Stimulated Percussions: Method to Control Human for Learning Music by using Electrical Muscle Stimulation

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ABSTRACT

In musical performances, it is important to produce rhythms correctly. However, when beginners play musical instruments, it can be difficult for them to understand rhythms using only visual and auditory rhythm information. To solve this problem, we propose the Stimulated Percussions (SP) system, which generates rhythms on a computer and transfers them to a user's muscles. In this study, we control the user's arms and legs using electrical muscle stimulation (EMS). We attach electrodes near certain arm and leg muscles, and provide stimulation in a manner that allows users to reproduce the correct movement when they play instruments. Our system enables a single player or multiple players to correctly reproduce generated rhythms. Experimental results show that our system is useful for beginners learning musical instruments, because it allows accurate rhythms to be mastered through bodily sensations.

CCS Concepts

•**Human-centered computing** → **Human computer interaction (HCI);** *HCI design and evaluation methods;*

Keywords

Musical performance; Electrical Muscle Stimulation (EMS); Rhythm learning

1. INTRODUCTION

Rhythm is one of the three elements of music (Melody, Harmony, Rhythm), and is an important aspect of musical performance. However, it is difficult for beginners to play rhythms correctly. Typically, when a person is producing a rhythm, the following process flow occurs.

1. The person looks at the notes and/or listens to the sounds.
2. He or she understands the rhythm in his or her brain.
3. His or her muscles move.
4. Sounds are produced by the musical instrument.

However, for those who are not trained, it is difficult to transition from process 1 to process 2. In other words, owing to their lack of musical experience, beginners cannot understand rhythm using only visual and auditory rhythm information. Especially in the absence of a teacher who understands the rhythm, beginners may be unable to understand the correct rhythm. Therefore, we consider that people can understand rhythm using a method that works in the different direction to the above-mentioned process. Whereas the traditional process is from the eyes or ears to the brain and muscle, the approach we propose is:

1. Computer provides rhythm information as muscle electrical stimulation.

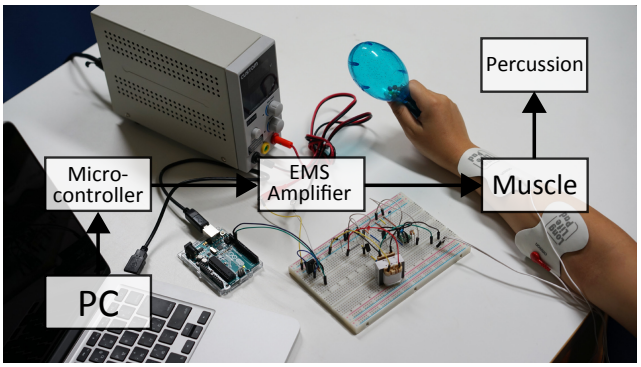

Figure 1: Overview of our system

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2. Muscles move (subconsciously).

3. Sounds are produced by the musical instrument.

4. The brain understands the rhythm.

5. Muscles move.

6. Sounds are produced by the musical instrument.

In other words, we are attempting to ascertain whether people can understand and reproduce their movements by moving their bodies independently of their consciousness. In this study, electrical muscle stimulation (EMS) is used to convey the rhythm to the muscle. EMS is used in low-frequency therapy equipment and muscle building machines. EMS recipients can be made to move their bodies without consciousness.

Our work is based on the contribution of [1]. In the current work, we make the following new contributions:

1. We discuss the muscle-brain-muscle process in terms of music learning.

2. We confirm by experiment whether rhythm learning can be conducted using the method described above.

3. We ensure that users can play musical instruments using the proposed method.

2. RELATED WORK

Continuous efforts have shown the possibility of controlling body movements using EMS. Lopes et al. proposed extending the affordance by allowing users to communicate dynamically. They actuated users by controlling their arms using EMS [4].

Few studies have attempted to use EMS to teach the playing of musical instruments. Possessed Hand stimulates the creation of several hand gestures by controlling fingers [9]. Using their fingers, users can play musical instruments such as a piano or Koto (Japanese harp). Nagashima et al. developed an electromyogram bio-feedback system and applied that system to musical performances [7].

In addition to the EMS-based methods, research has been conducted on various methods that support music performance. It is difficult for beginners to read music notation. The P.I.A.N.O. method makes it possible to play the piano without understanding music notation, by presenting visual information that is not a score [10]. Supporting methods are also being studied in terms of improvisational participation in music performance. Human Coded Orchestra makes it possible for several people to improvise choral music when guided by sound from directional speakers [8].

Music learning methods that include haptics in addition to vision and hearing have also been proposed [2, 3, 6]. These systems use vibrations to provide users with tactile senses. The fact that users can learn rhythm information through the body is a common point between haptics-based research and EMS-based research.

3. IMPLEMENTATION

In the current implementation, the stimulation pulse frequency was set to 40 Hz, the pulse width was 0.2 ms, and the pulse height (voltage) ranged from 17 - 29 V because it is adjusted to the human impulse required to exercise muscle [9]. We set the stimulation pulse frequency to 50 - 70 Hz, and the pulse width to 0.8 ms. The pulse voltage can be modified to accommodate different users and different muscles earmarked for movement.

SP consists of a circuit, a microcontroller (Arduino), a PC, DC stabilized power source equipment, and electrode pads (OMRON HV-LLPAD), as shown in Figure 1. In the circuit, we used a 555 timer to generate pulses, and a transformer was used to increase the voltage [5]. When the voltage of the DC stabilized power source equipment is increased, the electrical stimulus strengthens and the response of the human body is enhanced.

3.1 Pad Position for Playing Percussion

We searched for the correct pad position to reproduce the movements of a user playing percussion instruments, by considering the movement of the muscles as shown in Figure 2.

- **Pad position (Figure 2a)** shows the location for stimulating the extensor carpi radialis longus and brevis. These muscles extend the wrist joint. We consider this pad position to be suitable for playing the triangle or the maracas because players need to snap wrist when they play these musical instruments.

- **Pad position (Figure 2b)** shows the location for stimulating the biceps muscle of the upper arm, the brachioradial muscle, and the extensores carpi radialis. The biceps muscle of the upper arm and the brachioradial muscle control the flection of the elbow joint. Because the forearm and the wrist move, this would enable a person to play a beat with sticks. There are a lot of musica instruments played with sticks such as snare drum, glockenspiel and timpani. Players play these instruments using the extension and the flection of elbow and wrist.

- **The pad position (Figure 2c)** shows the location for stimulating the gastrocnemius muscle, which controls the plantar flexion of the foot joint. When stimulating the gastrocnemius muscle with the heel on the floor and the foot pointed upward, it is possible to obtain rhythmic movement with the foot. It is also effective for playing the musical instruments equipped with foot pedal. For example, drum set bass drum, vibraphone and piano have a foot pedal or multiple foot pedals.

4. USER STUDY

We determine whether the work process called muscle-brain-muscle is actually occurring by comparing it with the conventional process. Because it is generally difficult to produce different rhythms with the left and right hands, we asked the study participants to beat a quadruple measure on the right hand and a triple measure on the left hand simultaneously. They performed it first without SP; the next round was performed using SP. The correct rhythm is shown

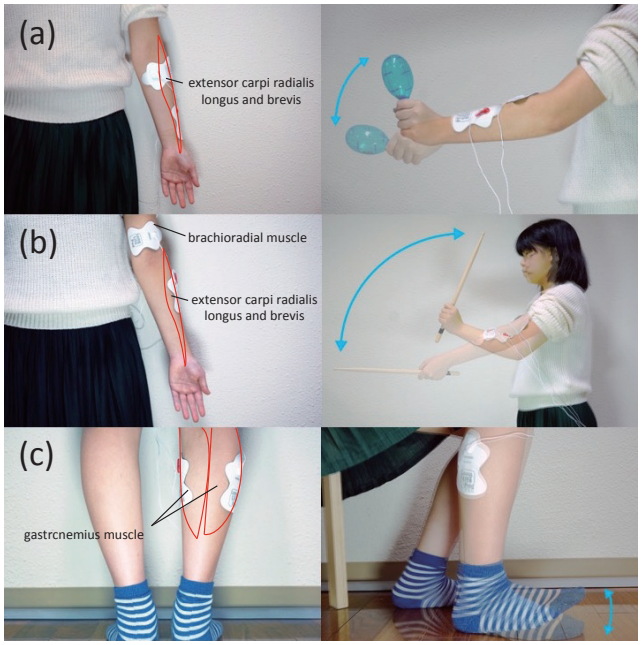

Figure 2: Pad positions of EMS and movement. (a) Extension of the wrist joint. (b) Flection of the elbow joint and extension of the wrist joint. (c) Plantar flection of the foot joint.

in Figure 3. There are guide sounds in both cases. Pad position (b) in Figure 2 was employed when using SP. To obtain the timing of the beat being played, we attached a marker to the end of the drumsticks and used motion capture to record the height from the top of the desk which participants beat. Twelve participants (2 females, 10 males) aged between 18 and 29 years (M = 20. 0, SD = 20.7) participated in the experiment.

5. RESULTS

Six participants produced the correct rhythm using SP. Figure 4 shows the height of both sticks and their timing. The quadruple measure produced by the right hand is shown in blue, and the triple measure produced by the left hand is shown in orange. The point where the height reaches 0 beyond the peak of the graph indicates the point of the hit. Without SP, the movements of the right hand and left hand are opposite, or the first beat is not aligned. As Figure 3 (b) shows, the height of both hands must be 0 at the same time at the first beat. In contrast, with SP, the point hit by the right hand and by the left hand almost agree with Figure 3 (b); thus, the correct rhythm is being produced.

5.1 Interviews

Participants who produced the rhythm correctly conveyed their impressions to us.

- P4 who has musical experience: this system may be good for people who have few musical performance experiences to confirm the rhythm.
- P7: When I was beating the rhythm with stimulation, my body understood the rhythm!

Others stated their impressions as follows.

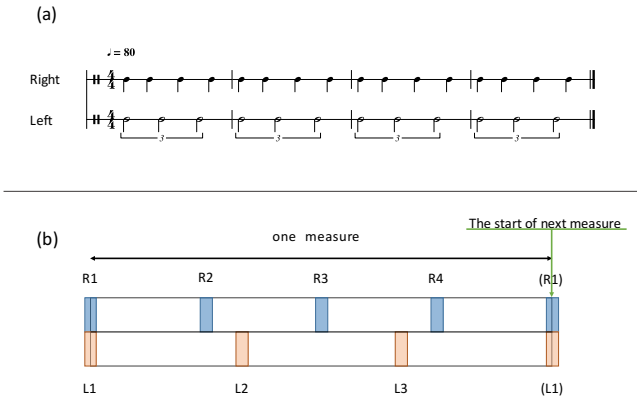

Figure 3: The correct rhythm that participants should produce in the USER STUDY. (a)Representation in musical notation. (b)Timing of beat (R is right, L is left; the figure indicates the number of beats in that measure)

- P8: "When I tried to beat the rhythm adjusting the stimulation, I couldn't understand the right rhythm."
- P11: I felt discomfort by stimulus before my arms or hands started moving.

6. APPLICATIONS

6.1 Learning Rhythms for Beginners

Experimental results suggest that SP can be used for learning rhythms. This method is not limited to playing percussion instruments, because pressing a key of a wind instrument or a piano is similar to beating a percussion instrument. With SP, it is possible for a novice who cannot read a musical score to learn the correct rhythm. The impression of participant (P4) indicates that a person with a little music performance experience can confirm the rhythm. Playing in an ensemble without understanding the correct rhythm will cause unacceptable deviations in the music. However, such situations can be prevented.

6.2 Ensembles of Several Percussion Instruments

When pads were attached to the four limbs of one person, the person could play the drums. In addition, when multiple people (who were each connected to SP) played several percussion instruments simultaneously, they could form relatively cohesive musical ensembles.

7. DISCUSSION AND FUTURE WORK

7.1 Comparison with other methods

In the RERATED WORK section, we mentioned other music performance support methods (visual, auditory, tactile). We need to compare these methods and our proposed method. We plan to study these methods in order to demonstrate that our method is more suitable for rhythm learning for future study.

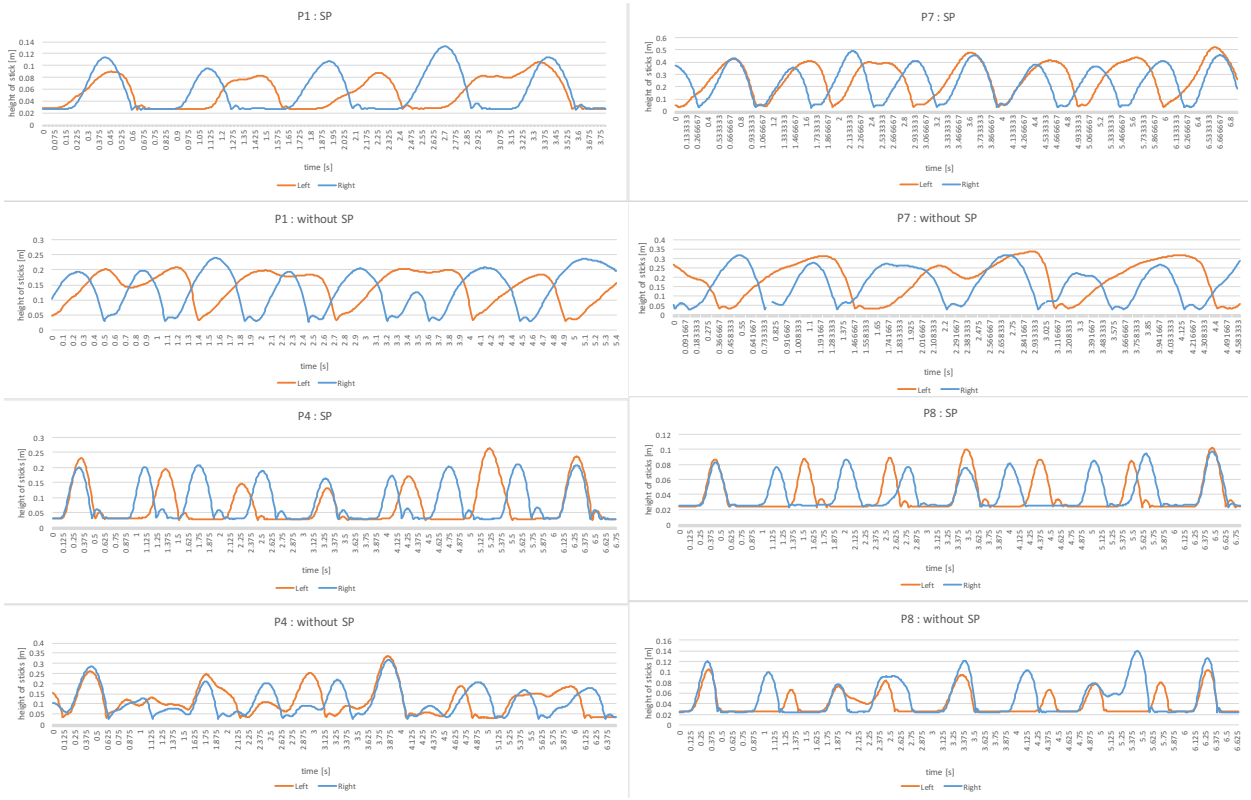

Figure 4: Results: Graphs of participants who were able to reproduce the rhythm relatively correctly

7.2 Individual Differences

Because of individual differences in muscle location, it is occasionally difficult to attach electrodes to the correct position. In addition, as the participants indicated, reactions to EMS vary widely. Some people feel discomfort or a small amount of pain in response to the unfamiliar electrical stimulation. Then we adjust voltage manually.

7.3 Tempo

Tempo is also an important aspect of musical performance. The range of songs that can be played will also change depending on the range of tempos that can be played. In one experiment, we used a tempo of 80; however, it is necessary to clarify how fast a tempo users can produce using SP. This tempo problem seems to be related to the speed of the body' s reactions to electrical muscle stimulation.

8. CONCLUSION

For rhythm learning, we proposed the use of the muscle-brain-muscle process through EMS. This process works in the different direction of the conventional rhythm learning process. We conducted an experiment to determine if a user can reproduce a complicated rhythm using this method. In the experiments, half of the participants were able to produce a complex rhythm with the SP method. From the experimental results and the participants' feedback, we found that our process is effective for rhythm learning by beginners. In addition, Stimulated Percussions can be applied to solo performances or ensembles with multiple people.

9. ACKNOWLEDGMENTS

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10. REFERENCES

[1] A. Ebisu, S. Hashizume, K. Suzuki, A. Ishii, M. Sakashita, and Y. Ochiai. Stimulated percussions: Techniques for controlling human as percussive musical instrument by using electrical muscle stimulation. In *SIGGRAPH ASIA 2016 Posters*, SA '16, pages 37:1–37:2, New York, NY, USA, 2016. ACM.

[2] S. Holland, A. J. Bouwer, M. Dalgelish, and T. M. Hurtig. Feeling the beat where it counts: Fostering multi-limb rhythm skills with the haptic drum kit. In *Proceedings of the Fourth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '10, pages 21–28, New York, NY, USA, 2010. ACM.

[3] H. Kanke, T. Terada, and M. Tsukamoto. A percussion learning system by rhythm internalization using haptic indication. In *Proceedings of the 12th International Conference on Advances in Computer Entertainment Technology*, ACE '15, pages 14:1–14:5, New York, NY, USA, 2015. ACM.

[4] P. Lopes, P. Jonell, and P. Baudisch. Affordance++: Allowing objects to communicate dynamic use. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, CHI '15, pages 2515–2524, New York, NY, USA, 2015. ACM.

[5] P. Marian. Electronic muscle stimulation.

http://www.electroschematics.com/2083/electronic-muscle-stimulator/.

[6] S. Miura and M. Sugimoto. T-rhythm: a system for supporting rhythm learning by using tactile devices. In *IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE'05)*, pages 5 pp.–, Nov 2005.

[7] Y. Nagashima. Bio-sensing systems and bio-feedback systems for interactive media arts. In *Proceedings of the 2003 Conference on New Interfaces for Musical Expression*, NIME '03, pages 48–53, Singapore, Singapore, 2003. National University of Singapore.

[8] Y. Saijo, K. Suzuki, N. Ito, A. Koike, and Y. Ochiai. Human coded orchestra: A system for extemporary group singing performance. In *Proceedings of the 13th International Conference on Advances in Computer Entertainment Technology*, ACE2016, pages 42:1–42:6, New York, NY, USA, 2016. ACM.

[9] E. Tamaki, T. Miyaki, and J. Rekimoto. Possessedhand: Techniques for controlling human hands using electrical muscles stimuli. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, pages 543–552, New York, NY, USA, 2011. ACM.

[10] M. Weing, A. Röhlig, K. Rogers, J. Gugenheimer, F. Schaub, B. Könings, E. Rukzio, and M. Weber. P.i.a.n.o.: Enhancing instrument learning via interactive projected augmentation. In *Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication*, UbiComp '13 Adjunct, pages 75–78, New York, NY, USA, 2013. ACM.