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Introducing Researchers

Each issue of the New "Kyurizukai" introduces a promising young researcher. Featured in this issue is Assistant Professor Junichi Ushiba who spearheads BMI – the highly expected research field to be used as an application for rehabilitation.

BMI to Revolutionize Rehabilitation

Linking your "Will" to "Movement"

A man is plodding along a freezing snowy path. It's true walking on a snowy mountain path is tough, but his movement is unnaturally awkward. Moving straight forward for a while, then abruptly turning to the right or left, and even turning backward at times . . . His destination seems nearby. He keeps walking desperately, putting forth his last efforts. At last, he arrived at a small hut on the snow-covered mountain. A sigh of relief . . .

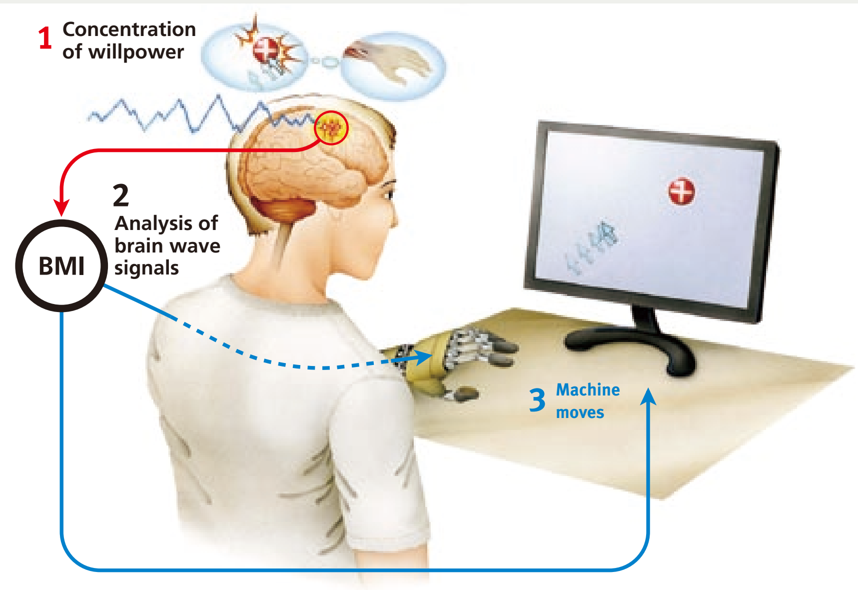
Several young men suddenly ran out of the hut. Surrounding the man, they unanimously said, "Congratulations!" "Thank you," the man responded vigorously

BMI enables your willpower to move an object

The young men who ran up to the man were undergraduate and graduate students of the Tomita-Ushiba Laboratory, Department of Biosciences and Informatics, Faculty of Science and Technology, Keio University and the person who struggled along to the hut was Mr. K., a former systems engineer aged 41. Mr. K. is suffering from myodystrophy. For the past 30 years, he has been unable to move his arms and legs. The man who had made his way through the snow was K's avatar in his Second Life in the virtual world. The students' avatars surrounded K's avatar.

While the students manipulate the PC keyboards to move their own avatars, Mr. K. himself moves his avatar only by concentrating his "willpower." This magical ability to "move an object with willpower" is the BMI (Brain-Machine Interface). The BMI is a new concept system that embodies the fusion of knowledge from neuro and medical sciences and the latest in information engineering. Assistant Professor Junichi Ushiba is spearheading this R&D project – an up-and-coming researcher aged 31 and 184cm tall.

Mr. K. has several electrodes attached to his head. As he pictures images in his brain (activating his brain), such as "going straight, or turning to the right," the corresponding brain wave patterns are sent out as signals. By transferring these signals into the computer, it is possible to move an avatar in the virtual world.



BMI directly moves a wheelchair, electrical appliance, artificial arm, avatar and the like by reading the brain's motion instructions from brain waves and analyzing them using a computer. Much is expected of the BMI as a technology that may enhance the quality of life for patients suffering from damage to the spinal cord or limb dismemberment.

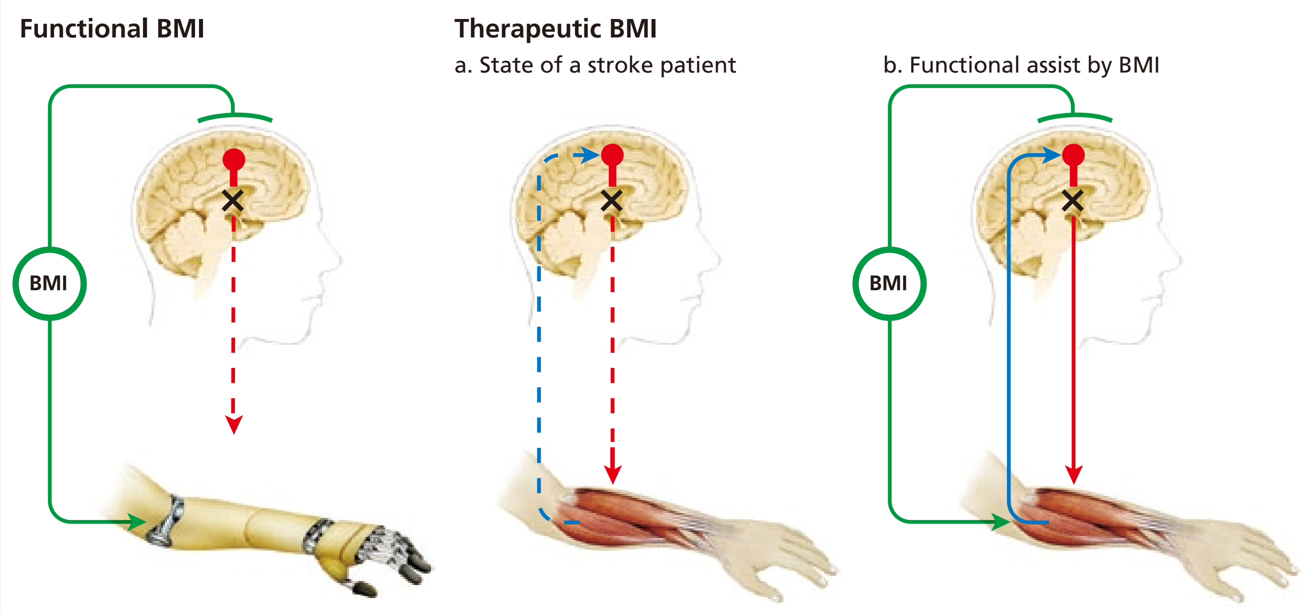
The use of BMI makes it possible even to move a piece of equipment or a system in the real world by concentrating one's willpower.

But when it comes to those who are physically disabled and have never moved their body for a long time, producing brain activity to create an imaged motion is difficult, resulting in failure to generate appropriate brain waves geared to the intended motion. Therefore, "rehabilitation" becomes necessary to activate the brain. Mr. K. took up the challenge of the "Second Life" again and again and finally succeeded in sending his avatar to the destination. This is why the fellow young researchers of the Tomita-Ushiba Laboratory ran up to congratulate him.

Bridging studies on the brain and the computer

Dr. Ushiba, the leader of the BMI project, first became absorbed in the computer as an elementary school student and was captivated by wonders of the brain during his junior high school days. (Please see pages 4~5 for an interview with Dr. Ushiba!) He has been engaged in studies on information engineering and electrical engineering with the Faculty of Science and Technology at the Yagami Campus in Yokohama City ever since he joined Professor Tomita's laboratory to complete his graduation research paper as an undergraduate. Then he took up and pursued studies in neurophysiology at the School of Medicine in Shinanomachi, Shinjuku, Tokyo and with the Tsukigase Rehabilitation Center in Izu City, Shizuoka. He says, "Both studies in the brain and computer have been the natural course of events for me. So I have long felt that my academic position should be in how I can fuse these two fields into one."

And it was in 2006 that Dr. Ushiba began to address research into the BMI, the system that directly links the brain to the computer. To begin with, he examined what brain waves would be generated from the somatic sensory-motor area of the cerebrum (the area presiding over senses and motion) when an able-bodied person does exercises or imagines doing exercises. The somatic sensory-motor area has specific places responsible for controlling the motion or sensation of arms, legs, shoulders or the torso, respectively. Dr. Ushiba mentioned, "Similar brain waves are generated from the same place of the motor area either when you are actually moving your legs



In the case of patients suffering from damage to the spinal cord, etc., their nerve conduction route that transmits brain's motion instructions (will) to the pertinent muscle (movement) is severed. Here BMI serves as a bypass, linking the will to movement.

With stroke patients, brain's motion instructions cannot be properly transmitted to the muscle, disabling the movement. This also makes it impossible for feedback of sensation to be generated (a). However, feedback can be generated if BMI is used since it enables the arm to move in response to motion instructions. It is presumed that the maintenance of the route from the brain to the muscle and vice versa stimulates rehabilitation (b).

or when just imaging so."

Thus he also developed a method to accumulate data on interrelation between the types of motions and brain wave patterns and process such data in real time. His next challenge was the development of a system designed to move an avatar with brain waves as introduced at the beginning of this article. Successfully developed within only six months, the purpose of the system was to use the BMI as an effective communication tool for those patients who cannot move their bodies due to damage to the spinal cord or ALS (amyotrophic lateral sclerosis). "For nearly ten years, I've conducted neurophysiological experiments jointly with doctors at the School of Medicine to identify differences in kinesthesia between able-bodied persons and disabled persons. These efforts seem to be the key to the smooth progress of our development."

Making BMI a tool for rehabilitation

In Dr. Ushiba's brain, perspectives, knowledge, methodology and techniques in a wide range of fields such as neuroscience, brain science, informatics and information engineering, among others, are accumulated and exist as an interdisciplinary wealth. In addition, on-the-scene feelings and experiences acquired at the medical care forefront are also an asset. He has opened up new BMI horizons by flexibly combining and deepening them. A fine example is the new concept calling for BMI to serve as a "rehabilitation tool for physical functions of arms."

Conventionally, BMIs in the medical care field have been developed from the perspective of "substituting physical functions of arms, legs, etc. for the physically disabled." But the foremost cause of physical disability is stroke. Many patients with stroke suffer paralysis on either the right or left side of their body and so do not require function compensation. Unlike cases of damage to the spinal cord and ALS, there are good possibilities that they can recover their impaired functions to a certain extent through proper rehabilitation. Dr. Ushiba says, "That's the key point. Yes, one day it dawned on me that BMI could be very instrumental in rehabilitation."

Seeking linkage between brain activity and movement

He was quick to structure the required BMI system and embarked on joint experiments with the School of Medicine. In this BMI rehabilitation system, the patient's paralyzed hand is fixed on a box that houses an electric motor. As the patient exercises his willpower to stretch his fingers, his brain wave signals are transmitted to the control signal of the motor via BMI, and then the motor moves to stretch the fingers. However, the motor cannot be switched ON unless the brain wave pattern coincides with that for the stretching of fingers, i.e. unless proper brain activity is generated.

For patients suffering from paralysis for years, this approach often does not work well at first because they can hardly picture the image of their paralyzed hand. If they force themselves to concentrate their willpower, unnecessary force is placed on the other hand that is not paralyzed, which works to alter the brain wave pattern. Dr. Ushiba adds, "But as they continue practicing by trial and error, they become able to do it properly while relaxing. Training is the key." Once the brain has been rehabilitated, positive changes become visible on the muscle side, too. The paralyzed hand muscle, with which no electric potential was formerly found, begins to show electric potential of muscle activity when the patient properly concentrates his/her willpower to stretch the fingers during the BMI-based rehabilitation.

As a result of such training, some patients began to feel some improvement, though slightly, in their finger movement while others became willing to use their paralyzed hand. The trend of BMI use for rehabilitation is increasing in the world. And it was Dr. Ushiba and his group who first proved that BMI is effective for rehabilitation.

As for research objectives for the future, he mentions as follows: (1) to shed light on the mechanism of BMI rehabilitation with which recovery is promoted; (2) to create an even more efficient BMI rehabilitation system based on the knowledge obtained in (1) above; and (3) to make the system less expensive to make it easily available to patients. To achieve these objectives, no one can predict what will pop up out of his brain that is packed with creative ideas like the cartoon character *Doraemon*'s magical pocket. (Reporter & text writer:Shinko Yuri)