Development of gait training system using the virtual environment simulator based on bio-information

Kazuhide UESUGI¹, Takahiro HATTORI¹, Daisuke IWATA¹, Kimiyasu KIYOTA¹, Yoshinori ADACHI² and Syoji SUZUKI³

¹Kumamoto National College of Technology (Kumamoto Japan)
²College of Business Administration and Information Science, Chubu University (Aichi Japan)
³Suzuka National College of Technology (Mie Japan)

Abstract: For hospitalized patients who cannot freely walk outdoors, we have proposed a new gait training system using a virtual environment simulator in which the scene reflected in the HMD (head mounted display) changes with walking. We have studied the association of electrical bio-information with various stresses, and a positive correlation between healing music and stress resolution has been obtained by pulse wave measurements. We developed equipment which measures pulse wave and heart rate and installed it in the virtual environment simulator. Then the conditions of the user were obtained while undergoing gait training, and the bio-information was fed back to control the gait training system.

Keywords: gait training system, virtual environment simulator, correlation, feedback control

1. Introduction

Recently, more people are hospitalized because of physical disabilities caused by traffic accidents or diseases. For such patients, gait training machines are utilized for physical recovery support and mental health care as one rehabilitation method.

In this study, we propose a gait training system using a virtual environment simulator. We think this offers more comfortable rehabilitation support than gait training in a bare room. Furthermore, pulse wave and heart rate are observed in the training, and the bio-information is fed back to design rational courseware and to evaluate the efficiency of the proposed system practically.

2. Outline of the system
Until now, rehabilitation facilities carried out gait training according to preset times and number of uses of a gait training machine placed in a room of each facility. The effects of the rehabilitation were discussed, considering the periodic training hours and number of uses.

However, recently it was pointed out that there are some mental effects upon the rehabilitation progress if the patients can strongly hope to recover as soon as possible, or can enjoy a feeling of being refreshed when they are hospitalized for a long time. Therefore, it would be useful to measure the conditions of the mind and body during gait training using subjective questionnaires and physical measurement equipment. In this way, a better training plan for each patient would be possible.

In most rehabilitation facilities, the therapy takes place in a bare room with many other patients. Patients are conscious of what other patients are doing in the same room and may not feel comfortable.

The system developed in this study has a virtual surroundings simulator on which the patients can receive walking training with imaginary bodily sensations as if they were freely walking outside. It is possible for the patient to enjoy a change of scene with the gait training and to obtain some sense of achievement of walking (Fig. 1). We can expect patients experience mental and physical relaxation as a secondary effect of the training. We hope that patients can look forward to the gait training using this walking system, and undertake it eagerly. At the same time, having fun while doing rehabilitation therapy can be useful for activation of the brain.

We consider that gait training with the HMD would be so interesting that the patient may want to practice for too long a time. Becoming overtired would lower the training effectiveness, so we provide courseware in which strength of the load and tempo of the music experienced during the training are changed according to the bio-information fed back by the system. Also, the effect of rehabilitation is constantly checked by the pulse image. When any effect of the rehabilitation is seen, the patient is able to know that from the display lamps, etc. Our gait training system provides comfortable and gentle rehabilitation support to the patient. From this viewpoint, excessive training is prevented and good effects are obtained by slight motions.
3. Walking and bio-information

Nowadays, many people are walking for health. It is said that humans become nervous and lack concentration if oxygen levels are insufficient for the brain. The oxygen supply to the brain during walking is 30% to 50% more than in resting. When a moderate load is given to the body by walking, the blood circulation improves and there is a refreshed feeling by getting sufficient oxygen for the brain\(^5\).

Previously, we studied relationships between electrical values of the palm and various kinds of bio-information related to stress. From our studies of pulse waves, we obtained a positive relationship between healing music and relaxation\(^6\). It has also been reported in the popular press that music therapy could be helpful to improve walking ability\(^9\).

Nowadays we often use a car, taxi, or other transportation if reaching our destination will take more than 20 minutes or exceed a 2 km distance\(^9\). Then, walking for 20 minutes as gait training was made as our goal.

4. Experimental method

The proposed trainer is shown in Fig. 1. Before the experiment was carried out, the measurements were explained and the subjects gave their informed consent. Examinees were 10 students in the 20-year-old\(^5\).

First, a questionnaire survey by SD (Semantic Differential) evaluation and sphygmomanometry, heart rate measurements were carried out, and the mental and physical conditions were evaluated. Next, subjects walked normally on the walking machine for 15 minutes, and their heart rate was measured. After taking a 15-minute rest, the subjects walked on the machine again while listening to music for 15 minutes. Their heart rate was measured again during this time. Afterwards, the subjects rested for 15 minutes, while listening to music. Heart rate and blood pressure were measured during the rest. Measurements were made for various patterns of music and walking. Heart rate data were stored in the personal computer using the IR communication USB interface (S810i by POLAR) in real time. After the experiment, the mental and physical conditions were analyzed using the attached analysis software.

We chose the music, considering differences between the rhythm and tempo. We examined differences for subjects' conditions between no music (quiet) and listening to music based on the questionnaires and measuring their heart rate.

For some subjects, the training time was too long to measure the effects accurately. There were changes in the heart rate, when a subject was talking.
From the viewpoint of rehabilitation, attention should be paid to individual differences.

5. Experimental results

The experimental results of heart rate are shown in Figs. 2 and 3. Generally speaking, the heart rates rise on breathing in and fall on breathing out.

![Fig. 2 Experimental results](image1)

![Fig. 3 Experimental results](image2)

In Fig. 2, by getting too tired, the subject dozed a little during the rest. The heart rate of the subject before the walking was around 80. Since he took a nap in the rest, his heart rate was lowered to around 70. While walking with the music, he listened to classical music. By having heard the music before and knowing it, the subject could walk easily at the tempo of the music. Then, the number of steps increased compared to the case without music. The heart rate was stabilized around 105. And, the subject felt it was easier to walk than before. During the 2nd rest, the heart rate settled to 80, the same as before walking. However, the first time, the heart rate was lowered because he slept. The graph for heart rate shows the difference between breathing in and breathing out. The fluctuation of the values increased, as he breathed deeply, by relaxing. Some of the subjects felt very nervous to be measured, and their heart rate might rise because of their anxiety. As they became more accustomed to the measurements, the rate seemed to be stabilized.

The subject from whom data in Fig. 3 were obtained was not in good physical condition during the experiment. He had sore muscles (muscular pain) in his foot. During walking while listening to music, his heart rate increased, and the change was bigger than for the case without music. Not liking music seemed to have been the reason for this. Resting did not lead to recovery, because the heart rate did not return to the rate before walking without music. And, when the heart rate during resting was compared between walking with and without music, the heart rate of the case
with music decreased and was close to the value before walking. The music listened to was *Enka* (Japanese ballads), which has a comparatively slow tempo. The subject did not know the music and did not like it. Therefore, the number of steps decreased compared to the case without music. This seemed to come from the slow tempo of the music and dislike of the music. The questionnaire after the experiment confirmed this as the subject stated it was music that he did not want to listen to, but it settled him down more than when there was no music.

Throughout the experiments, we tried to tell the subjects to be careful when their heart rate got higher than the rate we first set up (the target point). By listening to some slow tempo music in order to reduce the number of steps, the prospect to lower heart rate was obtained.

On the other hand, if the subjects needed to walk faster, we let them listen to up-tempo music. So their heart rate rose. During resting, by listening to slow music, the subject's heart rate tended to drop faster to the original condition than without music, and it was possible to observe the effect of the music therapy.

There were some differences in the degree of the lowering heart rate after the walking depending on whether the subjects listened to music or not. In short, without music, the heart rate dropped slowly. But, with music, it tended to drop suddenly. Classical music was the easiest to walk to. Because subjects walked to the tempo of the music, the number of steps increased from the case without music.

One examinee (21-year old male) answered the questionnaire that even though he did not like the music he listened to during the rest, he was much more relaxed than without music. The mental condition seemed to be more stabilized with any kind of music compared to quiet. But this must be checked further.

Then, we confirmed that music was effective for healing, if it was not like noise. There was an individual difference in the time until heart rate at rest returned to the value before walking. Therefore, setting of rest time (15 minutes this time) must also be considered.

6. Conclusion

We assumed that the rhythm of action might be controlled by the flexibility of the human brain to adjust music. In short, we considered that external stimulation such as a scene in a virtual environment affected the condition of the mind and body deeply. On the basis of this idea, we developed a gait training machine system using a virtual space simulator. Subjects used the system in a happy environment.
which provided "activation of the brain". We want to enhance the system so that users do not feel they are undergoing rehabilitation training, but are enjoying a pleasant walk and they can obtain a relaxation effect and make a physical recovery. This time we looked at effects of music on bio-information measurements.

7. Future problem

This time, only basic experiments were performed. In the future, we will look at the relationship between physical body and environment simulator which uses the music and the HMD.

Acknowledgment

This work was carried out under the support of the Japan Society for the Promotion of Science, Fiscal Year 2004 Grant-in-aid for Scientific Research number 16919021 (commendatory research). The authors express their deep thanks for this support.

References

1) "Whokingu no Susume (Recommendation of walking)"
3) "Saiensu (Science)", Nihon Keizai Shinbun, August 8th, 2004. (in Japanese)
4) "Hoko Undo no Jissai (Practical walking exercise)"
6) "Users guide of the software of the heart rate analysis", POLAR Co.