechanisms for changes in mental status are revealed, the development of technologies to provide peace of mind or increase vitality must follow. We need to advance research on the status of the mind and develop technologies that can alter them, synthesizing types of knowledge that lie outside of the natural sciences, such as culture, tradition, art, embodied knowledge (muscle memory) and practical knowledge to extract and measure the elements within these that are deeply linked to the human mind.

<Support for mental status in terms of interpersonal and intergroup communication>

We need more R&D to create and deliver technologies that help us to observe, learn and care for people so that in our increasingly complex social lives. We have tolerance for diversity, empathy, and mental revitalization. This can be achieved through the collaboration between cutting-edge science and technology and the humanities, which will create challenging new ideas.

<ELSI>

In addition to the above, it is essential that consideration be given to the impact and outcomes of the implementation of R&D outlined in section (1). It is important that the impacts and issues involved in applying research outcomes in real society are thoroughly discussed in a comprehensive manner from the perspective of business, academia, and citizens. In particular, a structure needs to be developed to enable specific and constructive discussion of the ethical, legal, and social issues (ELSI) for the future deployment of research outcomes in society, inclusive not just of the expert view via participation by researchers and experts in various fields, but also of the perspective of citizens Further, consideration shall be given to R&D stemming from the dialogue emerging from the disclosure of information to the public that ensures their understanding of the state and direction of the R&D.

(3) Direction of research and development for realization of the Goals

To achieve the <targets>, the direction of the R&D, based on (1) and (2), will be as follows.

<Targets>

Understanding of individual mental status and transitions, ELSI

○ By 2030

- Development of motivating technologies through extraction and measurement of elements that influence the human mind (present in culture, tradition, art, etc.) and elucidate the mechanism of mental influence. In addition, to undertake broad consideration of the issues in implementing these technologies in the community and thereby finding solutions to achieve a broad uptake by the populace.

○ By 2050

・Realization of a society in which people have high individual mental stability with an active role in their own lives, and people can accurately understand their own mental status and move towards their desired status through technology.

Support for mental status in terms of interpersonal and intergroup communication, ELSI

○ By 2030

・Development of a science and technology that enhances human communication and sharing of emotions, and to develop mental support services that enhance the empathy, stability, and creativity of groups through the collaboration with humanities and social sciences.

○ By 2050

・Realization of a society that can widely accept and utilize diversity, using technology to enhance the empathy, stability, and creativity of groups, and to disseminate mental support services around the world.

<Overall>

The mind is multidimensional, necessitating analysis of various dimensions including molecules, nerves, neural networks, mechanisms for carrying messages, functions, subjectivity (individual), and sociality (group, environment). It is not possible to comprehensively or systematically grasp the mental status or the mind with a unidimensional approach. From a biological exposition at the molecular level to an interpretation of the mind through social and environmental factors, an exploration of how the various phenomena are related is required from a multilayered and comprehensive perspective. While comparing and contrasting the correlations and causalities revealed as we seek a more genuine inquiry of the mind, there is also a need to pioneer new research fields through collaboration and fusion among cross-cutting academic fields.

<Understanding of individual mental status and transitions>

By 2030, the program will aim to discover the mechanisms behind changes in mental status by understanding the status of mind based on a range of data (verbal and non-verbal information, biological information extracted using sensors and other measuring equipment, etc.) to enable the deduction of a person's inner status from the outside, by creating simulations of mental status using big data analysis technology and AI, by revealing the details and mechanisms of the mind using neuroscience, which is deeply linked to human mental status, and by understanding the mechanisms and systems that stimulate the senses and the consciousness, and the interaction between the mind and the body, mental status and physical status. By 2040, the goal is to create technologies to shift status of mind and increase the peace of mind and vitality. By 2050, the goal is to develop technologies able to achieve an ideal status of mind in a sophisticated way, from elucidation of mechanisms and underlying technologies.

A strategic portfolio will be established using back-casting to find out the research outcomes required to achieve the 2050 goal, and the research processes needed to generate those outcomes.

<Support for mental status in terms of interpersonal and intergroup communication>

This project will aim to generate the underlying technologies enabling the acceptance of diversity and the sharing of emotions in social activities by 2030, using information helpful to deducing a person's internal status, and generate and deliver the technologies and services to facilitate communication among individuals and group social life. This will achieve greater peace of mind and vitality and excellent mental status. By 2040, having attained a certain level by combining underlying technologies and other means, we aim to announce and test technologies and services to support interpersonal and intergroup communication, thereby promoting the value of implementing research outcomes in the community. By 2050 we aim to develop communication support technologies to enable the sharing of thoughts and feelings among a variety of social groups, with abroad uptake in society of mental support services based on these technologies.

<ELSI>

As in (2), when verifying research outcomes, it is necessary to move forward transparently by engaging in dialogue with the community and deliberating with stakeholders. When it comes to implementing the outcomes in society in the future, consideration of the pros and cons and sharing of information will also be required. Thus, research and examination to resolve the ELSI of these issues will be carried out from the earliest stages of R&D.

Fig. 2 shows the R&D directions in order to achieve the Moonshot Goal by conducting this R&D concept.

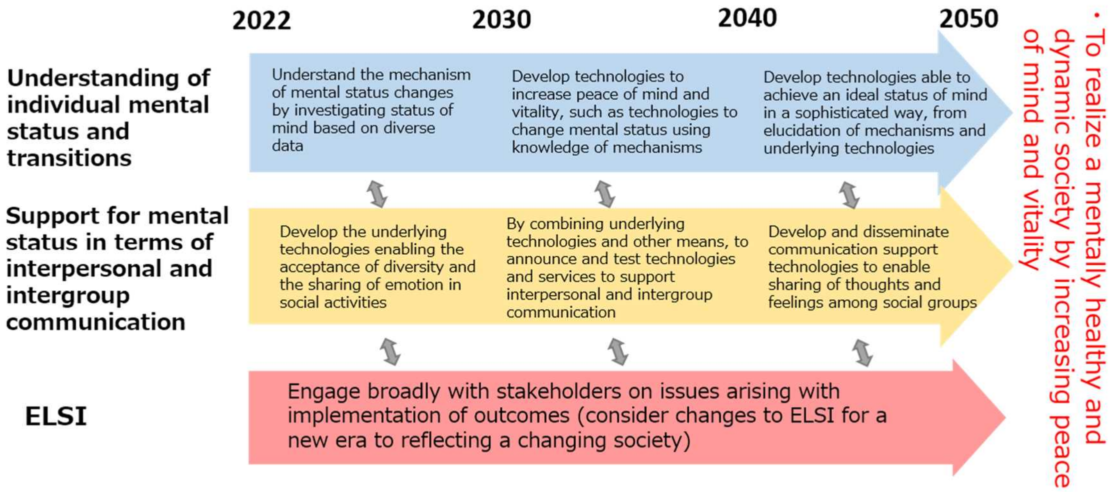

Fig. 2. The direction of R&D working toward 2050

In driving the above R&D, in order to achieve a broad collaboration and fusion of knowledge from the natural sciences and social sciences, there will need to be an initiative to gather ambitious ideas from around Japan and around the world. Firstly, to achieve the Moonshot Goal, measures will be needed in the R&D process such as vibrant information exchange and discussion that cuts across barriers among colleagues within the R&D project and the creation of mechanisms to jointly consider shared issues across multiple projects. As such, shared indicators related to the overall goal of peace of mind and vitality should be established, and they should be linked to activities such as the consideration of standardizing the technologies that are developed.

For the program as a whole, along with the adoption of diverse perceptions and ideas, evaluation phase-gates should be set up to guide the R&D toward achieving the Moonshot Goal. Here, it is not assumed that all individual R&D

projects will have all the required elements ready or that collaboration and fusion will necessarily be needed at first. So, rather than large-scale demonstrations, R&D will begin progressively with feasibility studies in terms of assessing whether individual research elements can be expected at a level that would contribute to collaboration and fusion across disciplines, or whether significant outcomes can be expected from genuine R&D resulting from organic collaboration and fusion.

It would be desirable to take actively into account the perceptions and ideas not just of public research institutions like universities but of diverse parties, be they private companies developing products and services (including large corporations, small and medium enterprises and startups), or schools and hospitals facing social challenges every day.

<Reference: Analysis for the Realization of the MS Goal>
Summary of content which is analyzed in the investigative research activities from the Moonshot Research and Development Program's MILLENNIA Program is shown, as follows:

(1) Structure of research fields and technologies

Fig. 3 classifies the underlying technologies required to realize the "Understanding of individual mental status and transitions" and "Support for mental status in terms of interpersonal and intergroup communication" into four categories: *To know your own mental status; To know the mental status of your groups/society; To Know about mental status transitions and how to improve them; To know what if deeply connected to the mental status.* In addition to information sciences, life sciences, materials sciences and instrumental technology, the necessary underlying technologies will also be researched and developed within the social science disciplines of cognitive science and psychology. As breakthrough R&D efforts will be needed, the idea would be to harness the knowledge built up in those elements deeply linked to the mental status (culture, tradition, art, etc.) for a synthesis of all fields.

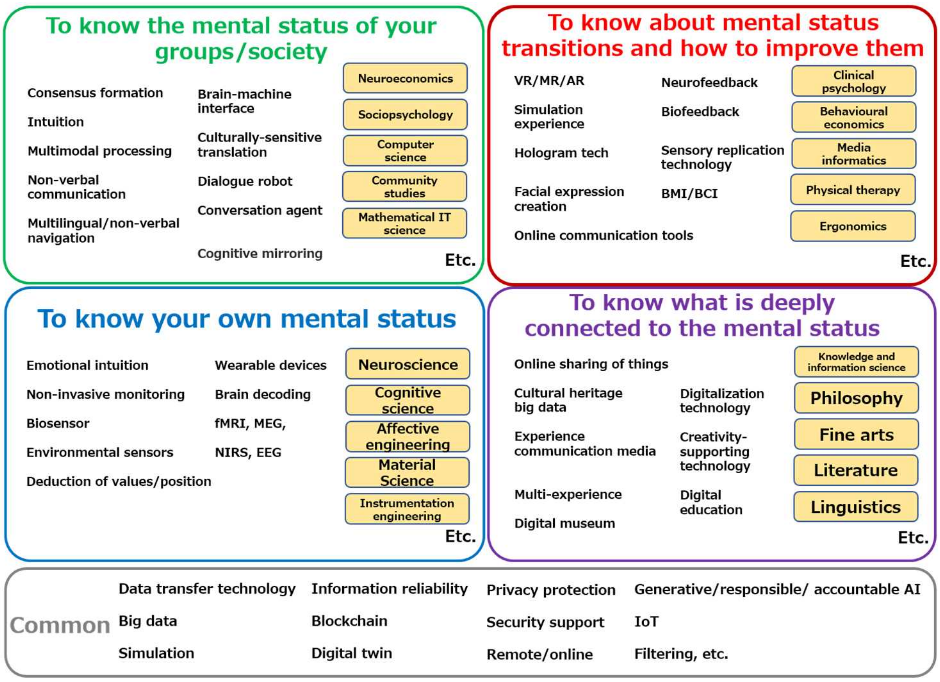

Fig. 3. Structure of main fields and technologies relating to "Understanding of individual mental status and transitions" and "Support for mental status in terms of interpersonal and intergroup communication"

(2) Relevant R&D trends

Traditionally, social sciences and psychology in particular have sought to understand the mechanisms underlying the human mind. In psychology, various discoveries about human mental health have resulted from, for example, the deep observation of human behavior over the centuries enabling insights into the workings of the mind, and from asking questions of subjects and analysing the responses. Merging with other research disciplines has resulted in the development of the disciplines of basic psychology (social psychology, experimental psychology, evolutionary psychology, developmental psychology, cognitive psychology, etc.) and applied psychology (educational psychology, clinical psychology, industrial psychology, political psychology, legal psychology, etc.).

However, the social science approaches are not always able to uncover the relationships with the inner human mechanisms, which sets them apart from natural science approaches. In Japan in particular, psychology laboratories are often set up in humanities departments, perhaps explaining why there has been little progress on physical science R&D. And while it is also a challenge among other disciplines, reproducibility has been poor (when reproducibility was tested on 100 past psychological experiments in 2015, 64% could not be reproduced).

However, the development of scientific technologies has brought great changes in the approach to human mental health. These include (a) improved sensor technologies and instruments for gathering data from people, (b) the rapid rise of IT related to technologies to analyze large volumes of data and (c) the development of neuroscience research deeply linked to human mental health and the emergence of knowledge and approaches to explore the mind.

Regarding (a), the advance of semiconductor technology has driven miniaturization of sensor-mounted devices. In recent years, there have been projects to make computer devices the size of a grain of salt, and devices the size of a speck of powder. Such advances allow the development of sensors with the ability to read biological signals, that place little burden on the body and can be used without their existence being noticed - perhaps enabling deeper exploration of the status of mind. Another major factor in the changed R&D picture has been the emergence of functional Magnetic Resonance Imaging (fMRI) and Near-InfraRed Spectroscopy (NIRS), neuroimaging technologies to explore the workings of the human brain. fMRI is highly precise, but due to the extremely large scale of the equipment and facilities required, improvements in size and portability will be particularly important, as will be the development of imaging techniques, technologies and devices that reduce the physical burden on subjects.

With regard to (b), as shown by big data, AI and imaging technologies, IT is evolving quickly. Advances in AI research can be expected to be increasingly involved in mental health research, given the history of the rise of cognitive science influencing psychology to create cognitive psychology. Affective Computing, pioneered in the 1990s, is the study and development of devices that can recognize, process, and simulate human emotions. Its goal is to make devices with the ability to improve emotions, which are the complex yet vital bedrock of human social life. It is a young technological field, but as of 2020, a survey found 29 emotion-sensing products applying expression, language and voice data, so there has been progress.

In Japan too, companies like NEC Corporation, Fujitsu, Shimadzu Corporation and Oki Electric Industry are all conducting joint research on emotion-sensing technologies in collaboration with universities and other institutions. Many projects deduce emotion from relatively simple biometric data. It is likely that more complex emotion-sensing technologies will develop in the future with more complex multimodal measurement and estimation technologies.

Regarding (c), this is a venerable field of research, with Japan traditionally strong in the field of neuroscience. Around 10 years ago, the MEXT report "Basic concept of neuroscience research from a long-term perspective and promotion policy: building general human sciences for a better world (first report)" (June 23, 2009, Council for Science and Technology)[in Japanese] conjectured that "in addition to the social sciences like philosophy, psychology, education, sociology, logic, law and economics thought to be far removed from the natural sciences, the fine arts and all other culture that is the fruit of human mental activity could be the subject of neuroscience research". While the report stated that there should be more interdisciplinary research with the social sciences, it has not yet been realized as envisaged due to the challenges involved.

Later, the Science Council of Japan recommendations, "Building a global collaborative structure in neuroscience"(2017)[in Japanese] felt the stage was increasingly set for interdisciplinary research between neuroscience and the social sciences: "Neuroscience today has reached the stage where it is able to reveal the workings of the key structural elements of the individual mind such as memory and learning. Neuroscience is approaching the point of embarking on questions involving the mind and the relationship between minds hitherto the domain of philosophy, sociology, literature and art. Neuroscience does not just address the biological and computational basis of brain function. It has the scope to engage in broad research exchange with the empirical social sciences, thereby exerting great influence on human society and economies."

It can be inferred that, as with the development of technologies like the fMRI mentioned above, this is related to the large-scale acquisition of knowledge of the brain and the nervous system through R&D investments by the US Brain Initiative, among others. Moreover, in recent years, technologies related to changing mental status that have attracted attention include Neurofeedback and Optogenetics (with lab animals). It is highly likely that its relationship to mind-related R&D will only deepen in the years to come.

As seen in (a)-(c) but beyond these too, the science and technology to approach the mind is developing, but at the same time the complexity of the mind is also becoming clear. That is why it is important not to stop at individual technologies or projects but to undertake initiatives that tie together a number of research projects and technologies. Working with the social sciences, disciplines that have traditionally dealt with the human mind, is surely full of possibilities.

The cyber physical system (CPS), in which the cyberspace and physical space interact at a high level, is a field that has grown rapidly in recent years. In the future, it is likely that research outcomes in all fields will be related to CPS. A breakdown of published papers related to CPS shows there has been a dramatic increase in recent years, although the number is small in Japan. However, by adding the mind-related keywords "psychology", "mind" and "mental" to CPS in a search, the number of papers in Japan and overseas reduces significantly. This shows how little research is being conducted in CPS with mental health-related elements, and how much potential there is for future advances.

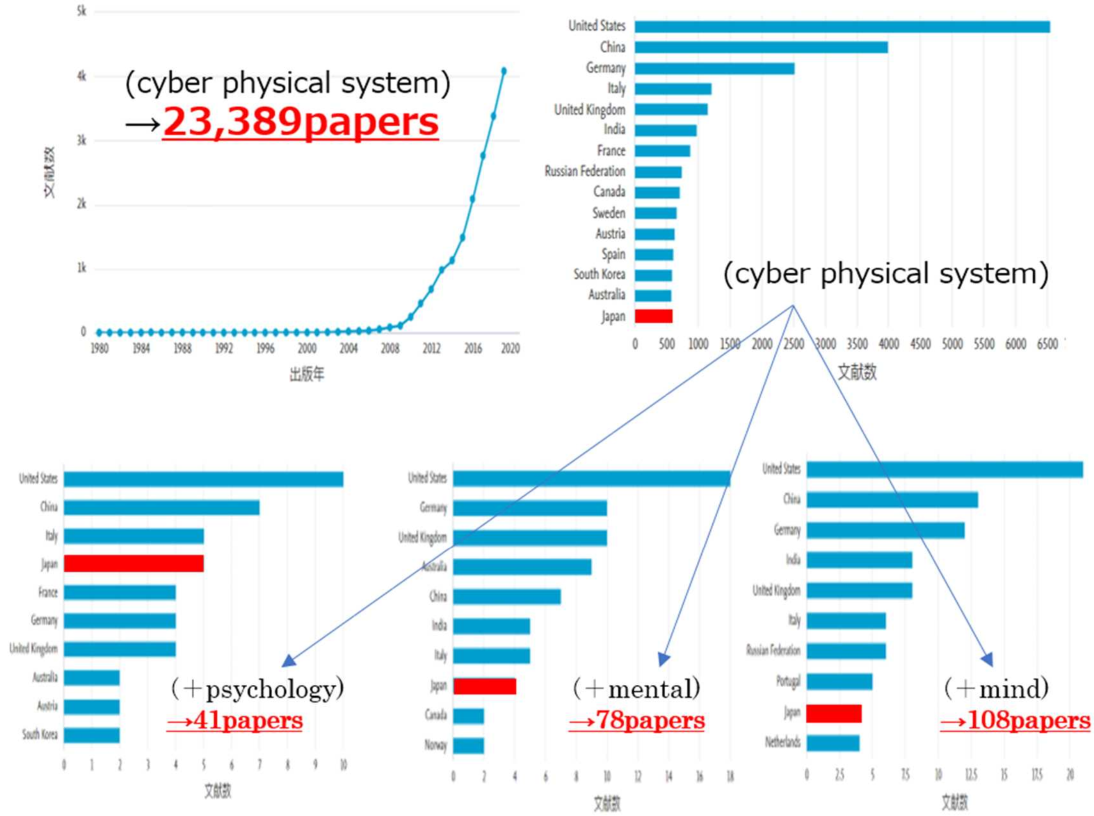

Fig. 4. Trends in paper numbers by CPS-related keyword
Source: JST, based on custom data from Elsevier's Scopus

In sum, with the increasing application of science and technology to the mind, we are now able to conceive of initiatives to increase the peace of mind and vitality, but the mind, the peace of mind and vitality are intangibles. Therefore, we are not yet seeing the establishment of technologies in either quantitative or qualitative approaches that are leading to measurement, deduction or evaluation. While a number of projects will be able to combine technologies that can analyze status of mind, it will likely be important to consider actions, shared indicators and standardization to enable such projects to be properly compared.

When it comes to the application of research outcomes in society, it is important to understand and clarify the relevant mechanisms in the body and to conduct R&D to prove the effectiveness of technologies. It is worth noting that the amount of research gathering data from individuals and sharing big data is likely to grow. As such, great care will need to be taken regarding the handling of personal information and relations with the community.

(3) Strengths of Japan, trends in global research community

Fig. 5 shows an analysis of a search for the number papers using keywords related to research on the mind.

First of all, when it comes to sensor- and device-related MEMS, biological signals, non-contact monitoring systems, wearable devices and sensors/devices/humans, Japan is third or fourth on all of them. Furthermore, Japan ranks the same or higher on brain/nervous system accepting and reacting to physical stimulus, and sensory organs, sensory nerves, peripheral nerves and haptics.

However, in Fig. 6, analysis of emotion measurement and evaluation technologies shows a bigger gap between Japan and the West. This may be a sign that while Japan has strengths in separate elements of technology, it faces difficulty combining them into systems. However, looking at composition, Japan has a particularly large representation in computer sciences, engineering and mathematics, which may have the potential to be harnessed in future.

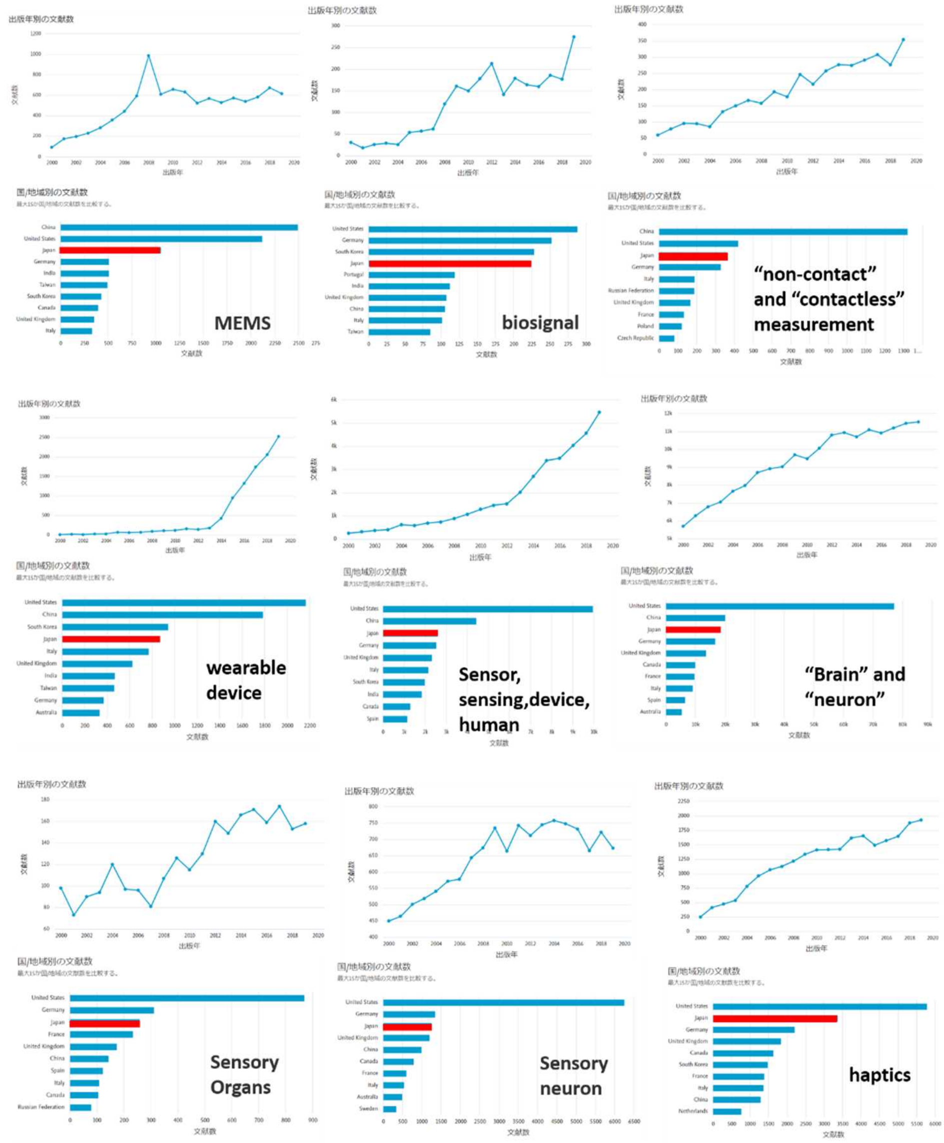

Fig. 5. Trends in paper numbers by mind-related keyword
Source: JST, based on custom data from Elsevier's Scopus

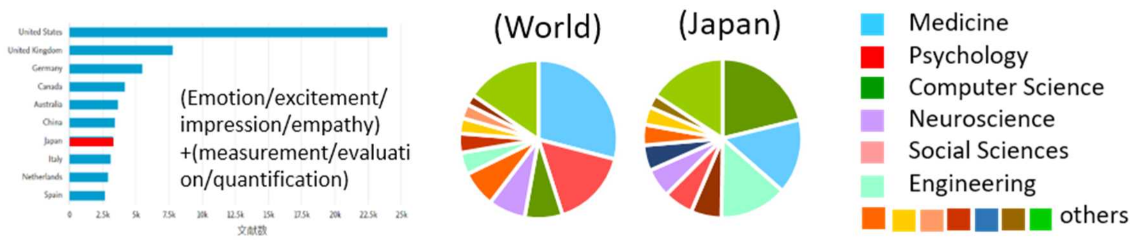

Fig. 6. Trends in paper numbers related to emotion measurement and evaluation technologies
Source: JST, based on custom data from Elsevier's Scopus

Table 1 summarizes an international comparison of relevant technology fields based on an overarching report from CRDS R&D. A very broad range of technology fields are related to this goal.

The United States generally dominates both basic and applied R&D in many categories, and the upward trends are notable in places. Europe is not quite as dominant, but it is broadly strong in both basic and applied R&D. Meanwhile, there are categories in which China shows no remarkable activity or outcomes.

Looking at each category for Japan, there are plenty of positive outcomes in basic research, but it remains relatively weak in applied R&D. However, when it comes to R&D undertaken for the Moonshot Goal, there is clearly plenty of potential for new initiatives that harness Japan's strengths in underlying technologies, as it is assumed that more progress is to be made in interdisciplinary collaboration.

Table 1. International comparison of relevant technology fields

	Country/region	Japan		US		Europe		China	
	Phase	Basic research	Applied R&D	Basic research	Applied R&D	Basic research	Applied R&D	Basic research	Applied R&D
Bioanalysis and diagnostic devices	Current	〇	〇	◎	◎	○	○	◎	○
	Trend	→	→	↗	↗	→	↗	↗	↗
Bioimaging	Current	◎	◎	◎	◎	◎	◎	◎	○
	Trend	→	→	↗	↗	→	→	↗	↗
New function nanotechnology	Current	〇	〇	◎	◎	◎	○	○	○
	Trend	→	→	→	→	→	→	↗	→
MEMS/sensing devices	Current	〇	〇	◎	◎	◎	◎	○	○
	Trend	→	↘	→	→	→	→	↗	↗
Decision-making and consensus-building support	Current	〇	〇	◎	◎	◎	◎	◎	△
	Trend	↗	↗	↗	↗	↗	↗	↗	→
Data-based problem solving	Current	〇	〇	◎	◎	〇	〇	〇	◎
	Trend	↗	↗	↗	↗	↗	→	→	↗
Computational neuroscience	Current	◎	〇	◎	◎	◎	◎	◎	〇
	Trend	→	→	→	→	→	→	↗	↗
Cognitive development robotics	Current	〇	〇	△	△	〇	〇	△	△
	Trend	↗	↗	→	↘	→	→	↘	↘
AI in society	Current	◎	〇	◎	◎	◎	◎	△	△
	Trend	→	↗	→	→	→	→	→	↗
Healthcare IoT (wearables, instrument implants)	Current	〇	〇	◎	◎	◎	○	〇	◎
	Trend	→	→	→	↗	→	→	↗	↗

Brain/nervous system	Current	◎	○	◎	◎	○	○	△	△
	Trend	→	→	→	→	→	→	↗	↗
Trans-scale imaging	Current	◎	○	○	◎	◎	◎	○	○
	Trend	↗	↗	↗	↗	↗	↗	↗	↗
BMI・BCI	Current	△	○	○	○	○	○	△	△
	Trend	→	↗	↗	→	→	→	↗	↗

Source: JST CRDS “Panoramic View Report 2021 Nanotechnology and Materials Research Field”, Panoramic View Report 2021: Systems and Informatic Technology Research Field, and Panoramic View Report 2021: Life Sciences and Clinical Medicine Research Field

(Note 1) Phase Basic research phase: The scope of basic research carried out at a university or national research institute, etc.
Applied R&D phase: The scope of technological development (including the development of prototypes)

(Note 2) Current: *This is an absolute evaluation rather than a comparative assessment based on the current situation in Japan.
◎: Especially remarkable activities/outcomes visible; ○: Remarkable activities/outcomes visible;
△: No remarkable activities/outcomes visible; ×: No activities/outcomes visible

(Note 3) Trend ↗: Upward trend; →: Maintaining status quo; ↘: Downward trend