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Human creative interaction of group sports: Information-based modeling

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Humans can creatively solve various problems through competition and cooperation among groups. However, with respect to the creative interaction such as sociality and body movement, we cannot even extract its feature from behavioral data yet. Here, we show information-based modeling in the creative interaction of group sport as an example of complex social interaction with an explicit and implicit context. First, we introduce the problems in intra-group cooperation and inter-group competition in the ballgame. In terms of information-based modeling, score prediction system and the cognitive process of cooperative players are explained. Next, we show two-player competition and its motor system modeling. Finally, we discuss future perspectives.

A Balance Study of Interaction between Martial Art Masters

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Martial art involves intelligent forces, not just physical actions and contacts between offense and defense. Practitioners have been exploring the flow of such forces through the history of martial art. Schools of Chinese martial art are of our interest as they have developed various concepts for controlling such a flow of forces extensively. One of skills for controlling the flow is to listen to or perceive the channel through which the opponent releases the force. The strategy that the ancient masters found to nullify the attack is to make no room between them so that the force finds no space to ignite itself. Keeping the contact without pushing or being pushed by the opponent requires a certain skill. Obvious question is how he is able to follow the opponent's motion without delay. With the goal in mind, we studied how the moment of instantaneous response can be identified. We employed four Wii Fit balance boards to collect pressure data of four feet of the two subjects and asked the pair of practitioners to exercise the pushing hand with each other. We analyzed the data to induce the impulse response functions between time series of pressures. We found that the response of the master is instantaneous to the opponent. Our finding may lead to establishing criteria for evaluating the degree of mastery in perceiving the channel through which a force is released.

Keyword: martial art, interaction, channel, perception

Analyzing Individual Unique Body Movements in the Skill Acquisition Processes

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Abstract. In sports and traditional arts, novices acquire motor skills through practice. For skill acquisition that requires periodic body movements, less variability in body movements is crucial; (1) less torso movement; (2) less variable arm swing; and (3) a stable swinging rhythm. However, the following question arises: Do novices always establish such stability as a prototype? To resolve this question, the present study experimentally investigated the motor skill acquisition processes of a sample of novice jugglers, who practiced three-ball cascade juggling over a period of one week. The findings revealed that two of the five jugglers who performed more than 100 successive catches produced individual unique body movements rather than establishing stable body movements as the prototype. Considering the participants' verbal reports, the results also indicated that such unique body movements were related to intentional control. This study identified the mutual relationship between automatic and controlled processing such as body movements and planning (Bebko, Demark, Im-Bolter, & MacKewn, 2005).

Keywords: Motor Skill Acquisition Process, Three-dimensional Motion Recording, Verbal Reporting.

1 Introduction

In sports and traditional arts, novices acquire motor skills through practice. In this regard, skill acquisition is usually evaluated according to the performance improvement criteria that includes task scores (e.g., [1]). In general, less variability in body movements is necessary for acquiring motor skills [1]. Especially, for skill acquisition that requires periodic body movements, establishing stable body movements is crucial. For example, Yamamoto and Gohara [2] discussed how variability in the arm swing of expert tennis players decreased during repeated strokes and how spatial flows converged into fixed patterns.

However, during practice, learners often invent and develop individual strategies for improving performance through trial-and-error [3]. In such situations, it is assumed that they do not always establish a prototype regarding effective or stable body movements. As a result, learners tend to scaffold their training temporarily and solve their problems by producing individual unique body movements. Such unique body movements may be related to one's intentional control for achieving optimum learning during practice. Bebko, Demark, Im-Bolter, and MacKewn [4] indicated that, during complex motor tasks, controlled and automatic processing build motor skills. In this regard, controlled processing is associated with deliberate and conscious processing such as planning, whereas automatic processing emerges as body movements when excessive attention to certain motor tasks decreases with improving performance. It is assumed that intentional control is important when learners produce individual unique body movements and solve their problems.

Therefore, our study investigates whether novices produce individual unique body movements during motor skill acquisition processes. In addition, it examines the verbal reports of a sample of novices regarding the most important factors for achieving a task to confirm whether such unique body movements are related to intentional control. More specifically, this study investigates the motor skill acquisition process in three-ball cascade juggling, which requires periodic body movements of tossing and catching each ball. The overall performance of the jugglers is based on the number of successive catches.

Previous studies (e.g., [5, 6]) revealed that for achieving a high performance level, it is crucial to establish stable body movements; this is especially with regard to the following three aspects: (1) less torso movement; (2) less variable arm swing; and (3) a stable swinging rhythm. For example, Haibach et al. [5] confirmed that the range of torso movement in the lateral direction and the variability of time intervals between one catch and the subsequent catch decreased with practice. Hashizume and Matsuo [6] also demonstrated that the variability of each hand's position in the lateral direction, at the timing of toss, decreased. Furthermore, Beek and van Santvoord [7] distinguished the different stages of learning in the motor skill acquisition process of three-ball cascade juggling. First, they defined the hand cycle time (HCT) as the time interval between one toss and the subsequent toss in a hand. HCT was subsequently divided into the time loaded (TL), which is the time spent holding a ball and the time unloaded (TU), which is the time spent not holding a ball. The ratio of holding a ball was calculated by the TL divided by HCT (TL+TU). When the ratio reached approximately 0.75, learning moved onto the next stage, following which the jugglers continued to practice cascade juggling by self-organizing stable body movements (i.e., a stable swinging rhythm).

In the present study, the participants practiced three-ball cascade juggling over a period of one week. Since the participants could perform more than 100 successive catches, they were regarded as intermediate level jugglers (e.g., [6, 7, 8, 9]). Considering previous studies (e.g., [5, 6]), this study defined the establishment of stable body movements according to the three aforementioned aspects (i.e., (1), (2), and (3) mentioned above), and regarded body movements other than these as “individual unique movements.” It also recorded the intentional control of jugglers autonomously found during practice, based on their verbal reports wherein they highlighted the most important factors for improving their performance.

2 Method

2.1 Participants

The participants in this study consisted of five right-handed male students who were requested to juggle three balls and performed more than 100 successive catches.

2.2 Procedure

On the first day (Day 1), the participants were provided three juggling balls and asked to train for approximately 60 minutes, while referring to an instruction sheet numerating the procedure of performing three-ball cascade juggling and a video demonstrating its expert performance. The following section includes a description regarding the procedure of performing three-ball cascade juggling [7].

1. If a juggler is right handed, then he has two balls in the right hand and one in the left hand.
2. Toss the right-hand ball toward the left hand.
3. As the second ball falls, toss the final ball in the right hand toward the left hand. Catch the second ball in the right hand.
4. As the final ball falls, toss the first ball in the left hand toward the right hand. Continue with this sequence for performing three-ball cascade juggling.

From the second day (Day 2) to the last day (Day 7), the participants were asked to train for at least 60 minutes without the instruction sheet and video. Their performances were measured from Day 2 to Day 7 in the laboratory. More specifically, on each day, 10 trials were performed within a frame border (70 cm x 70 cm) on the floor.

During the performance measurements, a three-dimensional motion recording system captured the positions of seven light-reflecting markers (in the three-dimensional space) using nine infrared cameras at a sample rate of 100 Hz (Hawk type, Hawk: four; Hawk-i: five, NAC Ltd., California, USA). The cameras were focused on the following anatomical locations: the left and right wrists, the left and right elbows, the left and right shoulders, and the chest. The anterior direction (X-axis), lateral direction (Y-axis), and vertical direction (Z-axis) of each location were recorded in the three-dimensional space.

Before and after the performance measurements on each day, the interviews were conducted in which the participants were required to describe the most important factors for improving their three-ball cascade juggling performance.

3 Analysis procedures and results

3.1 Performance

The five participants performed more than 100 successive catches in at least one trial during this study. Fig. 1 presents the means for the first, second, and third best performances of each participant on each day. The horizontal axis represents the dates of the measurements (i.e., from Day 2 to Day 7), while the vertical axis indicates the means of the successive catches for the first, second, and third best performances. According to the figure, Participant E performed more than 100 successive catches (128 successive catches) in one trial on Day 5.

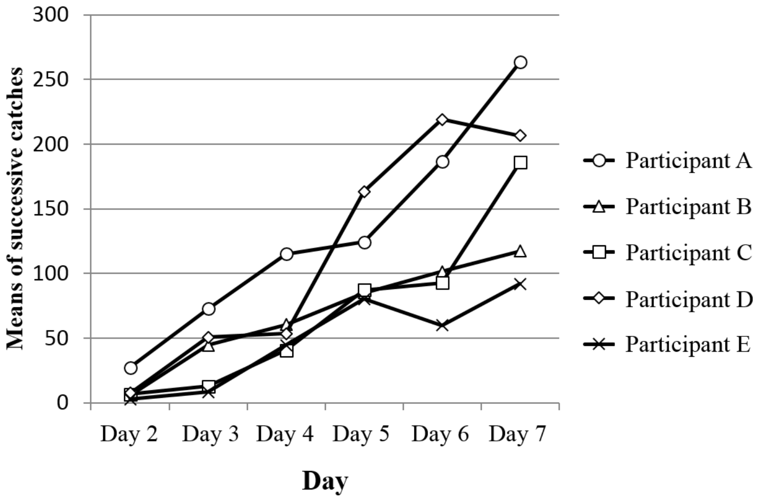


Fig. 1. Transition of successive catches.

3.2 Body movement

Analysis procedure. For evaluating the stability of body movements, the following three indexes of catching and tossing were examined: (1) the stability of chest movements (representing torso movements) was analyzed by using the first index, the fluctuations in the chest positions between one catch and the subsequent catch, and between one toss and the subsequent toss; (2) the stability of wrist movements (representing arm swing) was examined by using the second index, the fluctuations in the wrist positions between one catch and the subsequent catch, and between one toss and the subsequent toss; and (3) the stability of time intervals (representing swinging rhythm) was examined by using the third index, the standard deviations (*SD*s) of time intervals between one catch and the subsequent catch, and between one toss and the subsequent toss.

In addition, the following analytical procedures were employed. For identifying the timing of catching and tossing, our study focused on wrist movement. Since wrist movement was periodically repeated upward and downward, the peaks and valleys in this vertical movement were regarded as the catching and tossing points [10]. Regarding the timing of catching and tossing points, this study captured the positions of two locations (i.e., the chest and wrists) in the three directions and calculated the values of three indexes. For the first and second indexes, the fluctuations in the chest and wrist positions were analyzed between the k th and k+1 th catching points and between the k th and k+1 th tossing points. For example, regarding the fluctuations in the positions of the locations in the anterior direction between the catching points, this study analyzed $\overline{\Delta x_p}$ and used Equation (1). Here, $x_{p_k}$and $x_{p_{k+1}}$ represent the positions of the locations in the anterior direction at the k th and k+1 th catching points, while n indicates the number of catching points:

$$\overline{\Delta x_p} = \frac{\sum_{k=1}^{n-1} \left| x_{p_{k+1}} - x_{p_k} \right|}{n-1} \quad (1)$$

Our study also analyzed the fluctuations in the positions of the locations in the lateral and vertical directions between the catching points, $\overline{\Delta y_p}$ and $\overline{\Delta z_p}$. Moreover, it analyzed the fluctuations in the positions of the locations in the three directions between the tossing points, $\overline{\Delta x_v}$, $\overline{\Delta y_v}$, and $\overline{\Delta z_v}$. For the third index, this study analyzed the *SD*s of time intervals between the k th and k+1 th catching points and between the k th and k+1 th tossing points. For example, regarding the *SD* of time intervals between the catching points, it analyzed s_{t_p}, calculated by Equations (2), (3), and (4), where t_{p_k} and $t_{p_{k+1}}$ represent the timing of the k th and k+1 th catching points, while $\overline{\Delta t_p}$ indicates the mean of time intervals between the k th to the k+1 th catching points:

$$\Delta t_{p_k} = t_{p_{k+1}} - t_{p_k} \quad (2)$$

$$\overline{\Delta t_p} = \frac{\sum_{k=1}^{n-1} \Delta t_{p_k}}{n-1} \quad (3)$$

$$s_{t_p} = \sqrt{\frac{\sum_{k=1}^{n-1} (\Delta t_{p_k} - \overline{\Delta t_p})^2}{n-1}} \quad (4)$$

Similarly, this study analyzed the *SD* of time intervals between the tossing points, s_{t_v}.

Finally, for capturing the stable body movements that had reached a steady state, this study excluded the initial and last two successive catching and tossing points in each hand. Moreover, it analyzed the means of the values of three indexes for each hand. These are averaged with both hands. Meanwhile, for the trials in which less than 15 successive catches were performed, it analyzed them in all ranges of the catching and tossing points. These trials were then eliminated from the statistical analysis. In sum, the three trials that achieved the first, second, and third best performances on each day were analyzed, and the means of the values for the three trials were calculated. If the recording system failed to capture the positions of two locations for the three trials that achieved the first, second, and third best performances, and the loss rate in recording for each of the three trials exceeded 20%, then this study analyzed the trials that made the fourth (and any subsequent) best performance.

Results. Fig. 2, 3, and 4 present the transitions regarding the values of three indexes for each participant. The horizontal axes represent the dates of the measurements, while the vertical axes in Fig. 2 and 3 demonstrate the means of the fluctuations in the chest and wrist positions (in mm) between the catching points and between the tossing points. The vertical axis in Fig. 4 indicates the means of the *SD*s of time intervals (in sec) between the catching points and between the tossing points. The error bars indicate standard errors. The gray bars depict the means of the trials in which less than 15 successive catches were performed. In addition, the baselines represent the values for the three expert jugglers who had acquired the complete skills for performing five-ball cascade juggling. The data for the expert jugglers was from the study by [10].

Characteristics regarding a prototype of body movements. The findings indicated the following three points regarding the prototype of body movements since these points were consistent with the results of previous studies [5, 9].

First, the fluctuations in the chest and wrist positions on Days 2 and 3 were much greater than those on the other days, especially when the participants performed less than 15 successive catches. The participants significantly decreased the fluctuations in their body movements from the initial stage during practice. Meanwhile, from Day 4 to Day 7, the fluctuations in the positions of two locations and the *SD*s of time intervals did not decrease. 6 (Day: Days 2, 3, 4, 5, 6, and 7) x 2 (Event: catching and tossing points) ANOVAs were performed on the fluctuations in the wrist and chest positions and the *SD*s of time intervals for each participant. The data in which less than 15 successive catches were performed were eliminated from the statistical analysis. Among the 35 cases of ANOVAs performed, only three (Cases 1, 6, and 26 in Fig. 2 and 3) revealed a significant effect of the Day factor, illustrating that the fluctuations in the positions of two locations significantly decreased through the training sessions ($ps < .05$).

Second, the fluctuations in the chest and wrist positions and the *SD*s of time intervals on Day 7 for each participant were significantly greater than those for the expert jugglers. All the *t*-tests revealed significant differences between each participant and expert jugglers regarding the fluctuations in the positions of two locations and the *SD*s of time intervals at both the catching and tossing points ($ps < .05$).

Third, for arm swing, the fluctuations in the wrist positions and the *SD*s of time intervals between the tossing points were significantly less than those between the catching points. 6 (Day: Days 2, 3, 4, 5, 6, and 7) x 2 (Event: catching and tossing points) ANOVAs were performed on the fluctuations regarding the wrist positions and the *SD*s of time intervals for each participant. Among the 20 cases of ANOVAs performed, 17 revealed a significant effect of the Event factor ($ps < .05$). the 16 (from Cases 16 to 35, excluding Case 31 in Fig. 3 and 4) of these cases demonstrated that the fluctuations in the wrist positions and the *SD*s of time intervals between the tossing points were significantly less than those between the catching points.

Concerning the first point, Haibach et al. [5] reported that body movements became stabilized from the early to middle acquisition processes in three-ball cascade juggling, which was critical for establishing a prototype of body movements. Regarding the second point, van Santvoord and Beek [9] confirmed that stability in the hand movements of expert jugglers was higher than that of intermediate jugglers who had acquired the skills to perform three-ball cascade juggling. Finally, for the third point, van Santvoord and Beek [9] reported that the stability of hand positions at the time of tossing was higher than that at the time of catching.

Characteristics of unique body movements. Since different characteristics from those mentioned above were confirmed in two of the 35 cases, these body movements indicated the possibility of individual unique body movements.

First, the fluctuations in the chest positions in the lateral direction for Participant E was much greater than those for the other participants (see Case 10 in Fig.2). Even if he performed more than 100 successive catches, $\overline{\Delta y_p}$ and $\overline{\Delta y_v}$ demonstrated the fluctuations of more than 35 mm, and these values did not decrease from the initial stage during practice. This characteristic significantly differed from the first point regarding the characteristics of the prototype of body movements.

Second, the *SD* of time intervals between the tossing points for Participant A was much greater than those for the other participants (see Case 31 in Fig. 4). The *SD*s were more than 0.10 sec through the six training sessions. A 6 (Day: Days 2, 3, 4, 5, 6, and 7) x 2 (Event: catching and tossing points) ANOVA was performed on the *SD*s of time intervals, revealing a significant effect of the Event factor ($p < .001$). Meanwhile, the *SD* of time intervals between the tossing points was significantly greater than that between the catching points. This result was contrary to the third point regarding the characteristics of the prototype of body movements.

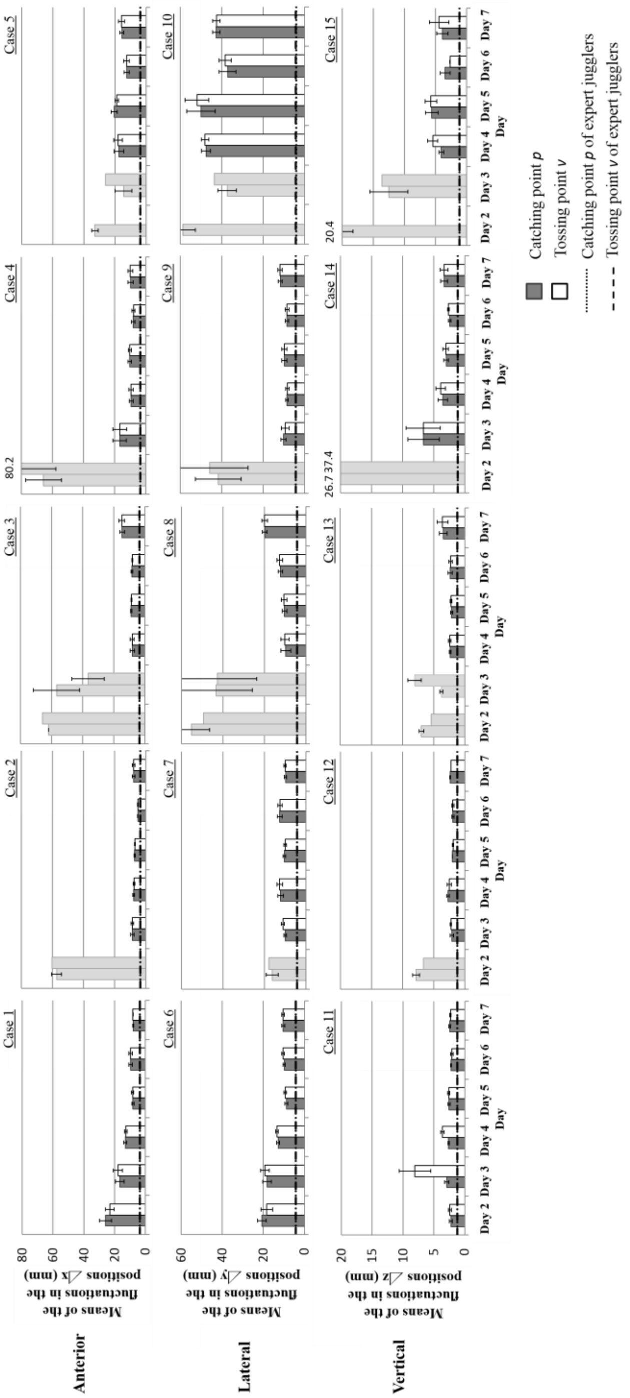


Fig. 2. Transitions regarding the fluctuations in the chest positions.

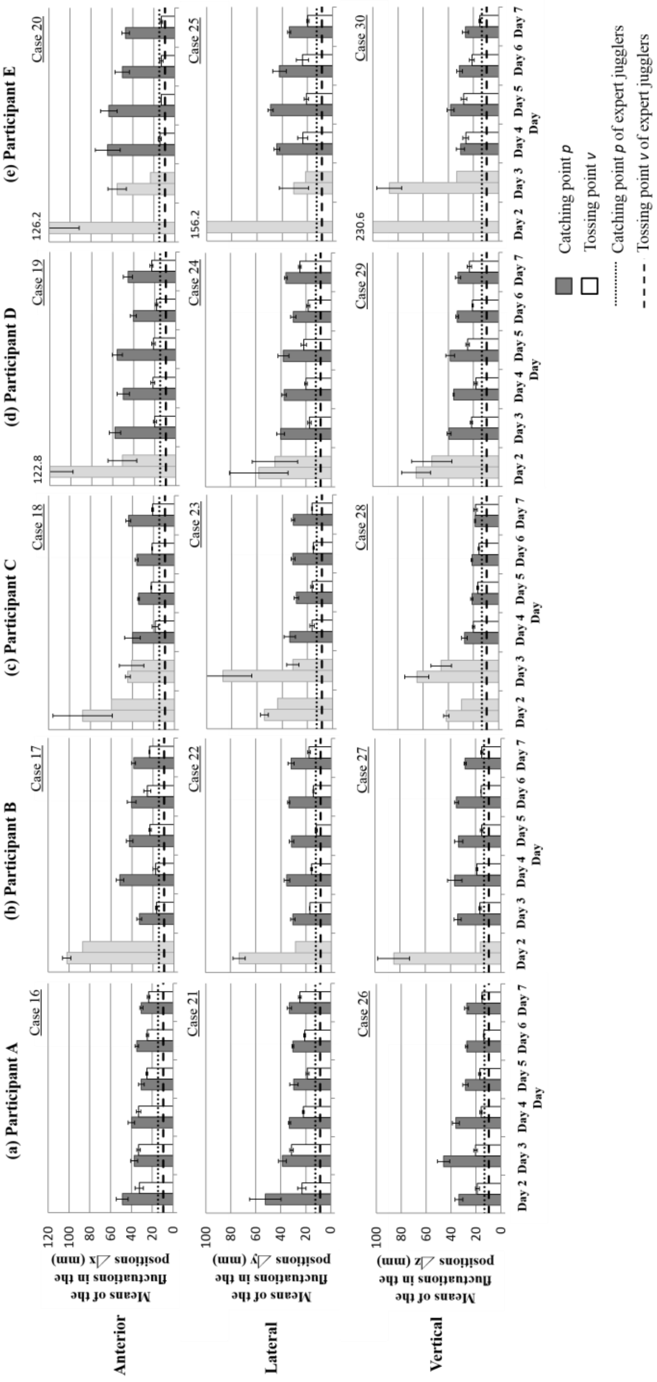


Fig. 3. Transitions regarding the fluctuations in the wrist positions.

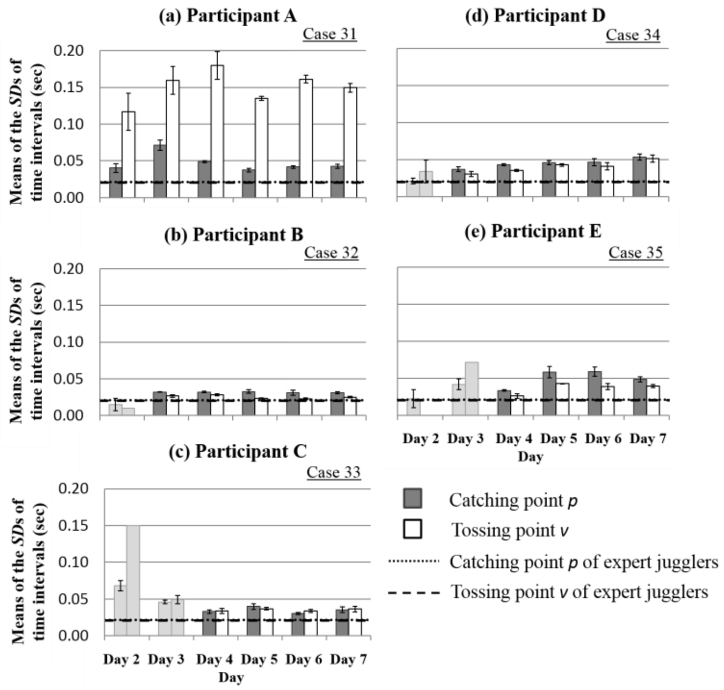


Fig. 4. Transitions regarding the *SD*s of time intervals.

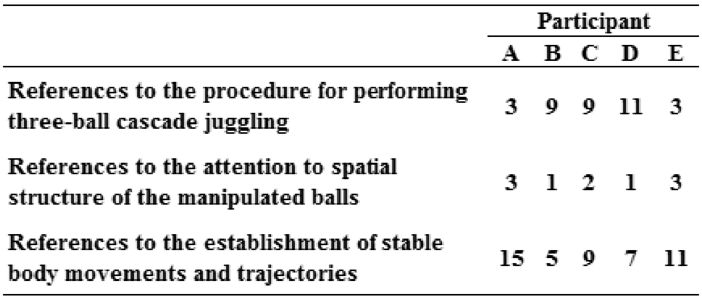
3.3 Verbal reporting

Analysis procedure. This study also recorded the verbal reports of the participants in terms of the factors that assisted them in achieving optimum learning over the six training sessions. After transcribing and generalizing the verbal reports, intentional control was apparent from the bottom up. The verbal reports were also separated into the following three categories, since previous studies confirmed that these categories were important for performing three-ball cascade juggling [5, 6, 7, 8].

The first category referenced the procedure for performing three-ball cascade juggling (e.g., toss the ball on the inside of the falling ball). As shown earlier, some points on the instruction sheet were explicitly described. The second category referenced the attention to the spatial structure of the manipulated balls (e.g., watching around the zenith of the parabolic trajectory for predicting where the ball will fall). The third category referenced the establishment of stable body movements and ball trajectories. More specifically, it indicated finding a rhythm of throwing the balls, consistently throwing and catching the balls at the same position, and attempting to fix the trajectories of balls for attaining a consistent arch shape.

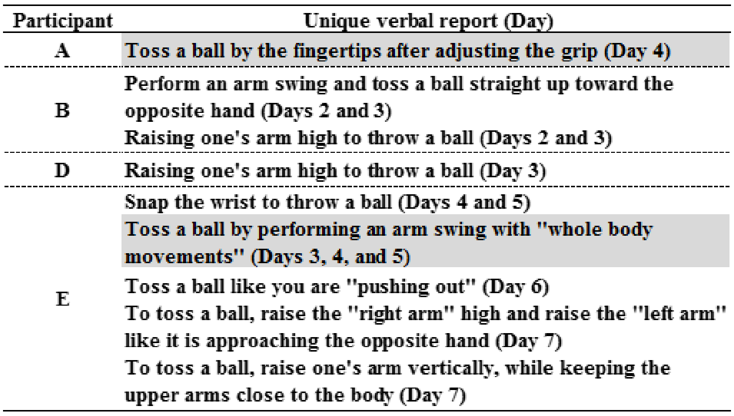
Result. Table 1 presents the number of categories that the participants mentioned over the six training sessions. All the participants mentioned the three categories (stated above) at least once. Table 2 demonstrates the details of their unique verbal reports.

Table 1. Number of categories in the verbal reports.



	Participant				
	A	B	C	D	E
References to the procedure for performing three-ball cascade juggling	3	9	9	11	3
References to the attention to spatial structure of the manipulated balls	3	1	2	1	3
References to the establishment of stable body movements and trajectories	15	5	9	7	11

Table 2. Unique verbal reports.



Participant	Unique verbal report (Day)
A	Toss a ball by the fingertips after adjusting the grip (Day 4)
B	Perform an arm swing and toss a ball straight up toward the opposite hand (Days 2 and 3) Raising one's arm high to throw a ball (Days 2 and 3)
D	Raising one's arm high to throw a ball (Day 3)
E	Snap the wrist to throw a ball (Days 4 and 5) Toss a ball by performing an arm swing with "whole body movements" (Days 3, 4, and 5) Toss a ball like you are "pushing out" (Day 6) To toss a ball, raise the "right arm" high and raise the "left arm" like it is approaching the opposite hand (Day 7) To toss a ball, raise one's arm vertically, while keeping the upper arms close to the body (Day 7)

3.4 Summary of results

For Participant A, the *SD* of time intervals between the tossing points was much greater than those for the other participants. Moreover, during the interview on Day 4, he reported tossing a ball by the fingertips for attaining a consistent arch-shaped trajectory (see Table 2). He attempted to adjust the grip to control each ball more accurately. This showed the high variability in time intervals between the tossing points that represented a swinging rhythm (see Case 31 in Fig. 4).

Meanwhile, for Participant E, the fluctuations in the chest positions in the lateral direction were much greater than those for the other participants (see Case 10 in Fig. 2). In the interviews from Day 3 to Day 5, he reported tossing a ball by performing an arm swing with ``whole body movements'' to avoid the collision of a held ball and a ball falling from the parabolic arc's zenith (see Table 2). This showed the significant fluctuations in chest movements that represented torso movements.

These results demonstrated that the individual unique body movements for the two participants were mutually related to their verbal reports.

4 Discussion

4.1 Causality between individual unique body movements and intentional control

Our study confirmed individual unique body movements were related to their intentional control for achieving optimum learning during practice. However, the results did not depict that such unique body movements were caused by the intentional control of the jugglers. Therefore, it is important to carefully examine the casual relationship. In this respect, Participant A on Day 4 reported tossing a ball by the fingertips. However, before that day, the recording showed that he had already adjusted the grip. Likewise, Participant E on Day 3 reported tossing a ball by performing an arm swing with ``whole body movements." However, before this report, he had already implemented this action.

Ericsson, Krampe, and Tesch-Römer [11] reported that activities and deliberate goals are mutually related. This suggests that intentional control not only causes an improvement in activities but also ensures that such an improvement can guide deliberate goals. However, our study did not determinate whether the jugglers consciously noticed that they had performed individual unique body movements. Instead, this study simply identified the mutual relationship between automatic and controlled processing [4]. In addition, Gray and Lindstedt [3] confirmed that learners repeatedly invent and develop strategies, and practice in the processes of skill acquisition. This also suggest they acquire skills through the mutual relationship between body movements and intentional control.

4.2 Function of individual unique body movements for the expert level

The jugglers who performed five- or more than five-ball cascade juggling were regarded as experts [12]. Meanwhile, in the present study, the participants who performed three-ball cascade juggling reached the intermediate level [8, 9] and remained on track toward the expert level. Fig. 2, 3, and 4 confirmed that the stability of body movements for expert jugglers was higher than that for the participants with intermediate skills.

Participant A succeeded in performing more than 400 successive catches on Day 7 (see Fig. 1). However, his unique body movements may prevent him from reaching the expert level. For five-ball cascade juggling, the performers must shorten the time loaded (TL), while lengthening the time between tossing and catching a ball [13]. In this regard, the TL for Participant A was much longer than those for the other participants, owing to his unique body movement (i.e., adjusting the grip). Furthermore, it is evident that the number of balls in the air in five-ball cascade juggling is more than that in three-ball cascade juggling. In this study, Participant E attempted to toss a ball by performing an arm swing ``with whole body movements." However, this strategy may be ineffective for skill acquisition in five-ball cascade juggling since implementing ``whole body movements" is more difficult when manipulating more balls in the air. As a result, Participant E may also face difficulties in reaching the expert level.

For reaching the expert level, Participants A and E were asked to transform their intentional control related to their individual unique body movements. Thus, in general, some expert jugglers display individual unique body movements that significantly differ from the individuality observed in the present study.

4.3 Future works

This study confirmed that individual unique body movements were related to intentional control. However, we have the three future works.

First, according to **4.1**, we need to develop the method to analyze the casual relationship between such unique body movements and intentional control, and examine what extent the jugglers consciously noticed the unique body movements.

Second, in terms of **4.2**, we need to examine whether the individual unique body movements observed in the present study eventually disappear during the practice of five-ball cascade juggling, in reaching the expert level.

Third, we should discuss coupling of body movements and visual information. It is important to coordinate body movements and visual information for performing juggling. The jugglers tend to adjust arm swing to watch around the zenith of the parabolic trajectory during three-ball cascade juggling [8]. We found that the participants reported visual information as the factors that assisted them in achieving optimum learning (e.g., watching around the zenith of the parabolic trajectory for predicting where the ball will fall). The interest is to examine the relationship between individual unique body movements and visual information.

5 Acknowledgement

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The Complicated Interaction between Expert Breakdancers: Distance as the Hidden Dimension

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In the performing arts, including dance, theatre, and music, performers present their art through complicated interactions with their co-actors, the audiences, and so on (e.g., Bailey, 1980; Walton et al., 2015). This study investigated the dynamics of these interactions, focusing on the battle scenes in breakdance as the target phenomenon.

In the battle scenes of breakdance, two dancers perform their dance in turn impromptu, adjusting to the music played by a DJ. In addition to the music, the performance of one dancer also influences on that of the other dancer. Furthermore, the opponent's performance affected by the dancer's performance or the music again influences on the next performance of the dancer. These dynamical interactions seems to be explained by the Dynamical Systems Theory that focuses on the interactions of multiple factors and emergences of some dynamical patterns (e.g., Haken, Kelso, Benz, 1985). We applied this theory to dancers' movements in the battle scenes.

In the analysis, we thought that the distance between two dancers in a battle scene indicates the patterns of their communication. Previous studies in social psychology suggested that distance between people is an important factor that affects their communication in the unconscious level (hidden dimension, Hall, 1959, 1966). Two groups of four expert breakdancers participated in the experiment. In the experiment of each group, four expert breakdancers conducted six battles in a round-robin, and we measured the distances between the dancers using motion capture. The distance data were analyzed using nonlinear time series analysis such as recurrence plot and cross recurrence plot. The results showed that clear distance patterns emerged during the battles. They also showed that the distance patterns changed as the performance proceeded.

Keywords

Interaction, Performing Arts, Breakdance, Dynamical Systems Theory, Nonlinear Time Series Analysis, Distance

A study on intellectual tasks influenced by the embodied knowledge

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Abstract. I have an assumption that knowledge of the known intellectual task will similarly influence on the new one. By using origami performances, it was verified the existence of embodied knowledge of the known intellectual task made the performance of unknown similar tasks better. Experiments were carried out as the origami performance of folding cranes and phoenixes. The performance of folding phoenixes consists of the common part of folding cranes and folding phoenixes, and the unique part of folding phoenixes. As a result of comparing execution time of the folding cranes with that of folding phoenixes, the following three observations were obtained. 1) If they had the embodied knowledge of folding cranes, they could finish the task of folding phoenixes more quickly than those who do not have the embodied knowledge. 2) Significant differences due to the presence or absence of the embodied knowledge were observed only in the performance of the common part. 3) Once if they have experienced to fold cranes, it was possible to complete the task of folding phoenixes even if they did not have the embodied knowledge of folding cranes. As shown in the above results, the embodied knowledge of folding cranes influenced only on common part of folding cranes and folding phoenixes. In the common part of folding cranes and folding phoenixes, only differences due to the presence or absence of experiences were observed, and no difference was found due to the proficiency in experience. The reason for the increase in the efficiency of the new intellectual task similar to the known intellectual task by the embodied knowledge is that only efficiency was increased as a whole because the efficiency of their common part was increased. Thus we cannot conclude that experiences have played some roles in the unique part. In addition, as shown in the above results, once they have experienced to fold cranes, they will be able to obtain the knowledge of how to fold the cranes.

Keywords: embodied knowledge, intellectual task, origami performance

1 Introduction

When we look at the various actions from our morning getting up to sleeping at night, it can be said that they are various kinds of task and accumulation of actions. In such tasks, even if it is intellectual tasks that are somewhat complicated, such as cooking, sports, creative activities, if they are always doing them, we can perform their intellectual task without any problems. This is thought to be because we have knowledge gained as experiences for those intellectual tasks, that is, intuition and feeling in task, movement, hand working, etc. by experiencing something.

On the other hand, when executing a new task, it is impossible to task as it is because it does not have that experience. In order to solve this problem and execute new task, we think that we are promoting understanding of new task by using know knowledge of known task like that. Therefore, it can be said that existing experiences are applied for understanding and execution of new task.

In Maruyama (2015), that study purposed the elucidation of image formation process of folding using Origami "Yakkosan of hanging display" that transforming of "Yakkosan". That study did not focus on influence of skills and knowledges on the tasks.

In this study, the degree of influence on the time to complete the intellectual task A in existence of the intellectual task B in some new intellectual task A and similar intellectual task B has been influenced I will examine it using intelligent task called Origami. In this paper, we focus on influence of embodied knowledge on new tasks.

2 Experiment 1

2.1 Purpose

We examine the influence of embodied knowledge on intellectual task using the intellectual task of folding origami.

2.2 Method

(1) Participant

16 college students (6 men, 10 females) participated. Both were undergraduates enrolled at the Faculty of Literature, Chiba University.

(2) Procedure

We asked the participants to fold two types of origami, crane and phoenix, and photographed the situation from the front with a video camera. After that, we output the captured image of the action underway to the personal computer and asked questions while confirming with the participant. The experiment time was 70 minutes. The method of recording the experiment and setting of the experiment time were made with reference to the problem of breaking the "Yakkosan of hanging display" of Maruyama (2015). Tasks are presented in the order of crane and phoenix. Presenting the sample (Figure 1, Figure 2) on each participant, fold the same thing, and telling the staff to present the hints in stages if there is a request from the participant, we tackled the issue.

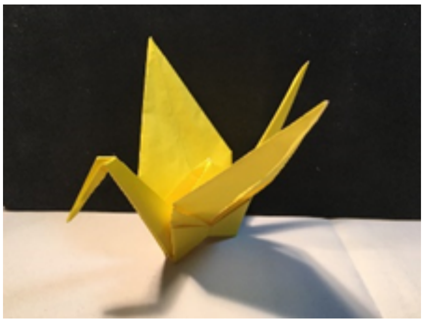

Figure 1 Crane sample

Figure 2 Phoenix sample

2.3 Result

Based on the shot image, the crane is the task time from the beginning of folding to the completion, Phoenix starts from the folding stage to the stage of "Tsuru no Kiso" (see Figure 3) which is a common part between crane and phoenix (Hereinafter referred to as "process α"), the stage from "Tsuru no Kiso" to completion (Hereinafter referred to as "process β"), the total working time from the beginning of creation to completion, were measured.

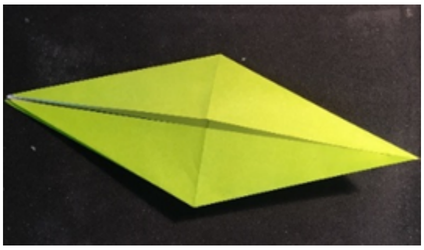

Figure 3 Tsuru no Kiso

We divided the result of measurement into a group that knows how to fold a crane (hereinafter referred to as group A), a group that does not know how to fold a crane (hereinafter referred to as group B), and classified it into each process as follows It is a graph (Figure 4).

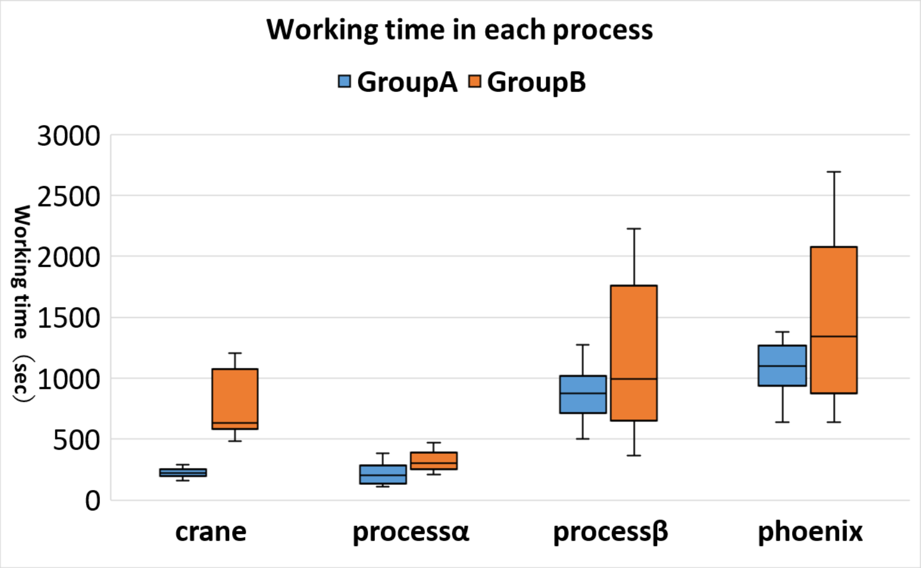

Figure 4 Working time in each process of Experiment 1

Based on the obtained results, Wilcoxon ranked sum test of crane and phoenix task hours for Groups A and B resulted in a significant difference between Group A and Group B only in crane task hours It was seen. (Z = -3.254, p-value = 0.0002498)

Also, in the question after the end of the assignment, there was a difference in answers among the groups on questions about cranes, such as "Where are the difficulties in folding a crane?" "Was there a part you care about folding a crane?" Regarding the question "What is the difficulty in folding a crane?", all the participants in group A responded that "there were no difficulties", whereas in group B, "it was difficult to form a crane head and tail "," It was difficult to grasp the whole form "," I did not know how to fold itself ", etc.

For the question "Was there a part you care about folding a crane?", Group A answered, "I did not care about it" and "I folded carefully as closely as possible to the sample" In Group B, responses such as "I was careful not to make a wrong fold".

For the question about phoenix, there were no characteristic differences in responses among the groups

2.4 Discussions

From Experiment 1, it was possible to obtain a result that significant difference was observed between Group A and Group B only in the working hours of crane in Groups A and B. From this result, it can be said that group A completed the task of crane significantly more quickly than group B. On the other hand, this also indicates that there was no significant difference in task time between groups A and B except for the working time of crane. This means that the hypothesis that experiential knowledge tasked well for similar tasks, even if it is a new task, the more time it takes to complete the task as the more task experiences like that task are done It is against. In considering the reason for such a result, paying attention to the working time of the crane between the groups A and B and the working time of the process α, the task contents of the crane and the process α are almost equivalent Despite the significant difference in the working time of the crane, it is understood that the significant difference is not seen in the process α. Regarding questions after the end of the assignment, as for the questions about cranes, group A is not the way the folds are folded or the contents of the task themselves, but most of them answer about the completeness of the task, but group B is a crane In the question about phoenix, no difference was found between groups, whereas the group that existed at the time of crane It can be said that the difference between Phoenix is no longer present.

Based on these facts, it seems that during the experiment, after the completion of the cranes task on Group B, there seems to be an influence that changed from the state before task execution. To verify the cause of the influence, looking at the group B in figure 4, we can see that the task time of the stroke α is shorter than the working time of the crane. For this reason, in Group B, we gained the experience of cranes that we did not have before because we made the task of folding a crane, so in process α, which is like crane, group A and significant It seems that task time has been shortened to the extent that there is no difference. Therefore, in Experiment 1, it is suggested that all participants became participants having experience of cranes at the time of the task of phoenix.

2.5 Further issues

From the analysis of the results obtained in Experiment 1, in Experiment 1 it was suggested that all participants had cranes experience knowledge at the time of performing the phoenix task, so to test the hypothesis. It is necessary to have participants who do not have cranes experiences perform the task of phoenix without having to acquire experience knowledge. Therefore, experiments are carried out using similar participants, and the tasks are carried out in the order of Phoenix cranes rather than Crane, Phoenix in order. Since it is thought that all participants can perform the task of Phoenix without acquiring new experiences, it is necessary to perform a new experiment in which the order of the experiment 1 and the task are exchanged.

3 Experiment 2

3.1 Purpose

In experiment 1, because of performing tasks in the order of cranes and phoenix, all the participants experienced experiencing folding the crane at least once at the beginning of folding phoenix. In other words, it is thought that all participants had acquired experience of cranes. Verify the influence of existing experience of cranes on Phoenix without changing the order of tasks to acquire new experiences.

3.2 Method

(1) Participant

Twenty college students (8 men, 12 women) participated. Both were undergraduates enrolled at the Faculty of Literature, Chiba University.

(2) Procedure

We asked the participants to fold two types of origami, phoenix and crane, photograph the situation from the front with a video camera, then output the picture taken about the action underway to the personal computer, asking questions while checking with the participant went. The experiment time was 70 minutes. The method of recording the experiment and setting of the experiment time were made with reference to the problem of breaking the "husband of a hill decoration" of Maruyama (2015).

The order of presenting the assignment is in the order of phoenix and crane. Tell us about presenting the sample (Figure 1, Figure 2) about each participant and folding the same thing, presenting the hint stepwise if there is a request from the participant We tackled the issue.

The difference from Experiment 1 is that the order of presenting the tasks was changed from the order of crane, phoenix to phoenix, crane in the order, and the rest is the same as Experiment 1.

3.3 Result

As in Experiment 1, the process α of the phoenix, the process β, and the total working time were measured. As for cranes, because there were many participants who were unable to carry out the task due to the relationship of experiment time, we did not use it for this analysis. The result is divided into a group that knows how to fold the crane (hereinafter referred to as group C), a group that does not know how to fold the crane (hereinafter referred to as group D) (Figure 5).

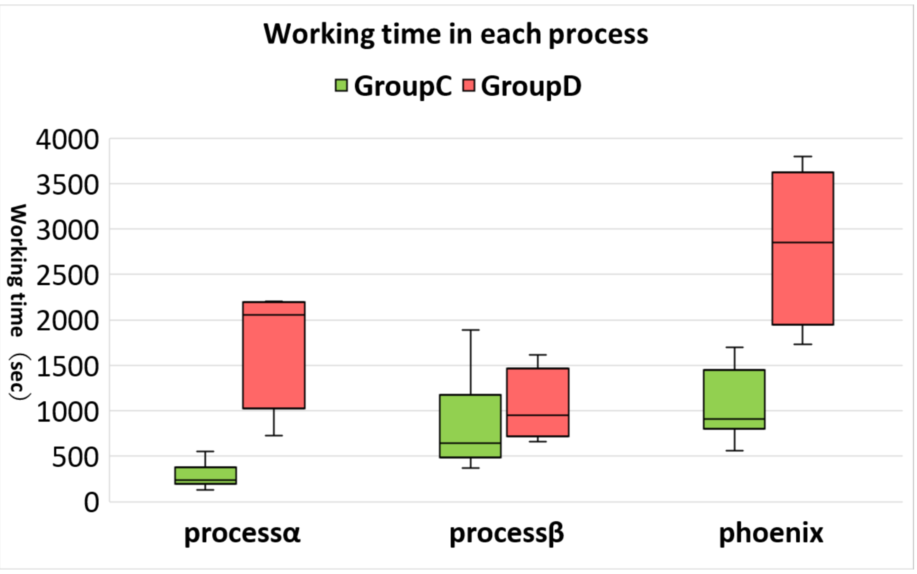

Figure 5 Working time in each process of Experiment 2

Based on the obtained results, Wilcoxon rank sum test was conducted for each working process of Phoenix against Groups C and D. As a result, significant difference was observed in Step α. (Z = -3.0237, p-value = 0.0004128)
There was also a significant difference in the working time of the entire phoenix. (Z = -2.9292, p-value = 0.0008256)
In the question after the end of the assignment, in group C, "I felt that phoenix was the same folding way as a crane halfway" "I think each part of the crane corresponds to each part of phoenix" I felt the similarity between the phoenix and the crane "such as" I felt the similarity of the crane. " In Group D, only answers about Phoenix such as "I did not know where to fold from the beginning", "Phoenix parts could not be formed successfully" such as the difficulty in folding phoenix were obtained.

3.4 Discussions

From Experiment 2, it was found that significant differences were found in the working time of process α, phoenix in Groups C and D. From this result, it can be said that Group C completed the process α, phoenix significantly more quickly than Group D. This means that the hypothesis that experiential knowledge tasked well for similar tasks, even if it is a new task. The less time it takes to complete the task as the more task experiences like that task have been performed.

Also, in the question after the task was completed, in group C, responses were mentioned referring to the similarity between crane and phoenix, whereas answers to phoenix were not obtained in group D at all in response to crane only the result was obtained. From this result, it is possible to point out the Phoenix has a common part of crane in case of having experience of cranes. Having experience of cranes helps understanding of phoenix. This also supports the hypothesis that it is effective to task on new task to have experiences like new task.

4 Discussions

Based on the data obtained in Experiment 1 and Experiment 2, comparison of data between experiments is a group that does not know group A and group C which are groups knowing how to fold cranes, group C I went to group B and group D. Wilcoxon rank sum test was conducted for each task time among groups for each, and significant differences were found in the working time of process α between groups B and D. (Z = -2.5584, p-value = 0.009524) From this result it can be said that group B was able to finish the task significantly more quickly than group D. The above result shows that group B who experienced once to fold a crane did not experience folding cranes at all at the beginning of the experiment even if it did not know the same way to fold a crane It also shows that the time to completion of the process α, which is a similar part between Phoenix and Crane, was significantly faster than Group D. For this reason, the reason there was no significant difference between Group A and Group B in the phoenix task of Experiment 1 is that the participants in Group B were acquiring cranes experience at the beginning of Phoenix's task It can be said that the consideration in Experiment 1 to be reinforced. Based on the results of comparison between the above experiments and the results obtained respectively in Experiment 1 and Experiment 2, the results obtained in this study are summarized as follows.1) If they had the embodied knowledge of folding cranes, they could finish the task of folding phoenixes more quickly than those who do not have the embodied knowledge. 2) Significant differences due to the presence or absence of the embodied knowledge were observed only in the performance of the common part. 3) Once if they have experienced to fold cranes, it was possible to complete the task of folding phoenixes even if they did not have the embodied knowledge of folding cranes. All of these results support the hypothesis in this research that it is effective to task on new task to have experiences like those for new task.

On the other hand, as shown in 2), the experiences of cranes tasked effectively only in parts like cranes in the task of Phoenix, and in the part with low relevance to crane, existence of cranes experience but did not give a significant difference. In other words, existing experiences are affecting only the part of new task which is like the existing task, which can be executed significantly by the existing experience, and similarity with the existing task will be diminished at all It can be said that existing experiences do not have a significant influence at all. Even if it seems that having experience knowledge of a certain task tasks effectively for other task, this tasks effectively for similar parts in the task, so task can also be said to be effective and it can be thought that it is not that experiential knowledge was applied to the whole task but experiential knowledge only affects the corresponding one.

In addition, as shown in 3), the influence of existence or nonexistence of experiential knowledge on task time is significant, but there is a big difference in task time among people with experience there was no significant difference in task time between those who were considered experienced at the time of the experiment and those who had experience before. This is because the presence or absence of experience is the most important factor for the task time of the intellectual task of folding origami, how much knowledge has experience, when to acquire experience such experiences. It can be thought that elements in intellectuals may not have much influence.

If it is assumed that only the presence or absence of experience has influence on the working time of origami, regarding the mastery of the movement touched in Suwa (2015), we have accumulated the experience of how to fold how much task time, it can be said that there is no effect even if it gets experience knowledge. Then, what part of the influence due to the difference in experiences appears? Considering elements other than the task time of folding an origami, verify the difference in the part relating to the completeness of the task such as the politeness of folding or the small degree of reworking It is thought that it can be done. In such parts, there may be differences among people with experience.

In Suwa (2015), as an ideal form of meta-cognition of the body, "Relationship of equality, neither language nor body is the main," "Linking the stable feeling of ourselves to the feeling” And by creating the relationship between the words and the words by yourself, we will spin our original words to drive the body. " Focusing on this "spinning your own original language to drive the body", even those who have experience knowledge that did not see significant difference in working time, such experience knowledge There is a possibility that a significant difference may appear in terms of verbalization towards.

In the present study, the participants of the participants to verbalize the participants are the self-evaluation of the task, the difficulty of the task and the similarity between the tasks, and the similarity between tasks, consciousness, understanding and task process for the movement itself of folding origami I do not make language of parts such as understanding. Also, there was no difference in self-evaluation among participants in self-assessment of tasks by participants. However, there was a difference such as the fact that the participants were nearly equal in completeness of the tasks, which one was doing well, which was beautifully done, and it is certain that comparing the tasks It can be said that there is a difference in its perfection degree.

In this study, since the evaluation to the task was only the self-assessment of the participant himself or herself, we did not externally evaluate the completeness of the task, but from this it is possible to externally objective by evaluating, it can be considered that differences in empirical knowledge between each participant can be confirmed numerically as a difference in evaluation.

5 Conclusions

In this study, for a certain new intellectual task, we examine the influence of knowledge of existing intellectual task like that on new intellectual task, using intelligent task called origami task time, and obtained the following two conclusions.

1) If you have experience knowledge of existing intellectual task like that for new intellectual task, you could do the task significantly more quickly than if you did not have experience, but existing experiences influence. What is in the new task is limited to parts like existing task.
2) Regarding working time in intelligent task of folding origami, the presence or absence of experience is the most important factor, and the elements in experience knowledge have no influence on working time.

For the further development of this research based on the above conclusion, the following problems can be considered.

First, there is an improvement of the hint of the folding method used in the experiment. In the experiment, we presented hints in the form of presenting hints in order as requested from participants, but the meaning of hint presentation is to present to guide the next stage to present task. However, in presenting hints, it is possible that the hint provided information to the participant more information than guiding the next step. I can not completely deny the possibility that participants themselves hindered their task because of misinterpretation of presented hints. To solve this problem, it is conceivable to propose experiments that do not use hints when performing similar experiments. When using hints, we devised a hint that gives participants information other than information on guidance to the next stage, so that seeing hints will not affect unnecessarily the performance of the participants alternatively, rather than doing the presentation of hints at the request of the examinee, it is necessary to control the influence of the hint by presenting in order by time.task.

Second, in this study, experiments were conducted on a single experience and a single new intellectual task, but in actual daily scenes, there are a plurality of tasks like a certain task, because there is experience knowledge, we think that expansion of the object is necessary to conduct research on the experience as knowledge and its influence on intellectual task. With respect to the extension of the object, it is given to each task for multiple experiences considered to be related to a certain task, for each task in the case where a single experiential knowledge is affecting a plurality of task a study of the influence that can be considered.

In the case of targeting multiple experiences, it can be said that it is necessary to verify which part of the task affects each of the experiences and verify each other's influence among the experiences. When there are overlapping parts between experiences in multiple knowledge experiences, it is thought that as for the overlapping part, more experience is gained than in the case where each experience has knowledge, it is thought that further development will be given to this research by conducting research such as verifying that fact.

Finally, it is important to verify the influence other than task time on intellectual task by experiential knowledge. In this study, experiments were carried out focusing on task time only on the influence on experience intellectual task given by experienced knowledge, but no differences in experiential knowledge were found among experienced persons in working hours. However, if it is origami, there are differences in experiential knowledge in terms of the completeness of the task, such as the precision of folding, politeness, or the skill of the task itself of folding origami, the awareness and understanding of task. In addition, this is described in Suwa (2015) It seems that there is great correlation with the promotion of proficiency in behavior by comprehension by the connection between the experience in the metacognition method and the word (concept).

From these facts, to verify the influence of experiential knowledge on intellectual task, it is necessary to focus on experiential knowledge itself and to look at the difference within experienced knowledge in more detail. Therefore, if this research is expanded, self-evaluation and objective evaluation of intellectual tasks, comparison of evaluations among the participants and participants, letting the participant orally describe the process of intellectual task, task It is considered effective to make linguistic to intellectual tasks, experiences, such as asking explanations about points and task content.

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Construction of Basic Skill Knowledge for Drawing Pictures

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Knowledge has power to improve human activities including industry and culture. People acquire large amounts of knowledge from their experiences, but the knowledge is not usually systematized and thus artificial intelligence (AI) cannot utilize this knowledge for people. Recent AI technologies such as machine learning and natural language processing support knowledge discovery, but they require big data. Knowledge engineering approaches such as interviews or protocol analysis are also useful to acquire knowledge from human workers, but such approaches are costly because many knowledge engineers must devote their efforts to each people. Under those circumstances, we have proposed a new methodology to develop knowledge structure in order to systematize implicit knowledge explicitly. We designated that methodology as knowledge explication. We have already applied the method to elderly care, university education, and the autonomous vehicle domain already. Sports coaching, playing musical instruments and various kind of therapy are also under consideration. In this talk, we investigate possibility to apply the method to drawing pictures.

Language Arts Education Method Using Programmable Humanoid Robots

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Key words:
Language arts, Language skills, Embodied knowledge, Explicit knowledge, Programmable humanoid robots, Sport onomatopoeias, Education method

Abstract

Professional sports coaches teach sports skills to individuals and teams of all sporting abilities. They help people to reach their full potential and take part safely in their chosen sport. They need to have a coaching qualification that is recognized by the governing body for their chosen sport. Sports coaches with schools and community groups need to describe effective body motion because they must give feedback on effective body motion and help to improve effective body motion. The effective body motion is implied their embodied knowledge and/or explicit knowledge. Embodied knowledge is knowledge that their experience and training are not verbalized. While, explicit knowledge is already verbalized based on their experience and training.

Good sports coaches have high language arts and skills. For example, they teach their embodied knowledge by using sport onomatopoeias and habitual words appropriately. However, some sports coaches cannot verbalize own it appropriately. The reason is that we acquire the embodied knowledge without being conscious of the acquisition of knowledge. Some sports coaches haven’t reached appropriate their language arts to teach their embodied knowledge. Hence, they need improving the language arts and skills to teach sports players.

In general, language arts and skills are composed in the following four aspects: discussion (speak and listen), reading comprehension (read), composition (write), consideration (critical thinking). In the Europe, especially in Germany, they study the language arts from childhood. However, in Japan, we study the language arts and skills only in Japanese (“Kougo”). So, our language skills are lower than theirs one. This is big problem in sports. Sports coaches cannot teach the effective body motion to players for their language are arts and skills are low. In addition, players cannot understand sports coaches’ words. Hence, it is important for sports coaches to improve language arts and skills.

The author proposes a language arts and skills education method to improve language arts and skills of sports coaches. We use programmable humanoid robots instead of "pictures and texts" as a media of language education. Our goal is to propose supporting method for improving of language arts and skills of sports coaches by using those robots.

Development of the pole to present the information for improvement of the skill in Nordic walking

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Keywords: Nordic walking, Accelerometer, Wearable devices

Nordic walking, or walking with poles, is an effective aerobic activity that uses the whole body, including the muscles of the lower body as well as the arms and the upper body. The benefits of Nordic walking are that it can easily be started regardless of the season, and the effect of the exercise is achieved within a short time. Previous studies aimed toward the scientific verification of the benefits of Nordic walking mainly focused on the alleviation of the load on the legs provided by the poles and on the energy consumption. Although a difference in the load on the legs and the energy consumption is expected to occur with technical mastery of the use of the poles, detailed research on this issue has yet to be conducted. Therefore, we analyzed the techniques of both experts and beginners of Nordic walking to gather basic data about their differences.

We developed a system to acquire data by using a three-axis accelerometer attached to the tip and grip of the poles used in Nordic walking. We collected and analyzed the data from both experts and beginners by using this system. One of the results of the analysis indicated that two or more significant peaks existed in the power spectrum of the data of the experts, whereas only one significant peak existed in the power spectrum of the data of the beginners. We expect the features will become useful indexes to differentiate between experts and beginners. Using the results, we developed a program automatically to analyze the data and indicate the features by sounds during the pole work.

Furthermore, in order to miniaturize the system and add other feedback functions like tactile stimulus, we developed another system using Raspberry Pi (a small PC) and Arduino (a microcomputer). Raspberry Pi and Arduino can work with a mobile battery as small wearable devices. The IMU (Inertial Measurement Unit) sensors attached to the poles can measure not only accelerations but angular velocities. The data are saved as CSV files for later analysis. Moreover, the system can provide feedback to the subject via the Arduino using vibrators, LEDs, and speakers. The system was tested by having one of the researchers walk along a mountain road with the equipment attached to the body. We believe that the system contributes to research on the relations between the load and the pole work and the through feedback, improves the pole work of beginners.

Behavioral strategy of stepping-over: differences in obstacle's height and individuals

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Kohei Sonoda, Ritsumeikan University

Keyword
Affordance, Dynamical systems approach, Adaptive behavior, Obstacle avoidance, Behavioral pattern

The present study aims to describe the dynamics of a human adaptive behavior, stepping-over an obstacle in various environmental conditions. The purpose of our study is to investigate how behavioral strategy changes of stepping-over a horizontal bar changing from zero to 90% height of each participant's leg length. Our study is motivated by the theoretical framework of affordance theory in ecological psychology and the dynamical systems approach (DSA) based on self-organization theory. Our goal is to integrate these frameworks with the present stepping-over experiment.

According to affordance theory, to act safely and adequately in the environment, animals must accurately perceive the relationship between environmental properties and their own body properties. For example, in a stair climbing behavior, the height of a displayed stair is perceived relative to the individual's leg length, and when the ratio of each property (stair height/leg length, called the *pi number*) reaches specific values, qualitative changes occur in the animal's behavioral pattern.

Conversely, within the framework of the DSA, an animal's behavioral pattern at the macro-level of the complex system can be modeled as a motion equation using a *control parameter* and an *order parameter*. The *order parameter* describes the low-dimensional behavior that emerges from the high-dimensional neuromuscular system. The model predicts the behavior of a system comprising numerous mutually interacting components (degrees of freedom) at the micro-level, as the dynamics of a few order parameters.

According to the Ecological approach, we apply the variables defined by elements of an animal-environment system to the DSA framework, that is the *pi number* as a *control parameter*. As an order parameter, in the current presentation, we analyzed the Coefficient of Variation (CV) of the toe clearance at the moment of stepping-over the bar.

As a result, although our hypothesis was not supported, some interesting findings were obtained. The Behavioral strategy of stepping-over changed depending on the obstacle's height. It also varied among individual participants. Some participants rotated their knees of the leading-leg horizontally when they stepped-over the high obstacle, whereas others didn't show such a strategy (they stepped-over the high obstacle with their leading-legs keeping vertically). We compared such differences in behavioral strategy and discussed them in terms of behavioral dynamics. Further investigation should be done empirically in the future. It may lead to better understanding of the safe way to avoid obstacles and have the possibility to obtain new insight into safe stepping-over strategy.

Characterizing task-specific motor variability in human skilled movements as dynamical invariants: a case study

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Abstract. Human body is at the center of our day-to-day activities. To reveal bodily skills hidden in our daily life, we need to understand how our central nervous system manipulates our body. Ones hypothesized that the motor variability of our skilled movements is constrained to task-irrelevant subspace. This hypothesis predicts that human skilled movements show small variability in trajectory, where the variability is critical in task performance. We attempted to test this prediction by characterizing human bodily movements regarded as those generated by a dynamical system. The results of our analysis matched this prediction: the motor variability in trajectory, or the degrees-of-freedom, reduces near the 'critical point' of motion regarding the task.

Keywords: skilled movement, motor variability, dynamical systems

1 Introduction

Human body is at the center of our day-to-day activities. Even a simple daily task, e.g., using chopsticks, the movements of our body parts are well organized and coordinated. Craftsmen are people who have elaborated use of their own body for their special task. Motor control system (including central nervous system) that produce movements solving their task flexibly is described as skilled. Nikolai Bernstein in 1940s [1] saw a source of flexibility of our bodily movements in our body's large number of degrees-of-freedom, or motor redundancy: one can achieve the same goal in multiple body coordinations. Among multiple body coordinations, how does our motor control system choose one out of many?

An attempt for this question is by identifying underlying principles of motor control from observed or realized skilled movements for some task. The research groups of optimal feedback control and experimental neuroscience hypothesized that the optimal motor control strategy permits motor variability in movements along task-irrelevant dimensions larger than task-relevant dimensions [7, 8]; Or equivalently, motor variability in movements is constrained to redundant subspace (uncontrolled manifold) [6, 4]. The hypothesis [7, 8, 6, 4] is illustrated in Figure 1 that depicts two kinds of trajectories of some body part (e.g., one hand) produced by well-skilled and less-skilled motor control systems. Their difference may be clear in details, when observing how a trajectory of repeated movements pass through a flat section. The hypothesis states that (a) well-skilled motor control systems constrain motor variability in movements along some task-irrelevant subspace but (b) less-skilled ones cannot constrain and so produce movements undirectedly variable in a (relatively) larger subspace. The key idea of the hypothesis is that the motor control system organizes our movements in order to minimize the task error, and resulting skilled movements show small motor variability where even small variability is critical in task performance.

Testing this hypothesis involves some difficulties in determining such task-relevant and task-irrelevant subspace [5]. In this paper, we view human body as a dynamical system. A trajectory of differentiable dynamical systems preserves the invariant, 'fractal dimension', under smooth transformations. A sort of fractal dimension characterizes the degrees-of-freedom or spatial variability at each point [2]. Thus, by studying such a dynamical invariant, we can confirm the hypothesis regarding skilled motor control systems via their produced movements: the skilled motor control system can be characterized by the dynamical invariant, 'dimension', as well-skilled movements have smaller dimensional than less-skilled ones.

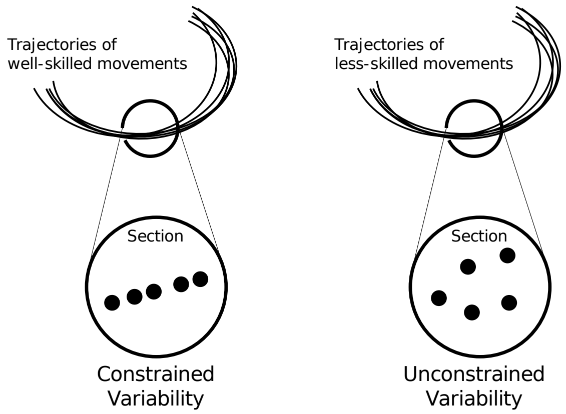

Fig. 1. Task-constrained motor variability. If the motor control system is well-skilled, motor variability is constrained to task-irrelevant subspace (the points can vary only along the 'line'). Unless (less-skilled), motor variability is not constrained to some specific subspace (the points can vary on the 'surface').

2 Experiment: setup and data

We human use primarily our dominant arm (hand) in our daily works, especially when accuracy in movements is needed (i.e., handedness). In this sense, our dominant arm (hand) can be well-skilled. On the other hand, our non-dominant arm (hand) can be less-skilled in our daily works. To test the hypothesis [7, 8, 6, 4] in human movements, our experiment consists of comparison between bodily movements using the dominant (well-skilled) arm versus non-dominant (less-skilled) arm of each subject. By comparing between dominant and non-dominant arms within subjects, the side-effects arising from differences between subjects, i.e., not motor control systems but physical and psychological factors, can be reduced.

The task adopted in this case study should satisfy the two requirements: (1) The task is usually done by the dominant arm but not by the non-dominant arm; (2) Even less trained, the task can be done by the non-dominant arm. 'Throwing-a-ball' is a motion satisfying these requirements, because (1) The dominant arm can be used because it needs accuracy in movements; (2) It is simple enough. For this 'throw-a-ball' task, the most critical point in motion can be about the release point. Based on the hypothesis [7, 8, 6, 4], we predict that this critical point (or release point) can be characterized by the dynamical invariant from the produced movements.

We recorded 'throw-a-ball' motion using the 3D optical motion capture technology of Vicon Motion Systems (8 infrared cameras; each 120 Hz) in our university. Subjects wore the body suit with 39 reflective markers (the plug-in gait marker placement [9] was used). Each subject performed first 5 trials with the dominant arm and next 5 trials with the non-dominant arm (throw a ball 5 times by each arm) successively. No specific target point was instructed. We recorded 4 subjects (3 males and 1 female; between 30–40-year-olds). One of them was a trained handball player in high-school. Another of them has less experience in sports. We analyzed these contrastive two subjects in this case study.

3 Results

To characterize motor control systems between the dominant and non-dominant arms throwing a ball, we focused the data of our analysis on the markers on both arms (6 markers) and shoulders (1 marker). Relative coordinates of the arm markers from the shoulder marker were analyzed to estimate the fractal dimensions. The point-wise fractal dimension estimation method was developed by [3]. For the results below, we used a time-delay embedding of length 10 (we obtained quantitatively similar results for other parameters). Depending on the recording quality of data, some of markers on the hands or wrists were ignored (see below).

First, the movements of the subject who was a trained handball player were analyzed. Figure 2 shows the 5 trajectories of 5 markers on each arm. The subject showed the upright standing posture for the first and last a few moments of each trial. The 5 trajectories (per each trial) were aligned at the times one of these markers reached the highest position. Immediately after these times, the subject released the ball (the release point in the figure). The colors of the points in Figure 2 indicate the estimated fractal dimensions of the points. The dimensions of this subject's movements got relatively smaller around the release point. This result suggests that the motor control of this subject achieved small motor variability around releasing the ball. The result matched our prediction that, in the throw-a-ball task, the dynamical invariant detects the most critical point that is the release point. This observation is common in both the dominant and non-dominant conditions. By comparing the estimated dimensions between the conditions, it suggests that generally the non-dominant arm movements have larger fractal dimensions. In other words, the non-dominant or less-skilled arm shows larger motor variability than the dominant or well-skilled arm.

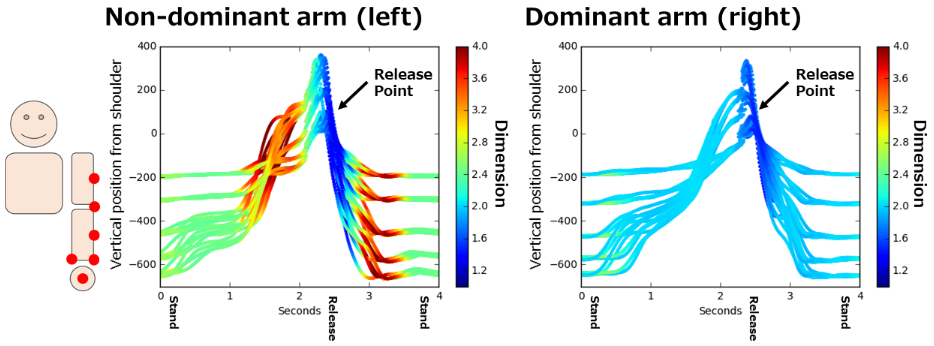

Fig. 2. Trajectories of the subject who was a trained handball player. The colors indicate motor variability characterized by fractal dimensions.

The same procedure of analysis was applied to the other subject who has less experience in sports. Figure 3 shows 5 trajectories of 4 to 6 markers on each arm. These trajectories were aligned in the same way. The colors of the points indicate the fractal dimensions. Similarly to the previous subject, the fractal dimensions of the movements come to smaller around releasing of the ball. That is, this subject's motor control achieved smaller motor variability; but it is not so clear unlike the previous trained subject. When comparing between the conditions, again, the dimensions of the movements by the non-dominant, less-skilled arm were generally larger than the dominant, well-skilled one.

4 Discussion

Within 'throw-a-ball' task, we examined the hypothesis [7, 8, 6, 4] (illustrated in Figure 1) that states (a) well-skilled motor systems constrain motor variability in movements along some task-irrelevant subspace but (b) less-skilled ones cannot constrain and so produce movements undirectedly variable in a (relatively) larger subspace. This was confirmed by our analysis that the dynamical invariant, 'fractal dimension', of well-skilled movements have smaller dimensional than less-skilled ones. Regardless of which arm the subjects use to throw a ball, the

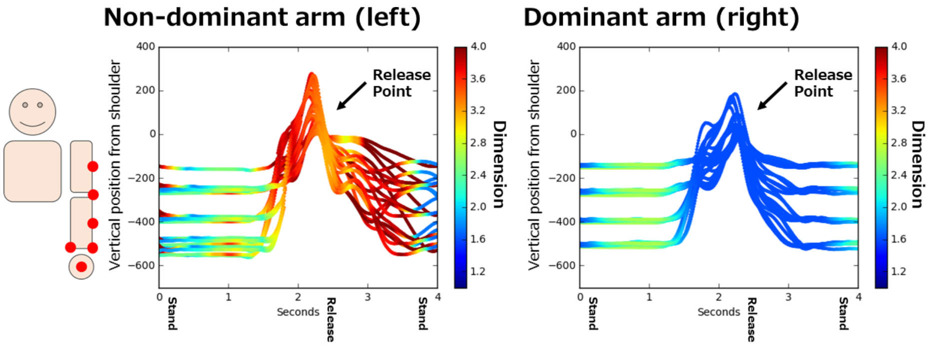

Fig. 3. Trajectories of the subject who has less experience in sports. The colors indicate motor variability characterized by fractal dimensions.

fractal dimensions got smaller around releasing a ball (the release point), which seems to be the critical point in this throw-a-ball task.

Our dominant vs non-dominant comparison seems to work well. The advantage of this experimental design is that the same brain is used to produce movements in both dominant and non-dominant conditions. This does not mean the subject uses in the exactly same way the motor control system; but we think that typically the ways of use of motor control systems within subject could be more similar than those between subjects. If this is true for a task, this paradigm works better to study bodily skills in our daily activities.

In this case study, we analyzed a subset of our full data: only the markers including arms and shoulders. (deleted) Other body segments could take each significant role in this task. We will develop the way to treat multiple body segments, each having different functions toward the same task. To understand how skilled movements are produced by coordinating our entire body, our future works include adding more subjects and developing such techniques. Automatically identifying the subset of mostly task-relevant body segments is a important research topic from the view-point of skill inheritance among craftsmen (how people can).

5 Conclusion

By characterizing the throw-a-ball movements of human subjects by a dynamical invariant, we confirmed the hypothesis that states motor variability is constrained by the task error. By comparing the dominant arm vs the non-dominant arm conditions in the throw-a-ball task, the skilled movements show smaller motor variability near the release point. This result suggests an advantage of this dominant vs non-dominant experimental paradigm for understanding bodily skills in our daily activities.

Acknowledgment

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Analysis of the mental time of participants using the coimagination method with expedition

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This study aims to investigate the suitable criteria for the coimagination method with expedition to help participants utilize recent memory functions during conversations about recent episodes. We analyzed conversation data supported by the coimagination method with expedition by classifying the mental time of participants based on their utterances. In this study, we discuss the effects of the theme of conversation and place of expedition on the mental time of participants using the coimagination method with expedition.

Keywords: Mental time・Coimagination method with expedition・Recent memory

Motion study of breakdancers in mastering Thomas Flare

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It is difficult for anyone to acquire complex skills, which require a long time to master. We investigate the process in which people acquire skills of breakdance called “Power moves”, especially focus on “Thomas Flare”. The same skill is found in gymnastics. Recently, the street dance becomes popular in Japan, as noticed by the fact that it has become compulsory for junior high school since 2012. Furthermore, breakdance was adopted as one of the Olympic programs and it will be held in next year, 2018. From the above there is a possibility that will grow as a market. It is worth probing the true nature of such a complex skill. We divided Thomas Flare by five period, 1: acceleration, 2: leg front, 3: opposite side, 4: leg back and 5: normal side. There is rotation direction in breakdance, and we will explain in the case of clockwise. The first period acceleration, step back with your right foot and plant your right hand, next swing right leg towards the back of your leg. The second period leg front, as you sweep your right leg, lift off the floor with your left leg. The third period opposite side, as your right leg swings up and lift off your right arm. The fourth period leg back, pull your left leg under your right leg. The fifth period normal side, release your left hand and keep your left leg and swing your right leg. We apply a motion capture device to collecting data of bodily movement of the subjects. A Japanese breakdancer, who is active around the world, says that an expert who is doing Power moves roundly move around the trajectory, seen from above. While beginners make progress the skill, it is supposed or expected to improve the locus that is drawn by their movement, for example, an elliptic orbit varies that of a perfect circle. It is said that we need well-muscled in order to do Thomas Flare. However, in our experiment, there is no big difference in a test of strength between beginner and instructor but we found that there are differences which is a movement of the legs while they are doing Thomas Flare. We build a hypothesis that is less important to build muscle than to understand how to move one’s own body. We found that when acceleration, the first step of Thomas Flare, the beginner’s leg moves in a linear, but instructor’s one moves like a circle.

Keyword: Acquisition of the skills, Thomas Flare, Mastery process