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Observing the Degree of Distortion in Coordinated Motor Actions

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Abstract: Integrative motor actions have a characteristic that consists of multiple primitive motions. A time-series of movement includes a unit of integrative motor actions. Movement rhythm arises from coordinated efforts in this exercise. This study tries to support learning, focusing on double-under in rope-skipping. Double-under has major primitive motions: jumping and rotating wrists. There is timing difference between primitive motions. Thus, we design and develop a supporting system for learning timing difference in dynamic sense. The system measures learner's data with wearable sensors, calculates the appropriate time and suggests feedback.

Keywords: Motor skill, repetitive exercise, learning support, wearable sensor

1. Introduction

This study focuses on learning support for motor skill based on human embodiment. It deals with motor skills as an ability obtained through learning in order to execute tasks requiring body motion. In particular, the domain on this study is continuous skills that are repetitive such as rope-skipping or hula-hoop. Among them, the target of this study is double-under skill in rope-skipping. The characteristic of double-under in repetitive exercise is to repeat movement pattern that is divided by a time. Fujinami (2006) states a rhythm arises from cooperative motion. This study regards it as rhythm of double-under and especially focuses on timing that is one of the timewise elements of skill. Johnson (1961) states the dimensions of skill have been identified as speed, accuracy, form and adaptability. Accuracy include skill done in good timing. To execute double-under, it is necessary to control primitive motions cooperatively at the right timing.

Besides, double-under is a sort of an integrative exercise with primitive motions classified broadly into two, such as jumping and rotating wrists. Each primitive motion usually has unique timing. There is a time difference between them. Those cooperative motions should have a certain association such as interval of each timing. The more fixed timing difference becomes, the more rhythmic double-under is. Thus, a learner's goal is an improvement of timing difference stability. However, as one of an issue with this improvement, cooperative motions require a skill for it. We design a learning support so that this difficulty is relieved. Therefore, we propose a learning support system in order for a learner to acquire an appropriate timing leading rhythmical movement.

2. Preliminary Discussion

2.1 Timing on Double-under

This study regards timing as one of the essential components of rhythm. In rope-skipping skills, double-under is more influenced by the feature of ballistic exercise. This exercise needs to calculate an expected time of next movement. The movement pattern on double-under becomes a segment that is not modified as ballistic exercise. In addition, double-under is an exercise requiring open skill. While performing it, we need to observe a trajectory of the rope because the timing differs at each time.

This study defines the appropriate timing of primitive motion on double-under as follows. Timing of rotating wrists in this study is the starting time at the first rotation to begin the rope movements (Karungaru et al., 2016). The actual rotation during a jump is twice per jump. The present study picks out the first time as timing of rotating wrists because it is a sort of ballistic exercise. Jump timing is defined as the starting moment of jumping. Figure 1 shows the image of the actual timing of primitive motion in double-under. Difference between jump and rotating wrists is not the motion but the phase difference between each wave form. This study defines the phase difference as a gap of timing difference by a feature of double-under for integrative exercise. We regard a mandatory task of the skill integrating motions as an inhibiting reason for learners from acquiring double-under. The degree of distortion in waveform makes observed data vary depending on the skill.

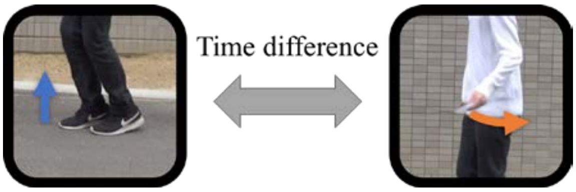

Figure 1. The timing of primitive motions

2.2 Theoretical discussion for Learning Support

Fitts and Possner (1967) classify learning stages into three. In the second stage, learners organize more effective movement pattern because they obtain embodiment to some extent in motor stage. Until the last stage at which they can acquire unconscious movements, they need to pay attention to learning the movement way. In particular, in motor stage, learners monitor feedback in order to improve their own performance gradually. On the conceptual model of human performance, it has two major categories of feedback: intrinsic feedback and extrinsic feedback (Schmidt, 1991). Intrinsic feedback is the information from visual sense, auditory sense, proprioception and so forth. On the other hand, extrinsic feedback includes a system that supports learners. It has two important information: knowledge of result (KR) and knowledge of performance (KP). KR is the information on whether movement is success or not. When we want to give more concrete advice, it means that the feedback must have kinematic information.

Besides, the present study assumes that movement differs from both body form and performance thereof every time. In relation to this, Schmidt (1975) states that motor-learning can be generalized with a schema theory from a skill science viewpoint. According to this theory, learners acquire schema that is rule-based. The rule is related to the joint result of trials itself and associated parameters for realization. Learners strengthen and renew this rule through practicing overtimes. Our target is learners who are in motor stage. They refine the schema derived from the past information stored inside, which is an experience. Each parameter that is able to succeed on past trials can comprise schema as with accurate parameter setting. Our support suggests a criterion for comparing with intrinsic feedback. Learners revise the error between this suggestion with feedback and learn so that they can decrease it.

2.3 Requirements

In this study, timing difference of movements between two body parts is observed. It detects elongation and contraction of the time scale identified as relative criterion. The anchoring point in this study is set to the highest time of the body movement, that is called jump timing. We support relative timing of rotating wrists against the anchoring point. The system observes two body parts in parallel for the sake of the detection abovementioned. It monitors myogenic potential of the forearm because muscle contraction causes the movement. On the other hand, it identifies jump timing by monitoring the acceleration of the waist.

Real time support seems better when learners try to stabilize double-under movement requiring open skill as the best support timing depends on current condition. When the system suggests timing as feedback to learners, it is better that there is not different between suggestion and actual motion timing. According to the literature review (Choshi, 1972), auditory sense works for a quick response to external stimulation during 120-185 milliseconds and haptic response does during 115-190 milliseconds while visual response does during 150-225 milliseconds. As a synchronous support, it is necessary to choose suitable feedback media. Moreover, the system needs to have two models for the support; i.e. a predictive model and a supporting model. By comparing current data to this model, it tries to realize the prediction. After prediction, the model for supporting helps it to determine the time showing feedback. This study utilizes the data on past trials in each person for determining each parameter as the models just like as schema is shaped.

Furthermore, in case of monitoring double-under by a wearable system, a system should avoid wired communication with sensors because it is more restrictive. In addition, the size and the weight of each sensor are problematic. Due to these considerations, this study adopts a microcomputer that is small and light. Additional advantage of the microcomputer is to combine the role of multiple inputs by sensors and an output to show feedback as an actuator. Therefore, a microcomputer linked to sensors and an actuator should be small and light under the condition that it is free and not an obstacle to performance.

3. Prototype System

We designed and developed a prototype system that has three basic functions: observation, analysis and feedback. What we had in mind in the initial design has been published (Yoshikawa, 2016). The total system weight is about 120 grams. A learner attaches the system consisting a microcomputer and an acceleration sensor to her/his own waist using a belt. This attachment method and weight are within a range of ignorable influence on embodiment.

Figure 2 shows the flow of the system support. The system needs to prepare models for real time support. Before creating the models, we define a local maximum on acceleration data as jump timing. We utilize average rectified value (ARV) for defining timing of rotating wrists. For computing ARV, this study regards myogenic potential during rest as 0, and rectifies it by a method called full-wave rectification. After that, low-pass filter with a time constant of 30 milliseconds smooths the rectified wave. Then, the system determines local minimum in ARV wave as timing of rotating wrists. However, raw data sometimes mixes with action potential leakage of adjacent muscles called crosstalk. When this case or becoming dull by smoothing happens to the waveform, we regard extremum values in differential values of ARV as timing of rotating wrists. Based on them, we decide each parameter in the models. Jump timing arises from double-under of repetitive exercise that closes the same cycle. This study treats it as a fixed value. There is timing difference between jump and rotating wrists. The learner's goal is to induce learner's diminution of dispersion on timing difference. Thus, the parameter on this system is the fixed value suitable for supporting as timing difference. When we set parameter as noted above, the system is ready to support.

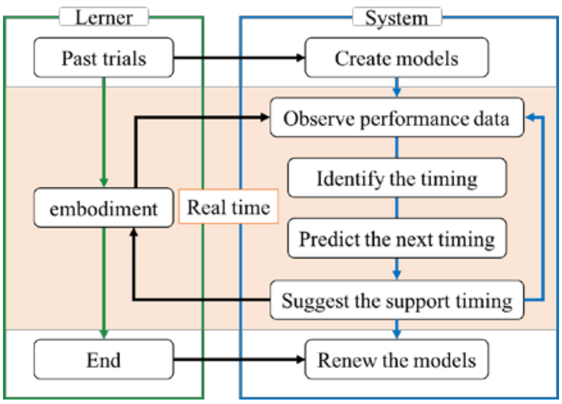

Figure 2. Flow of support by using this system

On real time support, at first, the system measures a learner's performance by monitoring myogenic potential of the forearm and acceleration of the waist. An electrode lead needs to be immovable on learner's body so as not to disturb the motion of rotating wrists because artifact gets mixed in the data. The microcomputer to control these sensors is Arduino Fio having a XBee socket that enables it to communicate wirelessly. Another computer is set up in order to store the data that is received from the system through the wireless network. The system observes a learner’s performance every 10 milliseconds. Secondly, the microcomputer analyzes performance data. Synchronous support system has to identify the timing and predict learner's movement within acceptable time range. The microcomputer executes the prediction that synchronizes with movement. Finally, the system provides feedback to learners as function. The supporting content is the first timing of rotating wrists in each jump. The time lag happens even if the system stimulates auditory sense. Hence, we suggest a sound of the primary timing on support 120 milliseconds earlier than the ideal one as a revision of the time lag in reaction to support. The system provides feedback by a speaker controlled by Arduino Pro Mini that is a different microcomputer from the Arduino Fio. After completion of monitoring learner’s embodiment, the system updates the parameter using monitored and stored data. In this way, the more learners use the system, the more suitable parameter the system assigns.

Learners get learning supporting context by training double-under while equipping the system. Since the support content is the first timing of rotating wrists in each jump, they receive one sound from the system every one cycle. Although learners' goal is learning the relative timing, the system relies on them to perceive criterion timing by intrinsic feedback. They solve this problem by training while recognizing timing different. Thus, they adjust motion timing to the suggestion gradually.

4. System Design and Development

4.1 Overview

The computer, which communicates with the wearable system using wireless communication, is only needed to store data received from the system in terms of the basic design of the prototype. The computer has powerful resources compared with the system. The analysis function in this system can move to the computer because it does not have to respond so quickly. Other than this, input/output functions are still necessary on the wearable system side; i.e. the part of myoelectric sensor. Ongoing prototype sensor system sometimes has the risk of mixing data and noise. The current design tackles to integrate *Myo (https://www.myo.com/)* for monitoring myogenic potential. It has 9-axis inertial measurement unit besides 8 separate electromyography (EMG) sensors. Those sensors attached to the forearm help this system more comprehensively figure out what the wrist is doing. It can send measured data to the computer using Bluetooth and reduce the risk. When the system converts the data with less noise into ARV, this waveform is useful to understand muscular activity and support learning double-under skill.

However, this device doesn’t get acceleration data for monitoring jumping. When the computer analyzes performance data, the system doesn’t need high performance microcomputer like Arduino Fio. It only has the functions of sensing and transmitting wirelessly. Hence, we can reduce its size and weight by the system measuring acceleration in parallel to control a speaker. Learners attach a speaker and a sensor to their body together. An attachment region of the microcomputer is at instep or ankle because it is more direct for detecting timing when the system measures the position of the foot.

The major improvement of the system is the analysis by the remote computer. Learners often have the distortion in movement cycle like Figure 3. Thus, the system needs to predict next motion dynamically.

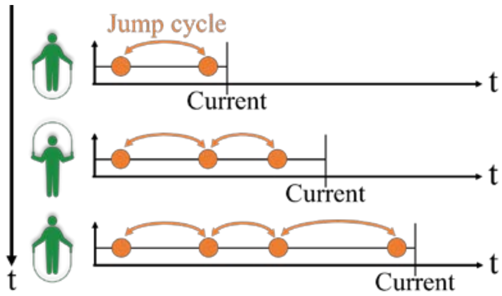

Figure 3. The distortion in jump cycle

4.2 *Consideration for Dynamic Prediction*

In our belief, novices perform double-under in unsystematic movement because they need embodiment with open skill just as jumping depends on motion of the rope. Thus, synchronous support for learners that have dispersion of jumping cycle expects the next timing dynamically from a current state. Jumping especially has a feature of repetitive exercise. Focusing on the centroid, this is simple vertical movements. Figure 4 shows the graph transformed time-series data of acceleration into time-delay coordinate system. The symbol $y(t)$ is the acceleration value of the waist at time t. Thus, the x-axis shows the value of acceleration at the current time and the y-axis shows the acceleration value at the last time. The shape converges to an ellipse shape to some extent.

When the system follows itself, one of the predictive methods is to draw approximate curve in the neighborhood in Figure 4. The graph line appears along with an approximate curve because behaviors seems to be similar to the past. This method may become more accurate if we measure the data by reducing noise. Besides, regression analysis seems useful for implementing dynamic prediction. Toyooka et al. (2016) propose a system that estimates the next cycle on repetitive exercise using regression analysis. This study needs to calculate the regression formula from any suitable data on double-under performance. It has some analogy with the above method using an approximate curve. Thus, we look for two kinds of data group that have relation to regression analysis.

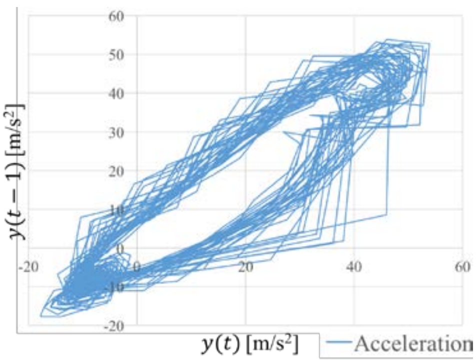

Figure 4. The acceleration data in double-under transformed to time-delay coordinate system

4.3 *Feedback for Effective Learning*

The influence of extrinsic feedback to learning is inestimable. Nevertheless, the prototype system doesn't provide KR. In case the system only gives sound to learners, we shouldn't compel its feedback to include KR. In spite of getting feedback once each cycle, learners feel that they cannot stop concentrating their attention on either embodiment or sound. We suppose the reason is too abstract feedback. There is characteristic sound that is wind noise arising from reiteration of movement pattern in double-under. This system provides sound three times a cycle as rhythm of double-under but we regard this pattern as once ballistic motion. The reason is that we should try to grasp rhythm as the flow (Fujinami, 2006). In addition, Sugawara et al. (2016) state that double-under has the correlation between components of motion. On integrative exercise, we assume that the system should support either one, if one of the component in primitive motion developed with another one. Therefore, it is necessary to investigate what the correlation between timing and the others is.

The beginning of a segment is the time that ballistic motion begins. When our body executes planned movement pattern by the rhythm provided, it will be an indication of the next embodiment as illustrations of more concrete motion. Thus, the system shows intuitive feedback as KP using sound. In addition, Learners may require that the system gives KR. This system has a function of showing KR because this feedback lacks efficiently. Fortunately, *Myo* has feedback method that is different from sound. The time of human reaction is relatively fast because its vibration stimulates haptic sense. *Myo* provides KR simultaneously or separately with sound. KR is the result compared with embodiment and suggestion. We must be careful of interference between feedback.

4.4 *Implementations*

The system follows the condition that the learners obtain calculated movement. They learn an appropriate movement to fit the beginning of motion close to the suggested timing but we assume that they perform the motion after listening to the sound. However, they might feel that it is hard to use it. Thus, we need to reconsider the necessity of the refinement. In repetitive exercise, there is a possibility of unnecessary feedback because the rhythm arises from almost constant movement that is readily understandable. When the prototype system applies these improvements, it needs to change the value per individual and a degree of calculating.

Learners use the system adjusted in this way. The system also follows the supporting flow in Figure 2. They only equip it and jump. As the system suggestion is the criterion for becoming stable of timing difference, they should endeavor to tune their motions to it while training. The system suggests more feedback for acquiring rhythmical movements. Learners don't need to pay attention to timing difference while training it. We expect their learning to have a good effect on an acquirement of another repetitive exercise and so forth.

5. Conclusion

In this study, a learning support system on double-under as integrative and repetitive exercise is proposed. In particular, the present study focuses on timing difference of primitive motions in integrative exercise and the timing that movement rhythm arises from repeating the movement pattern in repetitive exercise. We identify them by observing acceleration of jumping and myogenic potential of rotating wrists. In addition, this study designed the new system function. The proposed system observes the data by wearable sensors, analyzes to predict movement dynamically and shows feedback founded on analyzed data. Although this paper designed the learning support system for double-under in repetitive exercise, we plan to carry out an evaluation on an effect of supporting by dynamic prediction. We try to conduct an experiment for proving an efficacy of the proposal. We also proposed an actuator using two channels: sound and vibration. Therefore, we must implement the system concretely for a practice as a future work.

Acknowledgements

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