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Poster

Proposal for 3-Arm Motor Skill Training Considering Spatial Awareness and Cooperative Action Involving 3rd Hand

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Abstract

*The term **Jizaika** can be defined as the ability to work with high efficiency involving wearable robots such as 3rd Hand. However, research has shown that a conflict might arise when a person attempts to use both their natural and additional arms, which could make it impossible to optimize performance. Therefore, we proposed a 3-arm motor skill training in VR to observe the change of subjects' behavior. Our results suggested that the proposed training may improve performance of 3-hand body and provide a possible approach for future research.*

CCS Concepts

• ***Human-centered computing*** → ***Empirical studies in HCI; Virtual reality;***

1. Introduction

In general, Jizaika can be defined as the ability of working with high flexibility and high efficiency with the body involving augmentation devices. However, research has shown that although humans are able to control the additional limb with their natural limbs working concurrently, they might face a downgrade in efficiency for their own natural arms when robotic arms are involved [GPFA20]. Therefore, we consider an appropriate Jizaika training system to be essential if the goal is for users to not only know "how to use" the additional body part, but also "how to work with "both" of them.

Based on related works regarding training on human and external body [BDM11] [KCMMM21], a VR motor training system was proposed with a focus on improving two abilities related to 3-hand Jizaika: **spatial awareness** and **cooperative action**. Our study examined the change in performance and behavior after training with designed evaluation tasks. Our hypothesis was that the upgrade in performance (e.g., less complete time needed) could be observed and subjects might show difference in usage area of each arm between the evaluation task pre and post training, which could be an indication of how a practical "Jizaika" body with 3 arms looks like.

2. Experiment

2.1. Setup

12 participants took part in this study with VR experience ranged from 0 to 3 years. Our experiment required subjects to wear a VR headset, a VR tracker on their left shoulder, and hold a VIVE controllers on each of their hands. Subjects controlled an avatar in VR with a length-fixed 3rd Hand attached on the left shoulder, the movement of owns' hand could be tracked by VIVE controller and 3rd Hand could be control by head rotation (2DoF), as Figure 1 showed. The experiment procedure was shown as Figure 2. Evaluation tasks would be conducted before and after training for comparison.

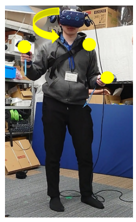

Figure 1: *Subject during the Experiment*

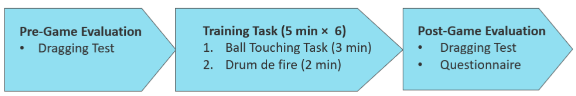

Figure 2: *Experimental Procedure*

2.2. Training Task

The training task consisted of 6 rounds and would last 30 minutes. There were two training tasks proposed. As shown in (a) of Figure

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4, Ball Touching Task was designed to develop **spatial awareness** around Jizaika body of 3 Arms. During the task, subject would touch the labelled ball (L/R/T) that appeared randomly with corresponding hand. We assumed that they would experience several motor motions and learn how to use **each 3 arms** quickly and precisely during the process, which eventually stabilized the spatial relationship within their mind between 3 arms (e.g., knowing to use which arm in certain area). The second training task was Drum de Fire. This was a game in which player prevented multiple fire targets from shrinking through constant touch. This task was used to develop **cooperative action** between 3rd Hand and their natural arms. During training, we wanted to determine whether subject is capable of learning how to use **all 3 arms** simultaneously and smoothly. With the acquisition of this skill-set, our assumption is that subject will eventually figure out how to combine the movements of 3 arms to perform in more complicated task involving the collaboration work between all of them.

(a) Ball Touching Task (Left) and Drum de Fire (Right)
(b) C1 (Left) and C2 (Right) of Bottle Dragging Test

Figure 3: *Training Task and Evaluation Task*

2.3. Evaluation Task

As shown in (b) of Figure 4. The evaluation task could be divided into 2 conditions (C1 and C2). Subject was expected to face more unpredictable situations and had to solve the required task with more free planning in using 3 arms compared to the training task. For both C1 and C2, subject were asked to drag bottles into the box in front as soon as possible. However, for C1, 20 bottles would appear **1 by 1**, which require subject to have clear spatial awareness for each arm. For C2, 20 bottles would appear **all at the same time**, which requires subject to preform cooperative action of 3 arms smoothly. The performance judgement would depends on the complete time of test. For C1, we recorded the complete time of finishing grabbing 20 bottles. While for C2, we recorded the complete time of finishing grabbing 14 bottles, in order to fully focus on the situation of subjects dealing with **multiple** targets.

3. Result and Discussion

The complete time of evaluation task significantly decreased after training in both C1 and C2 (Wilcoxon signed rank test, $p < 0.01$),as well as a clear growth shown in score for training tasks through round 1 to 6 ($p < 0.05$). It showed that subjects were indeed able to apply what they learned in training on other more general tasks,

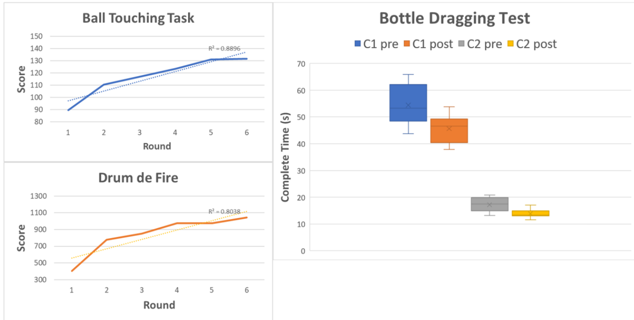

Figure 4: *Score of Training Task (Left) and Complete Time of Evaluation Task (Right)*

which might indicate a successful motor training as well as a successful skill transfer. Also, the usage number percentage of each arms didn't show significant change through training (n.s.). Therefore, we could also conclude that the improvement didn't come from solely focusing on specific arms, subjects did indeed improve the performance of "3 hands"-body by training.

Last but not least, several changes in behavior were also observed after training. In C1, subjects showed significant decrease in usage distance of left hand ($p < 0.05$) after training. However, in C2, we observed the usage of 3rd Hand moving toward right after training ($p < 0.05$), which was a totally different change to C1. These results indicated that the selective usage (C1) and cooperative usage (C2) of three arms might require different training approach in order to improve performance.

4. Conclusions

Overall, the performance of 3 hands body did successfully improve through proposed training and some changes in behavior were observed as well, which should be beneficial for future research. Further study are required to figure out how Jizaika might affect the natural body and the relationship between each change in behavior.

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