A supportive system focusing on the body coordination for neurocognitive rehabilitation

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Abstract Cerebral palsy (CP) is the most common physical disability caused by brain damage early in childhood. In the present study, we focus on the difficulty CP patients experience in performing motor skills in a coordinated and purposeful way, and attempt to design a support device for their rehabilitation.

Keywords—Physical therapy (PT), Robotic therapy, Epigenetic robotics, Neurocognitive rehabilitation

1. Introduction
Cerebral palsy (CP) is the most common physical disability, or disorder, of early childhood onset. Over the past four decades, the number of patients diagnosed remains constant at 2 to 3 per 1,000 live births in industrialized countries, with low fetal mortality [1][2]. Treatment of CP is a lifelong process that requires the collaboration of medical professionals, including physiotherapists, the children, and their families. Although this is a permanent disorder, it is still evolving from the viewpoint of neuro-developmental disorders.

The patients have problems with muscle tone, movement, and motor skills, especially with regard to their ability to move body parts in a coordinated and purposeful way. Some patients also experience other health issues, such as poor vision, hearing, and speech and learning problems, which implies a possible relation to the impairment of intellectual development.

Physical therapy treatments of medical professionals largely contribute to the development of motor skills. These procedures have been well investigated in adult cases, but to care for CP children the children’ expectations of physical therapy with well-equipped procedure often do not coincide with reality, and unwillingness often results.

Recently, brain plasticity enhanced by the presence of awareness, attention and concentration has become the focus in studies for recovery of brain function and clinical treatments called cognitive- or neuro-cognitive rehabilitation [3]. The combination of physical therapy procedures and the retention of cognitive process in thinking and awareness opens doors to experimental requirements. Subjects perform the task in different four conditions (with/without ball and/or guide)

Here, we present an idea for the development of low-cost and handy devices which utilize game machines for household use. Nindendo Wii is an option [5]. It may enhance the effect of the rehabilitation but it is still in a trail period. One problem with the use of the Wii is that the game software is designed as a commercial product for use by ordinary people. Simple usage does not clarify details of how the body moves in relation to the task it is performing and how to solve the problem by offering therapy tailored to specific developmental stages of children.

In the present study, we aim to provide children with a robotic training support system which utilizes automated parts to enhance, support and burden a user’s motion and chronological data-recording. We have designed a prototype with the following properties: 1) modifiable structure, 2) adjustable kits and 3) transverse wiring in the structure, and 4) the ability to switch tasks and 5) change levels of task difficulty as functions. For this purpose, monitoring and recording techniques have important implications. As the first step, we examined the accuracy and the response of the sensor equipment in the execution of various locomotive tasks.

Fig.1 A prototype of the robotic training support system with 2 x2x1[m] (left) and our simple oar task (right). The piping structure is adjustable to experimental requirements. Subjects perform the task in different four conditions (with/without ball and/or guide)

2. Method
We designed a prototype of the training device and the task focusing on the body movement coordination toward CP rehabilitation (Fig.1; left). Subjects enter the device frame either on foot or by wheelchair and perform the task. In a simple oar task, subjects can move the bar as oar or paddle (oar bar) in the frame freely and perform a rowing motion with/without the circular guide and/or balls with tips of the bar (Fig. 1; right). We initially hypothesized that the guide will help the movement of the subject’s performance.
In this experiment, we used the Nintendo Wii remote controller to gather real-time information of the subject’s movement, which connects to a personal PC quickly via Bluetooth communication. The communication speed is known to be sufficient for online monitoring. However, accuracy is a major concern because the positioning information caused by the error accumulation of acceleration sensors. In this circular movement, we can monitor acceleration values directly in a relationship of X-Z coordinates, as an alternative up-and-down property. The Z coordinate senses the force of gravity and exhibits the up-and-down motion vertically, and X exhibits the push-and-pull motion horizontally.

3. Result
As the fundamental data, the X-Z relationship of accelerometer values is clearly obtained when the Wii remote controller is set in a rotation machine with a constant rotation speed (Fig. 2). In the observation of the subject movement, smoothing curves by the moving average with ten points shows that the X and Z values clearly oscillate alternatively (Fig. 3). According to separations of Phase I-III, the X-Z plane shows accelerometer-based trajectories and temporal changes (Fig. 4). An ideal oval represents a constant power in the cycle (4a, 4b), and elliptic shapes are affected by different coupling between the own motion control and physical feedback from the oar bar. The guide supports a constant relation in X-Z while the fluctuation is small in without-guide conditions (4b, 4d).

4. Conclusion
We examined fundamental tests by using the platform to monitor the locomotive behavior and obtained basic data for visualizing of rotations in a simple oar task. Our actual goal is to bring subjects a support and monitoring system that will enhance and rein a target part of the body movement and will reveal how important the body balance and its coordination are. Our working hypothesis is that the body trunk is crucial for keeping of coupling between the brain control and physical body movements, through synchronization and desynchronization process among different body parts according to multimodal feedbacks, and we should develop our experimental platform for this purpose.

References

Fig.2 A Wii remote controller, which is able to connect to the remote PC via the wireless Bluetooth communication. This includes acceleration sensors with three orthogonal axes. (right: X-Z accelerometer values in machine rotations with a constant power.)

Fig.3 A temporal evolution of accelerometer values in the simple oar task. The oar bar is horizontally and vertically moved and then X and Z accelerometer values oscillate alternatively. We separate three phases I, II, III for data analysis of Fig. 4.

Fig.4 Experimental results of X-Z accelerometer values in the simple oar task. Subjects are required to perform the oar task for 45s (Fig. 1). Conditions are (4a) With-guide and No-ball, (4b) Without-guide and No-ball, (4c) With-guide and Ball, (4d) Without-guide and Ball. A large fluctuation is observed in Phase I at all, and trajectories tend to converge into a consistent cycle in Phase II and III, especially in 4b and 4d cases.