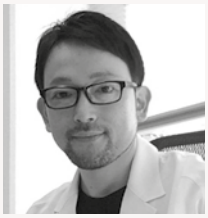
Impact Objectives

- Examine the effectiveness of rehabilitation in patients with brain disorders and spinal cord injuries
- Develop a multisensory stimulation therapy device
- Integrate the latest understanding of brain activity with new virtual and augmented reality to create novel physical therapies

Brain dysfunction explored

Professor Takayuki Kodama *speaks to us about his work to understand the neurophysiology of those with brain dysfunctions and how he used this knowledge to develop a novel treatment*



How did you become involved in neurophysiology?

I acquired my Physical Therapist qualification in 1992 and started providing rehabilitation for orthopaedic and neurosurgery patients. As a researcher, I have also been involved in the research of neurophysiology and psychoanalysis using electroencephalogram (EEG) at the Cognitive and Molecular Research Institute of Brain Diseases, Kurume University. During that time, I was trying to elucidate the visual information processing system and examine the effects of emotional stimuli (e.g., baby's facial expression, colour, environment etc.) on the brain function of patients with schizophrenia and head injuries. The contemporary knowledge of brain function, EEG analysis and brain function imaging analysis were the basis of the techniques and methods used in my research.

What are the knowledge gaps you want to address?

By examining brain function in a neurophysiological manner, the dysfunction of persons with disabilities becomes clear. However, the problem that has not been solved is whether understanding the dysfunction itself will help understand the essential problems of the person with disability. Sometimes it is important to read the world of the brain from the perspective of Bayesian inference, on the other hand, even if we can visualise the neural activity of the brain computationally, it is unlikely that the large and small numbers represent all aspects of a person's functions and abilities.

Your new project involves the development of a multisensory stimulation therapy device, what are the main goals and objectives of this study on neurorehabilitation?

Our lab is understanding and verifying sensorimotor disorders through many studies. We intend to help those who have paralysed limbs due to brain dysfunction to regain their function and be able to return to their original lives and work. Even if the function will not be regained to a practical level, if the change in function can be felt, the person's physical awareness of their limbs will improve. This is because the feeling of joy, satisfaction and quality of life that a person feels (thinks) is greatly influenced by the person's present self-efficacy. As a result, a person can bring back joy to their life, which we have proven in our results. We are aiming to create this kind of world!

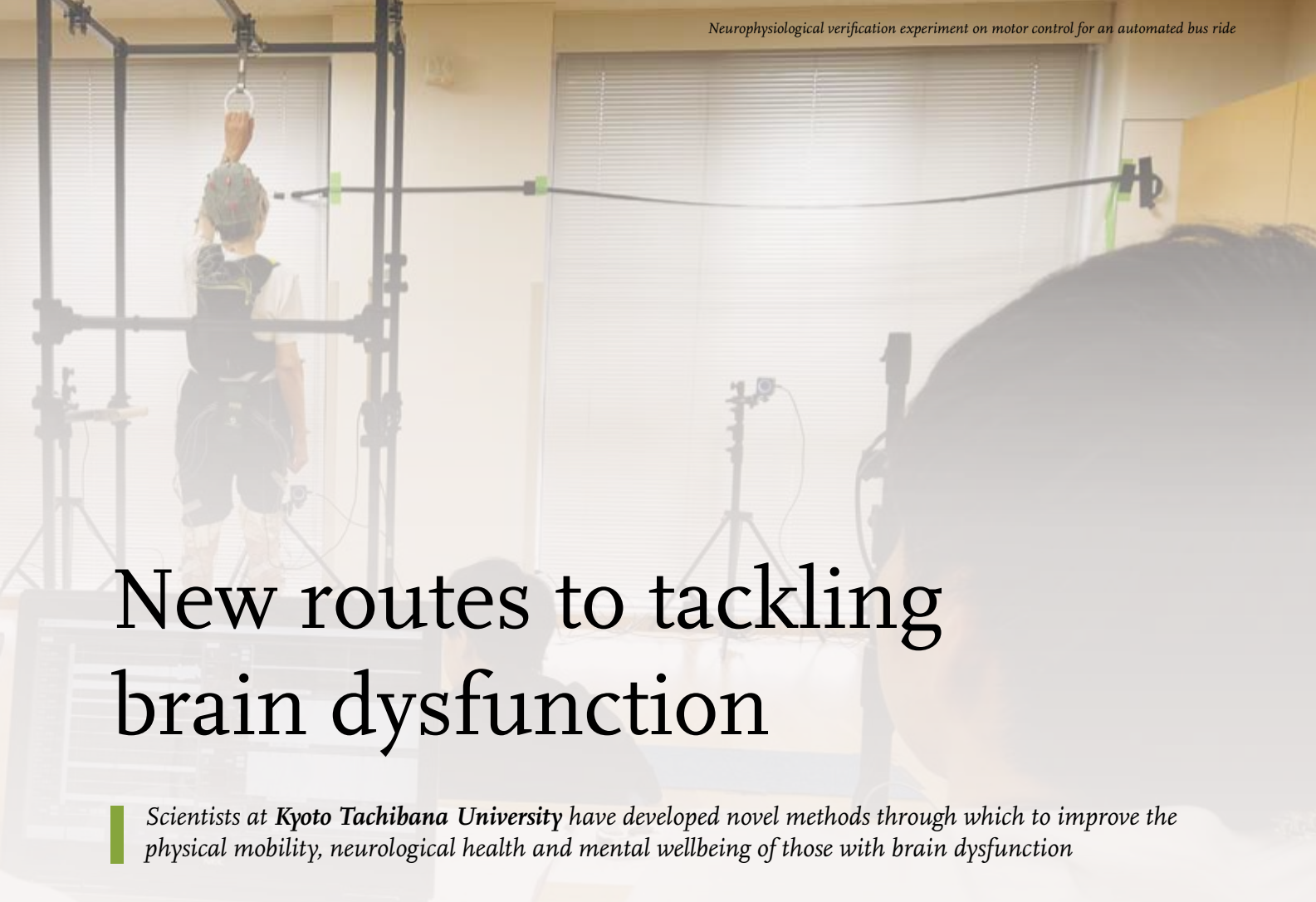
What have you learned about brain function and medical conditions?

We have gained a lot of knowledge, but we are currently focusing on the functions of the supplementary motor area of the frontal lobe and the parietal cortex of the parietal lobe. Its functions include controlling the physical consciousness of the body such as the perception of one's hands and feet. Physical consciousness means creating a sense of independence in physical exercise and a sense of ownership of the body. These are controlled without any special consciousness if a person is healthy, but it becomes difficult for people with brain dysfunction to see the image of their own body. Our training has been effective against these symptoms. This improvement of physical consciousness has yielded improvements in actual movements and in quality of life.

How do you plan to share the knowledge you have built up?

Based on the results and knowledge that we have gained through neurorehabilitation research and joint research with the companies, we would like to deliver as many of our systems as possible and make them useful to persons with disabilities and the elderly who have 'brain dysfunction', which has been considered almost impossible to cure.

Experiments to verify motor control using a 'visual-somatic' congruency/incongruency task based on the comparator model



Neurophysiological verification experiment on motor control for an automated bus ride

New routes to tackling brain dysfunction

*Scientists at **Kyoto Tachibana University** have developed novel methods through which to improve the physical mobility, neurological health and mental wellbeing of those with brain dysfunction*

Whatever one's philosophy, there is a general tendency to view the mental and the physical as somewhat separate. Whilst this can be useful for compartmentalisation, this tendency is ultimately incorrect. The brain and the body are part of the same whole and they evidently directly impact on one another. However, this does not stop the creation of tacit separations of these two realms in different medical treatments. Particularly, when a person has difficulty with brain sensorimotor function, the focus tends to be narrowly aimed at finding broadly physical techniques to recover motor actions. This can be useful and effective; however, it can be a slow process and leave many patients feeling worse when they do not see good progress through these typical techniques.

Professor Takayuki Kodama is a neurophysiological researcher based at Kyoto Tachibana University in Japan. He believes it is important to gain an idea of what is happening in the brain at a structural and mental level to better treat these conditions. Additionally, discounting the positive impact of perceived improvement in motor function also misses the opportunity to use such feeling to actually help with both recovery and quality of life.

It is always important to continue adding new tools and techniques to help treat any serious dysfunction or disease. In this regard, physiotherapy for brain dysfunction is no different. Kodama notes that the wider the range of approaches available, the better the chance of recovery and, crucially, the better the quality of life of the patient. New techniques, however, do not appear out of thin air. New ideas must be generated, and these can arise from new discoveries in medical science and technology. 'Such developments in physical therapy and motor function will be all the more relevant, not just for those recovering from serious accidents or surgery, but also have a direct impact on an ageing population,' Kodama explains. 'Physical impairment due to brain dysfunction is one of the hallmarks of ageing and finding methods that help stave off both the impairment itself and the feeling of helplessness that arises from it is key to maintaining a good quality of life in the elderly.'

FRESH IDEAS

To develop these new techniques, it is necessary to better understand the neurophysiology behind brain dysfunction and the process of physical therapy. Kodama has taken this exact approach and used it to also create new and effective methods. Having initially been a practising physiotherapist, he moved into research and has been pursuing innovative approaches towards restoring motor functions and increasing mental and physical well-being. The Kodama lab, which he spearheads, is developing and using the latest understanding of brain activity and integrating it with new virtual and augmented reality to create novel physical therapies.

The Kodama lab aims to understand the strong and important link between mental and physical health. 'The human brain consolidates various pieces of information about the mind and body and then deploys these pieces of information into action,' highlights Kodama. 'When brain function is disrupted, a wide range of problems appear in the mind and body.' It is this link that he is working to understand better and then utilise to aid those with brain dysfunction recover both their physical health and sense of worth and well-being. 'We are currently aiming to deeply examine the relationship between the degree of detailed sensorimotor dysfunction and the ability to generate body movements to verify the intervention effect of our new treatment system,' highlights Kodama. 'From this we are looking to develop an optimised tailor-made rehabilitation system that matches the disorders of sensorimotor function and body representation.'

MONITORING THE BRAIN

Brain dysfunctions can arise from many sources – injury, old age, during recovery from neurosurgery – however, Kodama believes they are likely to all arise from the same set of neurological and mental issues. The key ▶

When the neural activity of active motor imagery in the brain matches the EEG activity during actual movement, the iNems provide feedback of muscle contraction and visual limb movement

research technology underpinning Kodama's work is the electroencephalogram (EEG). This is a process of monitoring the electrical activity of the brain from the outside. 'It is particularly used in diagnosing and monitoring neurological disorders such as epilepsy where the pattern of electrical activity diverges from the average person,' clarifies Kodama. During an EEG, electrodes are placed in different positions on the scalp and will deliver readings of electrical activity. Broadly, regions where there is particular electrical activity correspond to the region of the brain being primarily used for a given task.

'With enough precision measurements, it is possible to build up a picture of patterns of electrical activity associated with a particular desired motor movement,' points out Kodama. This is what the team have done concerning basic sensorimotor actions. From this, they have created a patented method of analysing EEG readouts that can identify the type of movement a person intends to make. 'Whilst this research is novel, the real innovation is in how that EEG information is used,' observes Kodama. 'Using virtual and augmented reality tools, such as placing a hand behind a table which then shows a moving image of the same hand, we can input onto these virtual perceptions of the body the intended movement.' In the example of the hand, the EEG information of an intended movement is used to create movement of the virtual hand on the tablet screen.

This system, which Kodama has named the 'imagery neurofeedback-based multi-sensory systems training method' (iNems), means that even if the person's hand has not actually moved (or, at least, not moved to the expected extent), the person has convincing visual feedback of the movement. 'iNems measures the neural activity of the supplementary motor area on the non-damaged side of the brain through physical motor images,' elaborates Kodama. 'This enables synchronous supervised learning to the side of the brain with lesions and visually gives feedback on the success or failure of the learning process.'

The key to Kodama's proposed therapy process is the twin ideas of training the brain in the signals necessary to produce the desired movements and that of positive reinforcement. The practice helps the direct recovery process, whilst the sensory feedback allows for the development of a positive perception of the process. 'This latter effect speeds up the former as the patient develops a greater sense of self sufficiency and re-ownership of the body,' he says. 'This is crucial given that the feeling of helplessness and dissociation from one's physical body are two huge effects of losing physical movements due to brain dysfunction.'

> *'iNems enabled people with brain dysfunction to change not only their motor function but also their daily lives and quality of life'*

A STEP INTO THE FUTURE

Kodama and his team have already tested the iNems techniques and shown them to be effective in their case studies. 'iNems enabled people with brain dysfunction to change not only their motor function but also their daily lives and quality of life,' he enthuses. 'Although they were not all able to recover to pre-disorder levels of mobility, it was my greatest pleasure to help them regain physical consciousness of their impaired hand.' The team is continuing their pursuit of this technology, and Kodama has already planned new lines of research to build on iNems. He plans to expand the scope of the kind of neural dysfunctions he handles to include more disabilities, those recovering from neurosurgeries of all kinds as well as elderly patients with deteriorating neurological health.

Project Insights

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BIO

Professor Takayuki Kodama, a physical therapist, is a professor at the Faculty of Health Sciences, Kyoto Tachibana University. He has a scientific background in neurophysiology and rehabilitation science, with EEG analysis. His research interest is the development of neural rehabilitation for emotional, cognitive and sensorimotor dysfunction.