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Analysis of Two Kind of Control Dynamics on Cooperative Walk

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Abstract: In this paper, it was done the analysis of the dynamics on cooperative walk. As the results, it was clarified that leg has the dynamics, which is not influenced from attention, and arm has the dynamics, which is done. From the result, arm and leg has the respectively different dynamics, which is based on the two kinds of mechanism to percept the time-interval.

Keywords: cooperative walk, attention, walking dynamics, Co-creation

1. Introduction

Humans can create various kind of cooperative behavior simultaneously with adapting each other. The purpose of our research group is to suggest new man-machine system by regarding "Co-creation",[1]-[3] which is the function that human crate the cooperation with others as ideal. Especially, in this paper, it was done by two kinds of the mechanism of time-interval perception the analysis of the timing control dynamics characteristically on human-human cooperative system.

As an example of such system, we focused on the cooperative walk system, which was realized by the synchronization of two people's foot-grounding timing each other though the both footstep sound. Because it was necessary both the perception of walking period which had dynamic time development and the self-timing-control of walking period.

In former study, there is two kinds of the time-interval perception: one is the mechanism that supports the perception of short time-interval less than 1sec, which is based on the function of the cerebellum or basal ganglia[4]-[7]. The other is the mechanism that supports the perception of long time-interval more than 2 or 3sec, which is based on the high-level brain function as the attention or working memory[8],[9].

However these studies were clarified by applying the task that was given one-sided stimuli from machine, which were the synchronization-tapping task, the time-distinguish task, or the time-recall task by one-sided and constant auditory stimuli. Thus it was not clarified the relation to human's cooperative behavior. Therefore in this study, we made the new system to realize cooperative walk between two subjects by using only footstep sound, and the system to measure the subjects' body motion during cooperative walk. In addition, by using "dual task method", the subjects' attention was controlled. By the comparison of the results that was not set such task, the change of the subjects' body dynamics of the human-human system. From the results, the dynamics of timing-control on cooperative walk was analyzed.

2. Former study

2.1 Human's walking motion

In generally, human's walking motion is regarded as the generation by the organization of 3 functions[10]: (a) the activity of automatic mechanism of foot's stepping, (b) keeping standing posture, (c) keeping the body balance. (a) is mainly related the lower limbs, in short, which are the motion of legs. (b) and (c) are related upper limbs which are the swing of arms. Accordingly, in this study, we focused on the foot-grounding timing as the motion of leg and on the amplitude of elbow's angular oscillation as the swing motion of arm, and set them to the measuring objects.

2.2 Perception of time-interval

Already mentioned, as the nerve mechanism which support short interval period less than 1sec, it was clarified that the function of the cerebellum or basal ganglia are regarded as essential from the study of using the synchronization-tapping task[11], the time-distinguish task, or the time-recall task. It was clarified that the perception of time-interval more than 2 or 3sec relate the mechanism, which was based on the high-level brain

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function as the attention or working memory.

About the relation between the perception of time-interval more than 2 or 3sec and the attention, some perception models have already been proposed. In this models, there was "division-attention model" [9),12)]which is influenced the time judgment by the division of the system dealing information of time and the other system. According to the "capacity of attention model"[13)], in general, the resources of attention are limited, and it defined the limit of the process of dealing the perceived information. To realize mental activity, the resources of attention are necessary, and it is possible to realize more than one task by suitable division of the resources of attention with the agreement of intention and tendency of his personality. In such case, it is possible that the divided amounts of the resources of attention are quantified by the given size of mental load.

3. Experimental plan

We examine whether the attention of subjects with cooperative walk influent the control dynamics or not. If the subjects' attention aim at the other process of information in cooperative walk, it is impossible to apply the enough attention to realize cooperative walk. If the resources of attention needed on cooperative walk increase over than capacity, enough resources of attention are not provided to the system of process of time information. Accordingly it is assumed that they influent the timing control dynamics. Thus on this study, we decide to use "dual task method" to control the subjects attention. It is the process to decrease the ability of a particular process to realize the objective task (primary task) by realizing the other task (secondly task) during doing the objective task.

4. Experiment system

4.1 Cooperative walk system

The purpose of the system is to realize cooperative walk through the two subjects' footstep sounds , as shown **Fig. 1**. Both subjects footsteps was sensed by touch sensor (OJIDEN, OT-NO-I) set on foot. The information was measured the portable computer (Toshiba, Libretto 60), and transfer to the other

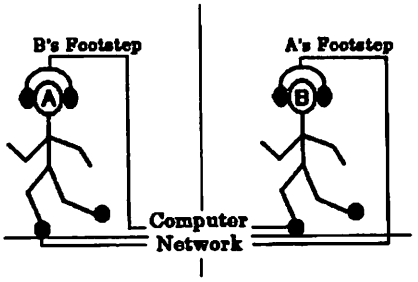

Fig.1 Cooerative Walk System.

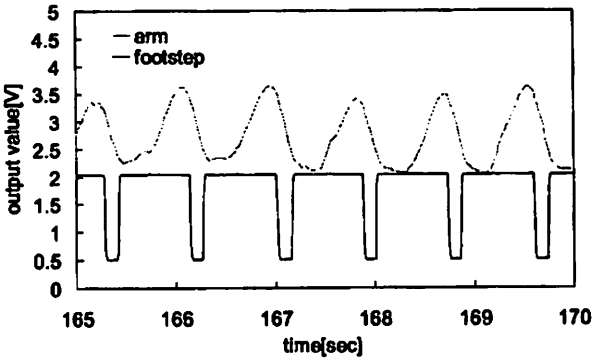

Fig.2 An example of measured data.

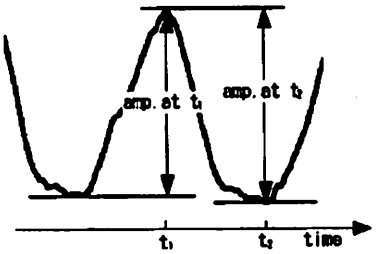

Fig.3 Definition of amplitude.

subject's portable computer by using TCP protocol on Local Area Network. When the information arrived to other subject's portable computer, he hear the rhythm sound which correspond to the other subject's footstep. The accuracy of time constant is less than 0.01sec.

4.2 Measuring system of body motion

The purpose of this system is to measure the dynamics of arm and leg simultaneously. The motion of arm is measured as the data of angular oscillation of elbow, which is measured by angular sensor (NIHON KOHDEN, EG 511H). The data is sent to telemeter (NIHON KODEN, WEB-5000) by its transmitter (NIHON KODEN, ZB-5812) and converted into discrete voltage data, which can be recorded by the PC (IBM, ThinkPad 570), by A/D converter (ADTEK, AXP-AD02). The motion of leg is measured as the data of step timing of foot, which is measured by touch sensor (OJIDEN, OT-NO-I). The foot's data was recorded as the time when the measured voltage drop down. The voltage value of arm's data is proportional to the angular value. The value 0V correspond to the status that the elbow is straight, and the more the value increase, the bent the angle of elbow become. Here shows an example of measured data in **Fig.2**. The amplitude of arm's angular oscillation is defined as **Fig.3**.

5. Experiment

The experiment is prepared two kinds. One is named normal condition that subject realize only cooperative walk with one

more subject task. The other is named attention task that subject realize not only cooperative walk with other subject but also attention task. The attention condition is the condition to examine whether the attention influent to the control dynamics or not.

5.1 Normal condition

Subjects (native Japanese, twenties, male, students) form groups of two (divided into other room), and walk along the circular tracks in the very quiet rooms in 60sec with measuring the grounding-timing of foot and the angular oscillation of arm. This condition is measure all patterns of groups, which is 6 patterns. We had already confirmed that all subjects were able to percept the rhythm sound, and required to concentrate only to hear it during cooperative walk.

5.2 Attention condition

The experiment same as the normal condition was realized with "word-memory task" which is one of the attention task. Subjects was showed 5words which were composed 3～5 Mola Hiragana or Katakana(Japanese letter) 3sec by computer display just before they start to cooperative walk. Just after that, they do cooperative walk in 60sec with keeping the memory of these words. Just finish walking, subjects was required to answer back those with oral expression.

6. Results

6.1 Rate of correct answer

Here shows the rate of correct answer in **Table.1**. the values in the table are the average of the correct answer rate. The average of all subjects are 90.83%. Accordingly it is assumed that the resources of attention achieved almost limit value by the short memory load.

6.2 Comparison of the dynamics of leg and arm

To analyze the dynamics of leg, the auto-correlation coefficient of the all subjects' period of foot from lag0 to lag10 was calculated in both normal and attention conditions. The time scale of 1lag is almost 1sec because the average of walking period in cooperative walk is 1.07sec(Normal condition: Ave.= 1.06sec S.D.=0.03sec, Attention condition: Ave.=1.08sec S.D.=0.03sec). The object area to analyze was the time start walking after 10sec. Here shows the results of analysis on **Fig. 4**. there are no significant correlation at both condition, and no difference between normal condition and attention condition.

Table 1 Percentage of correct answers.

subject	percentage of correct answer [%]
A	86.67
B	90.00
C	96.67
D	90.00
average	90.83

On the other hand, to analyze the dynamics of arm, the auto-correlation coefficient of the all subjects' angular amplitude of the swing of arm was calculated in both normal and attention conditions. The amplitude of arm's angular oscillation was defined in almost every half period of it. Accordingly the dynamics is defied at almost half time-scale of the leg's dynamics. Thus the auto-correlation was calculated from lag0 to lag20 with the lag2 interval. Here shows the result in **Fig.5**. From the result, normal condition took higher value of the auto-correlation coefficient than the attention condition, and that is the significant differences. In addition, the significant difference was observed the area between lag2 to lag6.

From the results, it was clarified that the dynamics of leg on cooperative walk was not influenced the effect of the attention

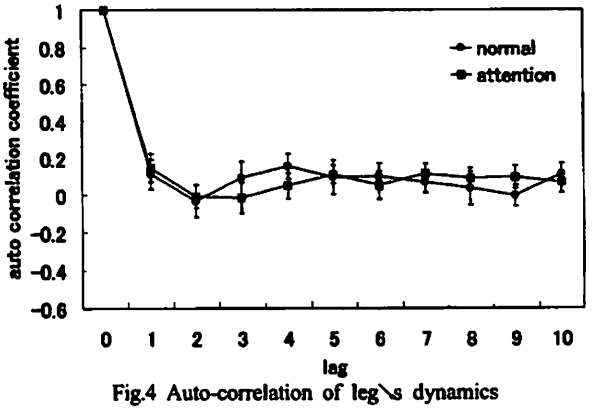

Fig.4 Auto-correlation of leg\s dynamics

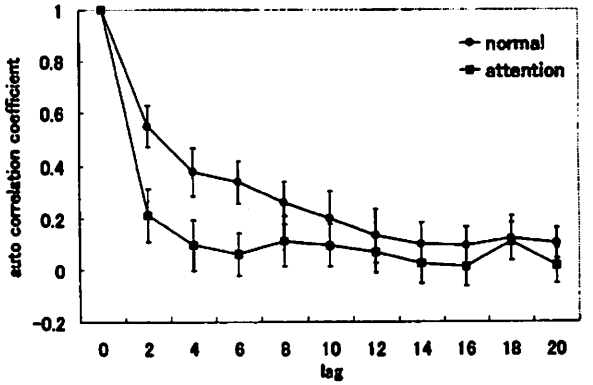

Fig.5 Auto-correlation of arm\s dynamics

task more than the dynamics of arm. Therefore it is suggested that the timing control of leg's motion do not use the resources of attention more than the timing control of arm's motion.

In addition, it was clarified that the dynamics of arm was influenced by the task of attention and the influence is observed within the time scale of lag6. This result suggest that there is the dynamics which have almost 3sec-time-scale, and the dynamics' activity was stopped to do the secondly task with the consumption of the resources of attention.

7. Conclusion

In this study, it was done the analysis of the dynamics on human's cooperative walk based on the two kinds of mechanism to percept the time-interval.

From the results, it was clarified that the dynamics of leg on cooperative walk was not influenced the effect of the attention task more than the dynamics of arm. Therefore it is suggested that the timing control of leg's motion do not use the resources of attention more than the timing control of arm's motion. In addition, it was clarified that the dynamics of arm was influenced by the task of attention and the influence is observed within the time scale of lag6. This result suggest that there is the dynamics which have almost 3sec-time-scale, and the dynamics' activity was stopped to do the secondly task with the consumption of the resources of attention.

Accordingly it is suggested that the dynamics of leg was controlled relatively by the mechanism to percept the short interval period less than 1sec, which is based on the function of the cerebellum or basal ganglia. On the other hand, the dynamics of arm controlled relatively by the mechanism to percept the long interval period more than 2 or 3sec, which is based on the function of the high-level brain function as the attention or working memory.

From the presents results, it is difficult to discuss how these dynamics realize the temporal development. However it is clarified human's cooperative walk was realized by these two kinds of timing-control-mechanism.On future works, it is expected it will clarified how, by analyzing the temporal development of that in detail, these two dynamics create cooperative walk between two humans.

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