Effects on Separated Learning of Acquiring Physical Movement Skills Classified by Level of Difficulty

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It is common to learn skills for sports while moving the body. Based on this premise, a number of supportive methods have been proposed to assist learners by moving their bodies while receiving information presentation, such as visual, auditory, and tactile information presentation. A previous research proposed a learning method called "separated learning", which divides the learning process into two phases: one is to concentrate on receiving information presentation without moving the body, and the other is to move the body. We validated the effects of this separated learning for learning percussion skills using the finger. However, we did not examine whether the effects of this method can be applied to learning whole-body movements such as dancing and whether the effects of separated learning are affected by the difficulty level of learning the dance steps involving the whole-body movements. In this paper, we developed a system to give information presentation on learning dance steps. We evaluated whether the system can be applied to learning the dance steps and whether the difficulty level of learning them has an impact on the effects of separated learning. The experimental results showed that there was no significant difference between the effects of learning the dance step without moving the body and the ones of learning the dance step while moving it.

CCS Concepts: • **Human-centered computing** → Interaction techniques.

Additional Key Words and Phrases: training, learning method, dance, physical movement skill, information presentation

ACM Reference Format:
Leave Authors Anonymous, Leave Authors Anonymous, Leave Authors Anonymous, Leave Authors Anonymous, Leave Authors Anonymous, Leave Authors Anonymous, Leave Authors Anonymous, and Leave Authors Anonymous. 2018. Effects on Separated Learning of Acquiring Physical Movement Skills Classified by Level of Difficulty. In *Woodstock '18: ACM Symposium on Neural Gaze Detection, June 03–05, 2018, Woodstock, NY*. ACM, New York, NY, USA, 17 pages. https://doi.org/XXXXXXX.XXXXXXX

1 INTRODUCTION

Many previous studies claimed that giving information presentation such as visual, tactile, or auditory information presentation in real-time helps people to learn physical movement skills, such as skipping, throwing a ball [31], and playing music [26]. In conventional learning, researchers created the support systems under the premise that learning physical movement skills while moving a body is effective. However, the movement tasks that are used for these researches often adopted simple movement tasks such as skipping and tapping. Under circumstances where people address more complicated tasks, they would not obtain the expected benefit from the information presentation. Also, Todorov et al. [58] developed a support system for learning difficult multijoint movement by minimizing information presentation. Still, it was not sufficient for transfer to the complicated real-world tasks. We should take account in a method giving information presentation should be adapted to various complicated tasks.

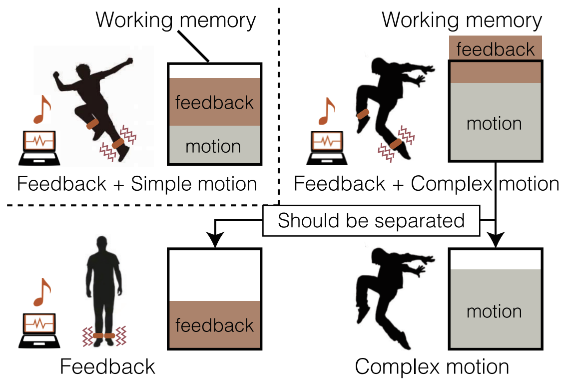

Fig. 1. Lack of working memory.

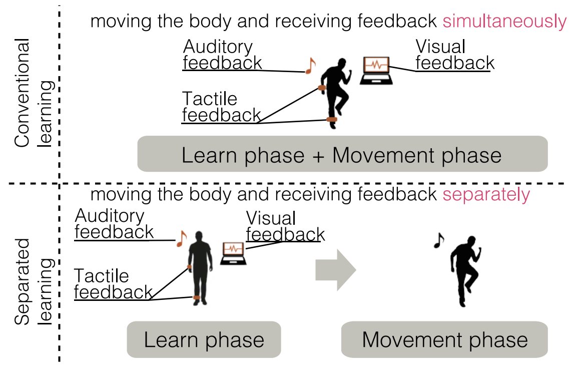

Fig. 2. Concept of a separated learning.

Therefore, we assumed that moving the body and receiving information presentation simultaneously when learning the skills lead to exhaustion in the working memory of our brains. Working memory is a function for handling other processing tasks in parallel, while temporarily storing the information required for various changing purposes. Complicated body movements consume a lot of working memory, leaving no room for embracing information presentation Figure 1). Indeed, there are papers on information presentation and working memory [39]. Buszard et al. [7] reported that when they provided children with five explicit instructions that were specific to the technique of shooting a basketball, higher working memory capacity children displayed consistent improvements, whereas the lower working memory capacity children had the opposite effect.

To tackle the above problem, the previous research proposed a separated learning [28] that separates a learning phase. In this method, information presentation is not given while the learners are performing complicated movement tasks. The learners first receive the presentation of performance information (they are given and internalize information), and then they actually practice it so that it is a two-part learning process (Figure 2). The separated learning supports learners to master some skills.

The previous research [28] applied this separated learning to support learners to master percussion skills. The percussion skills involve fingertip-only movements with complex rhythms. We found that learners who practised the percussion skills after internalizing the information about the skills mastered the skills about 5 minutes quicker than learners who were given information presentation. From the above result, the learners need to pay attention to various aspects when performing complicated movement tasks and have difficulty doing them simultaneously, which lead to a decrease in the effect of information presentation while performing complicated movement tasks. Therefore, the separated learning can be clearly more suitable for helping learners master complicated skills than conventional simultaneous learning.

However, the separated learning does not necessarily work best at all task levels of learning movements, so we need to investigate at which difficulty threshold the separated learning should be applied for the best results (Figure 3). For example, in the case of simple movement tasks such as skipping, we guess that the working memory can cope with both moving the body and receiving information presentation simultaneously. Therefore, the conventional simultaneous learning which provides information presentation in real-time is suited to these tasks. On the other hand, when tackling complicated tasks such as dance steps involving whole-body movements, the learners have a lack of working memory

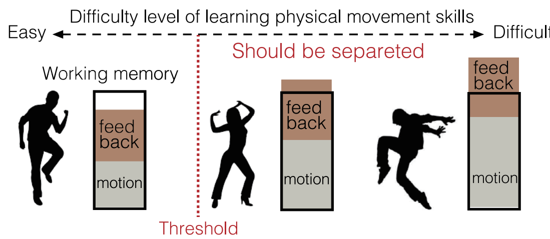

Fig. 3. Difficulty threshold the separated learning should be applied.

which deals with both moving the body and receiving information presentation simultaneously, so the separated learning should be applied.

Therefore, in this paper, which primarily focuses on mastering dance steps, we investigate the effects of separated learning on learning dance steps as classified by levels of difficulty. We aim at clarifying the movements and difficulty levels that affect the consumption of the working memory. This study will lead to clarifying what the most consuming factor is for the working memory, which helps us to understand which learning procedures the learners who want to master the skills should practice and enable teachers to support learners to practice according to individual competence and condition.

A user study prepared four dance steps corresponding to four levels of difficulty. Participants were required to learn these four dance steps with both the separated learning and the conventional learning that gives real-time information presentation. Participants received auditory information presentation via a musical piece, visual information presentation via a reference video displayed on the laptop (where a dancer shows the correct steps), and tactile information presentation via multiple vibration motors.

2 RELATED WORKS

In this study, we try to apply separated learning to the learning of dance movements. Since separated learning contains the process that learners conduct motor imagery, we first review the studies on motor imagery. Next, we describe various methods of supporting learning skills using information presentation. Finally, we describe some studies on dance learning support methods.

2.1 Motor imagery

Motor imagery is a mental process that they simulate their movements in their mind without actual movement for skill acquisition. In the research literature on motor imagery, many terms, such as mental practice [15], motor imagery training [41] and motor imagery practice [13] are used.

Researchers have reported that athletes widely use motor imagery. Murphy [43] reported that 90% of athletes at the U.S. Olympic Training Center claimed to use motor imagery on a regular basis. Ungerleider et al. [62] reported that 85% of over 600 prospective Olympic athletes employed imagery techniques while training for competition.

There are also many kinds of research suggested that motor imagery can improve learning and performance of various sports skills. The effect of motor imagery is shown in individual self-paced activities, such as golf putting [52] and rhythmic gymnastics jumping [2]. The effect of it is also shown in multiple skills that are not self-paced such as rugby tackling [40], tennis service return [53], and table tennis counter-attack forehands [36].

Our study focuses on working memory during movements while receiving information presentation.

2.2 Information presentation

Researchers have proposed many support methods for learning skills using information presentation via various perception.

2.2.1 Force information presentation. A system for learning piano performance with electromagnets [37], a system for learning calligraphy with a robotic arm [24], a system for learning piano performance with electrical stimulation and exoskeleton robot hand that gives a information presentation to skin and inherent senses [25], etc., various support systems that utilize force perception have been proposed. In this study, we first use the visual, auditory and tactile information presentation utilized in the previous research [28].

2.2.2 Tactile information presentation. Many support systems for learning skills using a vibration motor device are proposed [49]. Huang et al. [27] proposed a support system for learning a piano performance called "PianoTouch", which consists of vibration motors attached to the fingers of a glove and presents the fingering information by vibration. O'Neil et al. [48] developed a rehabilitation support system for transitioning from sitting to standing using vibration information presentation linked to users' body balance. Nakamura et al. [44] developed a device that uses vibrations to indicate the timing of dance movements. Camarillo-Abad [8] built a system for communication between a leading dancer and the following dancer via vibration information presentation. In this study, we present tactile information presentation of the timing of raising the knee and kicking the toes forward in a dance step by vibrating a vibration motor like the method that Nakamura et al. [44] used.

2.2.3 Auditory information presentation. A number of support systems using auditory information presentation have been proposed[3, 11, 17, 23, 32, 57]. Okugawa et al. [47] proposed a system that supports a constant pace of pedalling a bicycle using auditory information presentation. Grosshauser et al. [20] attached a pressure sensor to the feet and an angle measurement sensor to the knees of users and sonified the acquired data to support learning dance skills. Yamaguchi et al. [65] proposed a system to support dance education by generating sound in real-time in response to dance. Landry et al. [35] worked on a sonification project to sonify emotions as well as motions and described its application to dance training. In this study, we did not build a system to acquire and sonify the data. We will use a musical piece that contains timing of movement such as rhythm and melody as auditory information presentation.

2.2.4 Visual information presentation. Visual information presentation is one of the most widely used information presentation methods in support systems [4, 58]. Nakano et al. [46] proposed "MiruSinger", which displays the pitch of the current song and the correct pitch. Doi et al. [14] built a system to support learning Japanese traditional instrument "koto" by projecting images on a koto to show musical techniques. Wu et al. [64] developed a VR ski training system that presents the motion patterns of professional ski players in various ways in a VR space, allowing them to learn ski skills efficiently. In this study, as in the case of auditory information presentation, we do not construct a system to visualize the acquired data from dance steps, but display a reference video in which the dancer performs the dance steps on a PC.

2.3 Supportive method for learning dance skills

In this study, we build a support system for learning dance steps to present information. A number of support systems for learning dance skills have been proposed [51].

2.3.1 Automatic scoring and judgment. There are several studies to support the learning of dance skills by providing users with information presentation using some numerical values that get from the systems. Kyan et al. [34] proposed a system that captured and evaluates ballet dance movements in real-time in the CAVE virtual environment and visualized the scores. Chan et al. [10] proposed a system that displayed a virtual character as a instructor using a projector, captured and analyzed the movements of the learner, and outputted scores each body part. In this study, we asked the evaluators with more than 5 years of street-dance experiences to look at the learners' dance and judge whether the learners have mastered the dance steps or not.

2.3.2 Augmented reference video. Some methods to support the learning dance steps by changing the reference dance video or adding information to it are proposed. Fujimoto et al. [19] proposed a method to support learning dance steps by mapping learners' own video to that of a reference dancer. The system generates a sample video of learners' own dancing based on a reference video to support learning dance steps. Some systems [38, 42] mirrors to support learning dance steps. Anderson et al. [1] proposed YouMove, which allows users to check their own movements from various directions in 3D space and provides a variety of information such as scores, movement effects, and text instructions. In this study, our proposed system repeatedly play and display a dance video of about 12 seconds as a reference, without changing the reference video or adding information to it.

2.3.3 Mobile Robot. Some studies with mobile robots are proposed [33]. Nakamura et al. [45] proposed a system in which a screen with reference video is projected on it moves while facing the learner, which allows the user to check the physical distance such as back and forth while practising. Tsuchida et al. [61] proposed a method to support formation practice in group dances by moving a self-propelled screen on which dancers are projected instead of the group members. In this study, the dance steps as a movement task did not include moving to other positions and made learners dance in the same position. Moreover, we did not use a mobile robot to present information.

2.3.4 Virtual reality (VR). Although this study does not utilize VR-based information presentation, we could applied a separated learning to VR systems. Several VR-based support systems have been proposed [16, 50, 66]. Tsampounaris et al. [59] developed a system that allows users to change into different avatars, visualize traces of the movements of various body parts, and interact with virtual objects. Senecal et al. [55] developed a system for presenting virtual partners in salsa dance where practicing with a partner is important. This study found that the motions of inexperienced participants converged with those of skilled participants by practicing with the system. Kasahara et al. [29] found that showing a slightly futuristic video from motion information of users made them feel their body lighter.

All of the above support systems for learning skills are limited to giving information presentation in real-time while moving the body or giving information presentation after practice. It is unclear whether concentrating on receiving information presentation without moving the body is more effective than practising the dance step while moving the body. Our study is challenging in this respect.

3 SYSTEM DESIGN

3.1 Target

This study addresses first-time learners of dance steps as the users of our proposed system. The system focuses on learning elementary dance steps. To avoid giving information presentation, including overly complex information, our proposed system mainly supports learning skills related to lower body movements.

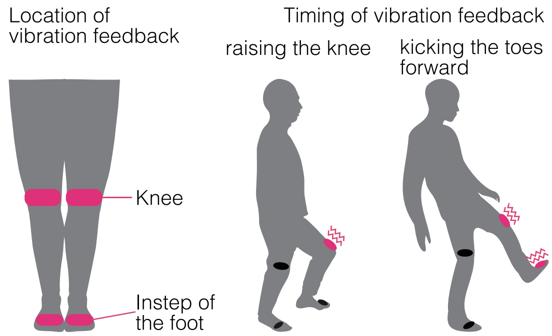

Fig. 4. Location and timing of vibration information presentation.

3.2 Designing information presentation

Camarillo-Abad [9] attempt to indicate the timing of dance step movements using a combination of vibrations from a wearable vibrating device. As well, Nakamura et al. [44] have developed a system to support the learning of butoh dance, including the direction and timing of movements, by placing multiple vibration motors on Velcro straps which can be wrapped around learners' wrists or other joints. In this study, we develop a system that demonstrates the timing of dance step movements through vibration. Specifically, vibration information presentation devices are attached to the learner's legs at four locations: on the knees to indicate the timing when the knee is raised, and on the insteps of the feet to indicate the timing when the toes kick forward. The vibration information presentation device mounting positions are shown in Figure 4. Also, Hall et al. [22] recommend using videos to help learners recall motor imagery; our proposed system presents a reference video in which a dancer performs the dance steps as visual information presentation. This makes it possible to apply separated learning, including a *Learn phase* in which learners concentrate on receiving information, to dance steps at various levels as well.

4 IMPLEMENTATION

We implemented a system for information presentation that can be applied to separated learning in learning dance steps. Our proposed system consists of vibration information presentation devices with four vibration motors for tactile information presentation (Figure 5), a main module for controlling the vibration information presentation devices, a PC for video and audio output, and a timing editing application for vibration information presentation (Figure 6).

A disk-shaped vibration motor (FM34F) was used for the vibration motor, and a MacBook Pro (13-inch, 2019, Four Thunderbolt 3 ports) was used for the PC. The main module is controlled via ZigBee by the PC. The PC sends instruction information to the main module in synchronization with the rhythm of the musical piece in the video, the vibration motor connected to the main module vibrates, and the LED flashes in conjunction with the vibration. A strap and rubber band are used to fix the vibration information presentation device and the main module to the learner's body. The PVC wires connecting the main module to the vibration information presentation device are wired so that they do not interfere with the learner's dance steps.

An application was implemented using openFrameworks v0.11.0. We conducted the operation check on macOS Catalina. The application allows users to control the video and edit the timing of the vibration information presentation. The editing interface for the timing of vibration information presentation is shown in Figure 6. The vertical axis indicates

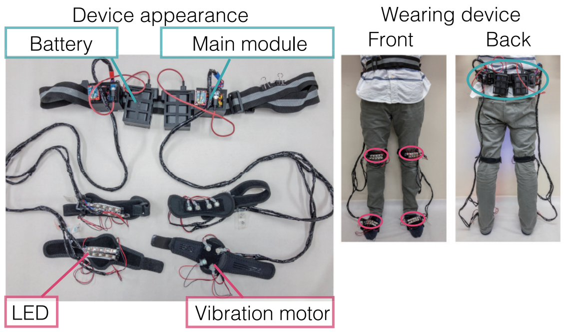

Fig. 5. Vibration information presentation device.

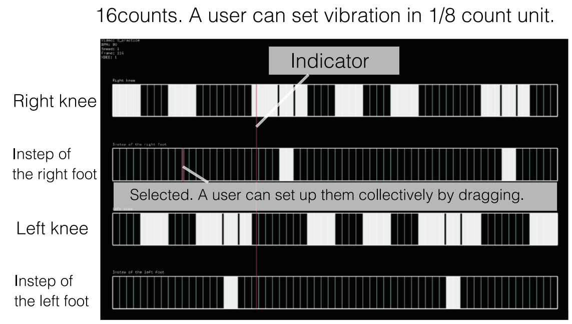

Fig. 6. An interface for editing timing of vibration.

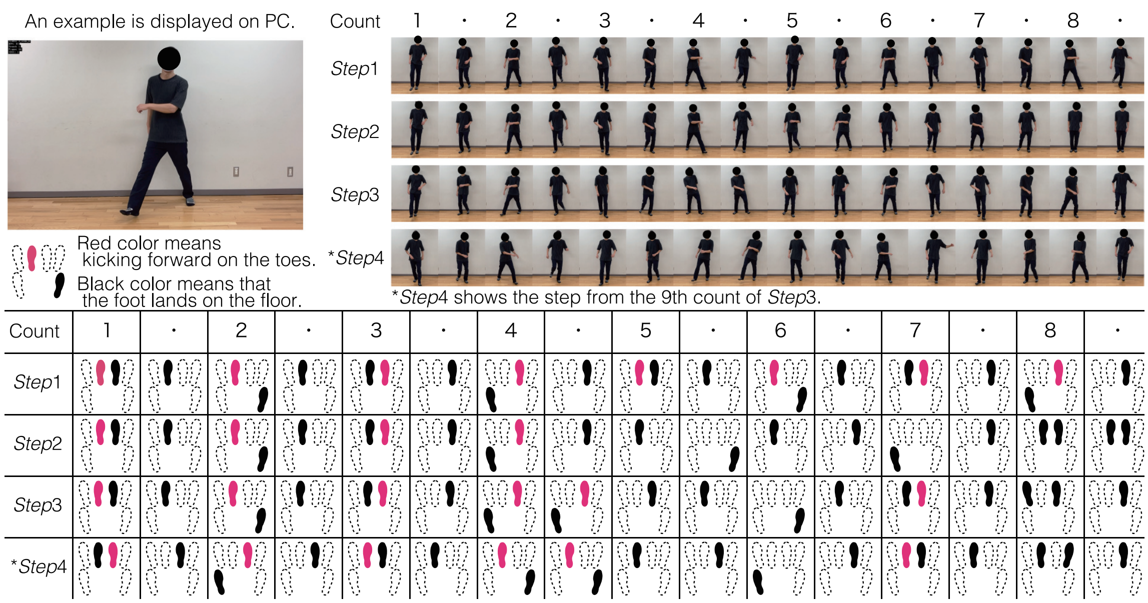

Fig. 7. (Top-left) A reference video for learning the dance step. (Top-right)Images for each dance step per count. (Bottom) Dance notation using footprints (referring to Browning's notation [6])

each position receiving the vibration, and the horizontal axis indicates the timeline. The horizontal axis interval is the beat unit, which is defined as quarter notes within a measure. When the indicator, which moves as the video plays, comes within the range indicated by the white square, the PC sends the vibration indication information to the main module. By dragging a mouse pointer across the rectangular frames on the screen, the user can designate the timing of the vibration to be adjusted. The reference dance video displayed on the PC is shown at the left of Figure 7. The reference dancer's dance steps are shot from the front. When learning steps, it is effective for learners to practice with a mirror [12]. In order to simulate the effect of a mirror, the displayed videos are flipped left to right. For example, when the learners raise their right leg, the reference dancer in the video raises his left leg. The musical piece included in the video uses *mBR0* with an 80 BPM tempo, from AIST Dance Database [60].

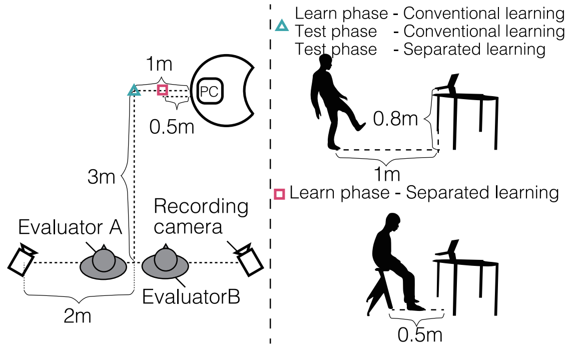

Fig. 8. Floor plan.

Table 1. The number of foot-step combinations. For example, in the RL(right-left) case, the dancer switches the stepping from the right foot to left foot. In the RB(right-both) case, the dancer switches the stepping from the right foot to both feet. In the RS(right-stop) case, The dancer steps to their right foot and stops moving for 0.5 counts.

Step	RL	LR	RR	LL	RB	LB	RS	LS	BS
1	12	12	4	3	0	0	0	0	0
2	12	12	2	0	0	2	0	0	2
3	8	10	4	0	0	2	2	0	2
4	9	9	2	2	1	1	1	1	2

5 EXPERIMENT

We conducted an experiment in order to clarify the effects of separated learning on learning whole-body dance steps classified by levels of difficulty. The participants were 12 university students in their 20s (9 men and 3 women). Their dance experience was at a beginner's level, having participated in group dance performances at school events or taken part in physical education classes in junior and senior high school. The experiment was conducted in a university dance studio with a 43m^2 wood floor. The floor plan of the experiment is shown in Fig 8.

5.1 Dance steps

Participants wore the vibration information presentation device shown in Figure 5 and learned four dance steps (see Figure 5 right). The four dance steps were designed by the first author, who has more than 10 years of street-dance experience, to make each dance step progressively more difficult to learn. Specifically, the dance steps were designed with reference to the combinations of left and right steps (Table 1).

We assumed that the learners would have more difficulty learning dance steps with more variations in foot-step combinations. We also asked a dancer with over five years of street-dance experience to observe the four dance steps and confirm that they were graded by increasing difficulty. We filmed the first author dancing these four steps. The video was cut to approximately 12 seconds and 16 counts at 80 BPM.

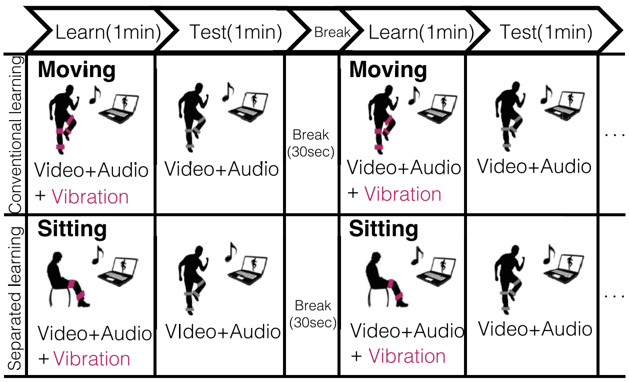

Fig. 9. Learning cycle.

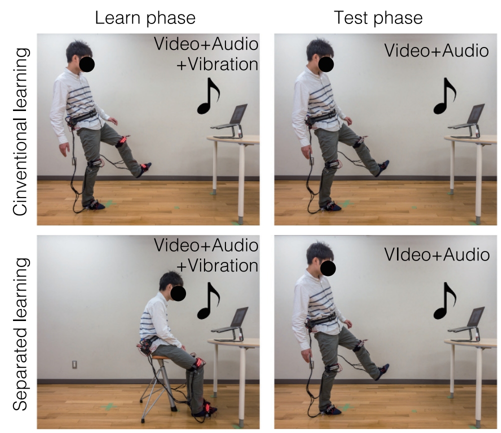

Fig. 10. *Learn phase* and *test phase*.

5.2 Learning method

In the experiment, while receiving auditory information by sound, visual information presentation by video, and tactile information presentation by vibration, participants learn the dance steps through the following two methods:

Conventional learning Learners learn the dance steps by dancing them while receiving information.

Separated learning Learners first receive information presentation, and then dance the steps.

The learning cycle of the experiment consists of two phases, the ***learn phase*** and the ***test phase***. In the *learn phase*, participants learn a dance step for one minute. After one minute of learning, the participants proceed to the *test phase* to check whether they have mastered the dance. If they are not able to perform the dance step correctly in the confirmation test, they take a 30-second break and then return to the *learn phase*. The participants repeat these two phases until they are able to perform the dance step correctly (see Figure 9). Many studies [21, 54, 63] have claimed that the combination of relaxation and motor imagery is effective. Therefore, in order to allow the participants to relax, we provided a 30-second break after the *test phase*. The details of the learning and testing phases are set out below.

5.2.1 Learn phase. Figure 10 shows participants learning the dance steps in each of the phases and with each of the learning methods. The participants received three types of information presentation: auditory information presentation by an audio output from the PC's built-in speaker, visual information presentation by a reference video in which the dancer performs dance steps on the PC's display, and tactile information presentation by vibration information presentation devices that vibrate in sync with the music. During the *learn phase*, the video of the dance step is repeatedly played. The participants, who cannot stop the video, constantly receive information presentation based on the dance step.

In the *learn phase* of conventional learning, participants receive information presentation while performing the dance steps. Our system is not designed for interactive vibration information presentation to the participant according to their dance steps. Rather, it gives vibration information presentation at regular intervals in sync with the rhythm of the music.

In the *learn phase* of separated learning, participants do not perform the dance steps. To focus on internalizing the correct dance step information mentally, they receive information presentation while sitting. We assumed that the stimuli caused by friction between skin and clothes while performing the dance step would reduce the sensitivity of their perception toward the information presentation. The participants were allowed to perform small movements such as foot taps while sitting on a chair, so as not to interfere with the information presentation. In this way, in the separated learning process, the participants first receive information presentation without performing the dance steps; then, in the following *test phase*, they perform the dance steps to check their mastery thereof.

5.2.2 Test phase. In the *test phase*, the evaluators check the dance step that the participants learned in the *learn phase*. In the *test phase*, as shown in Figure 10, the participants listen to the musical piece and perform the dance steps while watching a reference video in which the dancer perform the dance steps. If the participant can perform the dance step correctly for 32 consecutive counts, evaluators judged the participant had mastered the dance step, and the *test phase* ends. If the participant fails to perform the dance step within one minute from the start of the *test phase*, the participant is allowed to retry to perform. In order to judge whether the participant performs the dance steps correctly and continuously, evaluator A, who has more than 5 years of street-dance experience, and evaluator B, who has more than 10 years of street-dance experience, respectively judged. Finally, whether the dance steps were performed correctly was judged by the agreement of the two evaluators. We adopt this subjective judgement procedure by two evaluators because it is difficult to construct an automatic judgement system that can accurately judge whether or not a participant performs dance steps correctly, such as moving the foot laterally or kicking the toes forward.

5.3 Learning cost

In our experiments, we regarded the *learn phase* and the *test phase* as one set of learning costs, and we defined it as the minimum unit of learning costs. For example, if the participant conducts the *learn phase* three times, and they performs the dance step correctly in the third *test phase*, the learning cost is three sets.

5.4 Experimental conditions

All participants learn the four dance steps (*Step*1∼*Step*4) in the same order. This is because the four dance steps were designed to be progressively more difficult to learn. Also, the more difficult dance step is designed on the basis of the movements of the easier dance step. We assumed that if the participant once learned the more difficult dance step, it would take less time to learn the easier dance steps. All participants learned the dance steps twice, once in conventional learning and once in separated learning. For example, a participant applied conventional learning to *Step* 1 and 2 and separated learning to *Step* 3 and 4. We conducted these six combinations of conventional learning and separated learning in two sessions for 12 participants.

5.5 Experimental procedure

Participants first enter the studio, wear the vibration information presentation device, and check that the device does not interfere with their movements. The experimenter explains the participants have to master the four dance steps and our proposed system. To understand the information presentation from the proposed system, the participants watch the video that consists simple foot-steps and kicking the toes forward while receiving visual, audio, and tactile information presentation from the system. This video do not have much influence on mastering the four dance steps. As a *warm up task*, the participants perform foot-steps and kicking in rhythm with the video while watching it. They confirm that they receive vibration information presentation on the knee when the participants raise their knee and on the instep of the foot when the participants kick out forward. While the video is playing, the experimenter explains

Table 2. Learning cost for each participant (white filled cells indicate conventional learning, gray filled cells indicate separated learning).

Participant	*Step*1	*Step*2	*Step*3	*Step*4
A	3	3	2	4
B	3	1	1	2
C	4	3	1	6
D	3	7	2	5
E	1	3	5	5
F	1	1	1	3
G	2	2	3	5
H	1	1	2	5
I	2	1	1	3
J	5	5	1	8
K	3	2	1	3
L	2	2	3	5
Mean	2.5	2.6	1.9	4.5

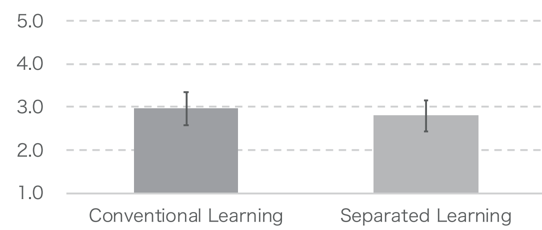

Fig. 11. Average learning costs of each learning method.

the counts while clapping their hands. The experimenter tells the participants that if they perform dance steps for 32 consecutive counts without failure, they have cleared one dance step task. Once the participants are familiar with the system and its tests, they can finish the *warm-up task*. Next, the participants were explained that there are two learning methods (conventional learning and separated learning) and two phases (*learn phase* and *test phase*). Also, they were told to judge whether they perform the dance steps correctly by the agreement of two evaluators in the *test phase*. Moreover, the experimenter explained that the evaluators cannot give any advice to the participants during the experiment in order to unify the experimental conditions. After all the explanations are completed, if there are no questions, the participants signed an agreement document. The experimenter also asked the participants to respond to which of the two types of learning methods they felt was easier to learn: learning the dance steps while moving (conventional learning) or sitting on a chair to focus on receiving the information presentation (separated learning).

6 RESULTS

6.1 Effects of separated learning for learning the dance steps

To begin with, in order to examine the effects of separated learning to learn the dance steps involving whole-body movements, we analyze the learning costs of each learning method. The learning cost of each learning method is shown in Table 2 and the average learning cost of each learning method is shown in Figure 11. The gray shaded cells in Table 2 show the results in separated learning. The vertical axis of Figure 11 shows the mean value of the learning cost and the error bars show the standard errors.

The learning cost for conventional learning is $M = 3.0$, $SD = 1.8$, and that for separated learning is $M = 2.8$, $SD = 1.7$. We conducted a significance test using T-test according to the two learning methods, and there were no significant differences ($p > .05$). This result means that there is no difference in the time it took to learn dance steps between practising without moving under the condition of receiving information presentation and practising while moving the body under the condition of receiving information presentation from the system.

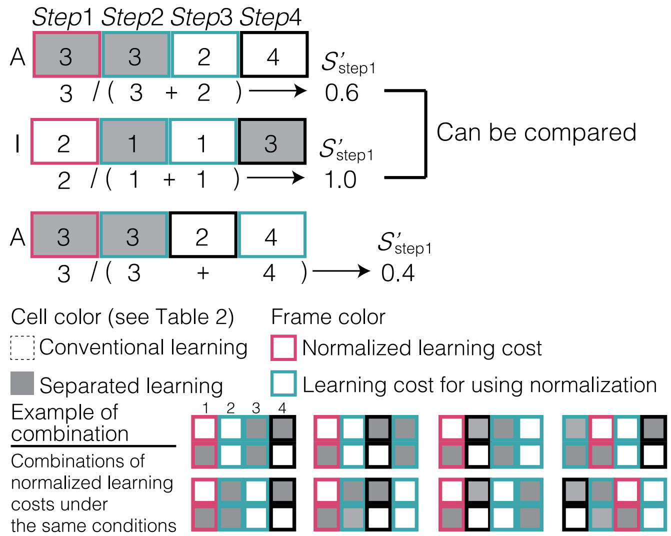

Fig. 12. Combinations of learning methods for normalization that takes into account participants' learning ability.

6.2 Difficulty threshold for separated learning

We analyze the learning cost of each *Step* in order to examine whether there are any changes on the effects of separated learning on learning dance steps classified by level of difficulty. The average learning costs between the learning methods in each *Step* cannot be compared as is, as they vary based on each participant's learning ability. Therefore, we compare the average learning costs by normalizing them by using the sets of learning costs for other *Steps*. Specifically, normalization is conducted based on the following formula(1).

$$S'_{\mathrm{step}k} = S_{\mathrm{step}k}/(S_{\mathrm{step}i} + S_{\mathrm{step}j}) \tag{1}$$

The step number to be normalized is k, the step numbers to be used for normalization are i and j respectively, and we calculate $S'_{\mathrm{step}k}$ after normalization. However, if all the *Steps* except the one to be compared were used for normalization, the difference in learning methods would mean that learning costs could not be compared. For example, suppose we focus on participant A and participant C and want to normalize their *Step1* cost. In that case, participant A uses a separated learning method in *Step2*, while participant C uses a conventional learning method. Therefore, if we simply use *Step2* to *Step4* costs to normalize *Step1* cost, we will ignore the effect of the difference in methods. Thus, they were grouped under the same combinations of learning methods and normalized respectively. Examples of normalization calculations and combinations of learning methods are shown in Figure 12.

The average learning costs after applying normalization based on the participants' learning ability are shown in Figure 13. The vertical axis shows the average learning costs, and the horizontal axis shows the combination of participants. For example, in the case of GH-CD, the bar graphs respectively show the average of the normalized learning costs for participants G and H in conventional learning and the normalized learning costs for participants C and D in separated learning. *Average* is the average cost of learning costs for each learning method. The error bars indicate the average error. We assessed the difference between these normalized learning costs by using analysis of variance (ANOVA). There are two types of factors here: learning methods and *Steps*. There was a significant difference in

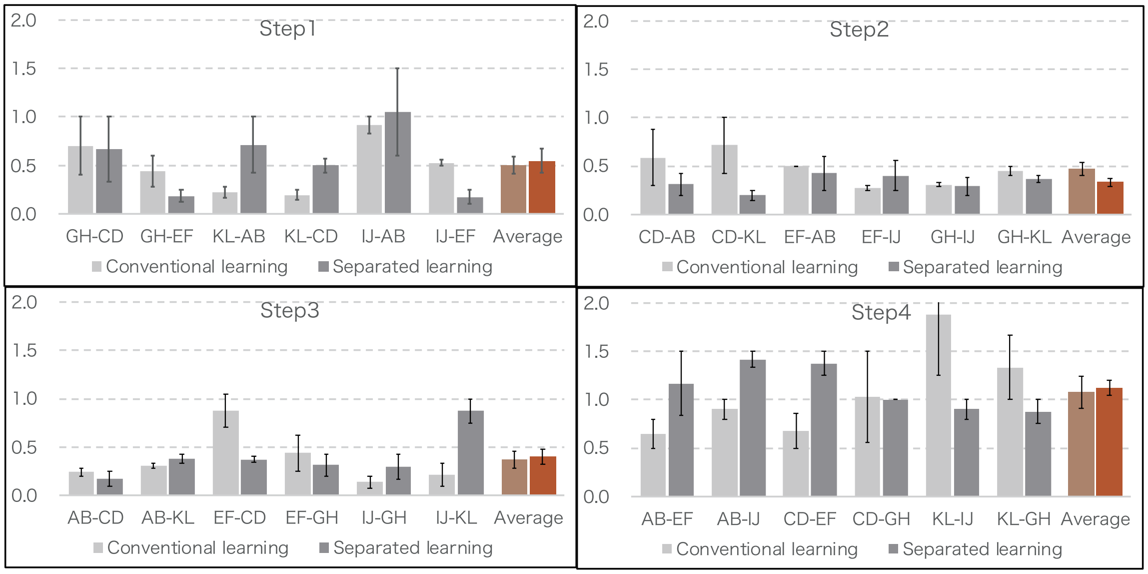

Fig. 13. Average learning costs after applying normalization based on the participants' learning ability.

the *Steps* condition ($F(3, 88) = 23.69, p < .05$), but there was no significant difference in the learning method condition. We also assessed the difference in the *Steps* by using a Bonferroni test. *Step* 4 was significantly greater than all other *Steps* ($p < .05$). The difficulty level of learning *Step* 4 was higher than that of the other *Steps*. However, there was no significant difference between the effects of separated learning on learning dance steps as classified by levels of difficulty.

In each *Step*, the learning costs of separated learning tend to be lower in *Step* 2 than those of conventional learning. In the interview, one of the participants commented *"In the second half, I learned how to remember myself, so I proceeded smoothly"*. This comment was translated by Google translate. In separated learning, learners imagine their own motions in the *learn phase*. However, compared to the index finger tapping movements which were adopted in a previous study [28], dance steps require whole-body movements, which makes it difficult for the participants to imagine their own movements if they have little dance experience. Bertram et al. [5] showed that video information presentation may hinder beginners' learning, so there is room for improvement with visual information presentation. Also, before proceeding to separated learning, participants should begin with a preparatory phase, such as mental rotation [56] for improving motor imagery skills, to help them visualize the whole-body movements mentally. This experiment was unable to confirm that the effects of separated learning changed according to the difficulty levels of learning.

7 DISCUSSION AND FUTURE WORK

During the interview after the experiment, two participants mentioned the gap between their imagined movement and their actual one. The imagined dance steps involving whole-body movements are more likely to be different from the actual movements than in the case of the imagined tapping with the fingertips. The system should give information presentation to perceive, grasp, and visualize three-dimensional whole-body movements to fill the gap between the imagined movements and the actual ones. For example, the system can adapt a method to have a learner perceive three-dimensional whole-body movements by connecting multiple controllable wires [18, 30] to the feet, and a method to give information presentation to the skin sensation and intrinsic sensation by using electrical stimuli and exoskeleton robot hands [25]. Moreover, the visual and auditory information presentation in the experiment consisted simply of playing back the reference video with the musical piece. For example, to support motor imaging from whole-body movements, the system could display a video in which the dancer performed dance steps shot from various directions to enable the learner to see the whole-body movement in 3D space [1]. Text information could also be added to the video [1]. The system could also support the imaged motion by giving audio advice such as "Raise the right knee" or audio output at different pitches depending on the movement of the right and left feet [35]. In this way, increasing the amount of information presentation could make separated learning more effective.

There is also room to redesign the dance steps to create a more sensitive test protocol. In the previous study [28], the average time for mastering skill in separated learning was about 10 minutes. When considering the sets in this experiment, it takes about two minutes per set (one minute each for the *learn phase* and the *test phase*). Therefore, we should adopt tasks requiring an average of five or more sets for learning. However, in the experiment, an average of 4.5 sets was the maximum, and eight out of 12 participants learned the dance steps in one set. If learners master the skills in about one set, they are less likely to receive the beneficial effects of separated learning which are useful for mastering whole-body movement skills. Therefore, the dance steps should be designed so that learning them will take longer.

8 SUMMARY

In this study, we developed a system to give information presentation for learning dance steps involving the whole-body movements. We examined whether separated learning is effective in learning dance steps. The experimental results showed that there was no significant difference in the effect of learning dance steps between receiving information presentation while moving the body and concentrating on receiving the information presentation without moving the body during performing dance steps. This shows that even though the participants felt it was more effective to learn dance steps while moving, learning them while moving was not necessarily more effective than learning without moving. Based on the findings from the experiments, we present a proposal for improving the proposed system to apply separated learning. We also examined whether the effects of separated learning is affected by the difficulty level of learning the dance steps or not. There was no significant difference between conventional learning and separated learning. However, for some people, separated learning may be effective depending on the difficulty level of learning. In the future, we will investigate the structure of the system and the phase for applying the separated learning, and aim at finding the threshold of effects to apply the separated learning according the difficulty levels of learning.

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