Embodied Noise – Towards Augmenting the Dart-Throwing Practice over a Sleeve with Randomized Haptic Actuation

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ABSTRACT

Effective training lives from a large degree of variation according to physiological research principles of deliberate practice. In this paper, we introduce a novel way of training by adding kinetic noise (randomized haptic vibrations) to the training process. Over the vibrations, we make the training process more difficult and hope to add variation (an important aspect of skill training in the psychology literature). We present an initial study (n=8) of dart-throwing training as a system test. Four users train with a sleeve (random vibro-tactile and thermal actuation) and 4 users are the control group (no sleeve). Both groups improve significantly over the training period (p <.05). Yet ,the effect size is too low to make any claims regarding effectiveness between the groups. Still we believe our approach could be promising, we will explore in future work how to enhance skill acquisition training over randomized haptic actuation.

CCS CONCEPTS

• **Human-centered computing** → *Wireframes.*

KEYWORDS

Noise, Training, Human Sense, Human Computer Interaction

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1 INTRODUCTION

Imagine the following: You are learning to ice-skate. At the beginning it seems a daunting task, requiring several skills at the same time and the dedicated advice and feedback from a teacher. Yet, after a couple of years, even if you haven't been skating for a long time, you can probably just start doing it again (maybe a bit rusty) without thinking much about it and without even being able to describe the individual steps it needs for a novice to perform well. There are a lot of tasks that involve body control and movement that are difficult to learn, but more crucially also difficult to describe in terms of learning steps. Yet, if you have done them once you can do them again (and over time you gain a mastery of them), from skiing, over riding a bicycle, to juggling and even simple tasks of balancing to the expertise of playing musical instruments or making pottery.

Applied psychology literature suggests deliberate practice as an important concept for successfully training such tasks [1, 4]. Deliberate practice involves engaging in activities beyond your current abilities, usually under a teacher's instruction and monitoring. The key is not to power through m̈indless repetitionsb̈ut being engaged in the learning task and getting constant feedback. Given the time, engagement and variation, the learner will get an inert feeling on how to perform or practice right [1]. In signal processing terms, the learner comes to understand the signal over variation, such as the relation between body posture, movement and negative/positive outcomes. Our approach follows deliberate practice in adding variation and difficulty to the training over random hatpic actuation. We hypothesize that it will help the learner to grasp the core concept of what they want to learn better and faster.

In this paper, we focus on thermal and vibrotactile actuators for the random haptic actuation during dart training. We apply the stimuli together, as we are interested in the technical feasibility of our prototype and a first user test. In later studies, we will apply the actuation separately.

In terms of related work, there is of course a lot of research focusing on skill acquisition using virtual and augmented reality technologies [5, 6, 8, 9, 11–13, 15]. A lot of researchers take advantage of the immersion of VR to present a more realistic experience during training [3, 13]. There are however, some publications focusing on proprioceptive and kinetic learning, for example, using artificial muscles to actuate finger movements during piano or other musical performances [2, 14].

Closest to our research is work, Milton et al. and colleagues found that balancing a stick on a vibrating board made a positive, significant difference [7]. To the best of our knowledge, we are the first to apply random kinetic actuation for skill training.

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The contributions of this paper are as follows: (1) we present the concept of Embodied Noise adding practice variation over random haptic actuation to the human body to improve the learning of skills, (2) we design an initial haptic noise (vibrotactile and thermal) generating prototype to implement the concept for dart-throw training, (3) we present an initial study (n=8) of dart-throwing training, showing that it's technically feasible to implement our approach using a haptic sleeve (vibrotactile and thermal) with random activation for dart training.

2 EMBODIED NOISE APPROACH FOR TRAINING

For the purpose of the paper, noise is defined as irregular fluctuations that accompany a type of signal or information. Noise is usually seen as something unwanted or detrimental to signal quality that needs to be removed. There are already some reported instances where adding noise has been shown to improve overall system performance in several medical and physiology domains, etc.[10]. There is related work showing motor learning improve over random variation [16].

We approach noise as something useful that can not only enhance motor skill task performance under the right circumstances but can also potentially enhance learning through assisting deliberate practice over increasing variation during the training process [1].

3 DART TRAINING PROTOTYPE AND USER TEST

We present an initial experimental setup focusing on random vibrotactile and thermal actuation on the arm during dart training. We hypothesize that training dart-throwing with the sleeve will be more difficult introducing random variation to the training [16]. Our critical assumption is that kinetic activation of the arm can be seen as a kind of random variation of the training practice, making the user more aware of their movements.

The initial user test is to evaluate the validity of the experimental setup. We build a sleeve with 2 types of actuators. As mentioned, we focus on thermal and vibrotactile actuators and we apply the stimuli together, as we want to see if the approach is technically feasible and if our prototype can work correctly during the setup. In later studies we will apply the actuation separately. In the following we describe the initial prototype and the experimental setup.

Apparatus. The device is worn as a band the forearm of the user's dominant arm (Fig.1,B). The device has two Peltier elements(TEC1-12708) and an oscillator(LD14-002) each presenting random vibrations and warmth through the ESP32 and Bluetooth modules (Fig.1,A). Each actuator and module is placed on the outside of the arm so as not to interfere with elbow flexion. The controls utilize a specially designed PCB, and the whole thing runs on a common lithium-ion battery. The uniform randomly presented warm sensations are presented for no more than 3 seconds at maximum and cool down for 0.8 times longer to prevent thermal runaway of the Peltier elements. The actuation of the Peltier elements and the vibrotactile actuators are simultaneous for this setup. The device prototype PCB and description is open-sourced under **blinded for review**.

As participants are to aim for the center of the board, we use the distance of the dart and the center as a factor of improvement in darts training. In order to calculate them, we used OpenCV analysis was used to detect the coordinates. For this purpose, we set up two cameras at a distance of 1m from the dartboard as shown in Fig.1C, and a dart arrow with a green colored tip. The markers obtained from the left and right cameras were detected with green pixels, labeled, located, and presented as shown in (Fig.1,D) by projection transformation.

Participants. We recruited 8 participants the university bulletin board to our experiment. 6 participants identified as male, 2 as females and 0 as non binary with an average age of 29. All participants were students at **blinded for review**, yet not familiar with the type of research our researchers were performing. All participants were beginners in darts (they had either never played or just tried it once or twice a couple of years ago).

Ethics. The experiments were conducted according to the ethics rules, regulations and approval of **blinded for review**. All users were informed about the experiments goals and risks and agreed to participate with informed consent (signing a form). Participation was voluntary, and users were free to decline or cancel their participation anytime. We did not disclose our concrete hypothesis related to the vibrotactile sleeve (increasing the difficulty to make them better) until after the experiment was concluded.

Study Setup. The study period was 5 days. The fist day started with a baseline assessment, the last day ended with a final assessment. The study was conducted according to the official dart rules: we used a 15.5 inch board, with a height of 173 cm from the floor to the center, and the throwing line was at 237 cm. Each events to be played were based on a count-up system, with a total of 1 game, 8 rounds, 24 throws. The experiments were divided into three phases: baseline assessment, training period, and final assessment. The baseline assessment and final assessment consisted of one game, while the training period consisted of three games per day for five days. Four users were randomly selected to wear the device and train in the presence of vibrotactile noise during the training period. Baseline and final measurements were taken with all users not wearing the device. Users were instructed to always try to hit the center of the board when playing, and all results were measured by coordinate detection. All participants were beginners in darts.

4 INITIAL INSIGHTS AND DISCUSSION

In the experiment, we counted a total of 408 throws for each user and 3264 throws in total. At baseline, the device users had M=9.648cm (SD=2.187) and the control users had M=7.884cm (SD=1.692) distance from the center. At final assessment, the device users had M=8.706cm (SD=1.793) and the control users had M=7.04cm (SD=1.918) distance from the center. As a result of t-test, there was a significant difference between the scores on the first day and the last day in both data. Device user ($t=3.168$, $df=3$, $p<.05$) , Control user ($t=3.138$, $df=3$, $p<.05$). The data were normalized and the average change in distance between the baseline (indicated with "B") and each day's data is shown in Fig.2.

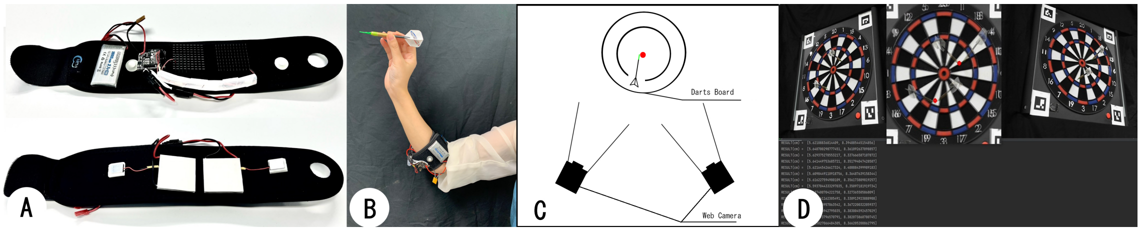

Figure 1: The thermal/vibrotactile sleeve prototype (A), participant wearing the prototype on their dominant arm(B), the scoring system schematics to record the result (C), pictures of the experimental setup system for dart training (D).

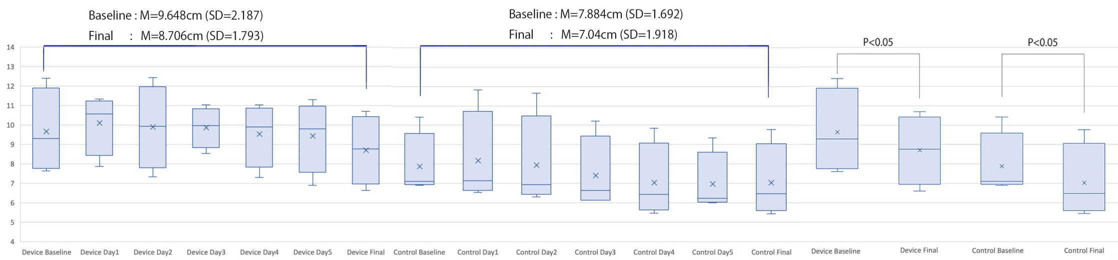

Figure 2: Initial results. Distances to the center for dart throws over all participants, left is the device group (n =4), middle the control group (n= 4), on the right the comparison of the beginning versus the final assessment.

The results show that for the training period, the group without the device was able to throw more centrally compared to the baseline. Fig.2 shows this as the distance to center is overall smaller for the control group compared to the device group. We assume that the device makes the throwing more difficult. Yet, there are also a lot of other confounding factors. Due to the small sample size we cannot see any significance in terms of learning efficiency or speed between the groups.

Overall, the technical feasibility test worked, we can actuate the randomized haptic feedback while the users are throwing and we can record the distances for both groups, control and device. In the next study we will run a longer more representative test to see if we can find an effect in terms of training.

5 CONCLUSION AND FUTURE WORK

We propose to use random haptic actuation during motor skill learning, to make the learning process more difficult and increase movement variation which should lead to better overall performance according to the deliberate practice concepts. For a first implementation, we focus on a haptic sleeve for dart-throwing practice. In this study, we conducted a short-term feasibility test for training dart-throwing, and found that our prototype works as intended.

We show the technical feasibility of our approach and will now continue to conduct a larger experimental study exploring different randomized thermal and vibrotactile patterns versus a control group to explore improving the dart training. We also want to explore comparing thermal versus vibrotactile activation in the future works.

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