An evaluation of the interstitial beat across multisensory modalities for characterization of a meaningful haptic enviro-sensing metronome

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To my grandmother, for instilling in me a thirst for knowledge and the joy of learning.

Abstract

The interstice is an intervening space. When applied to a rhythmic context, the interstitial beat can be represented by two distinct states; whether energy exists within this small moment in time or if it does not.

Does filling the space provide an added awareness or preparation for upcoming onsets? Can the gestural motion of the conductor be justified scientifically?

Nevertheless, the underlying question when applied to either the daily practice of a trained musician or the innate entrainment (external rhythmic synchronization) of the average human being, is whether the space between the beat matters.

The objective of this work is to display whether a continuous wave, one which leads up to the maximum amplitude of the beat and trails off into a smooth decay, exhibits differentiation from it's instantaneous counterpart in communicating regular or irregular pulses. To quantify this differentiation, an expansive set of analog and discrete tap synchronization test cases spanning the modalities of sight, sound, and touch will be conducted across groups of musicians, amateurs, and non-musicians.

Ancillary to this work, a haptic wearable design is prototyped and evaluated for optimization of physical spacing with an overarching goal of communicating dynamic changes more effectively.

Although rhythmic accuracy is proven to be most effective through discrete audible means, the work hypothesizes that there will be improvement shown when the interstitial beat is occupied with a continuous wave across the modality of touch at slower tempi, where space between successive beats is significantly spread apart, as well as throughout the occurrence of unpredictable or dynamically changing events.

Furthermore, the wearable haptic will provide an inconspicuous yet meaningful gestural system key towards future entrainment studies in expressive performance.

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Chapter 1

Introduction

1.0.1 Motivation

Prof Neely

Eurythmics training

Is there missing information from the daily practice of a trained musician to an audible metronome.

Consequentially, the following assumptions arise:

What knowledge and/or science is missing?

This research will add another dimension to each sensory modality to resolve the inquiry as to whether filling in the space between the beat, the interstitial, has an impact on rhythmic accuracy with the potential to impact future metronome implementations.

1.0.2 Background

Brief metronome history

In a traditional sense, the audible click of Maelzel's metronome minimizes the interstitial space with an instantaneous (or discrete) impulse signal. However this representation is only half of the puzzle since the pendulum motion exhibited seeks to convey meaningful rhythmic information through the visual , much like the gestural motion of a conductor.

The conductor "fills 100% of the space between the crusis (the click moments of a beat) with a natural analogue wave that provides the build-up and decay common to natural happenings."[Haptic Enviro-Sensing Metronome, 5]

Work of Jacques Dalcroze

Humans are one of the few species who exhibit the ability to synchronize to a beat. From a neurological perspective, it has been thought to be connected with the capacity for vocal learning. [CITE]

The preceding research within the field of sensorimotor synchronization identifies an auditory advantage, or the dominance of auditory/motor connection within the task of beat synchronization. However, recent studies have proven given meaningful spatiotemporal information, as in the bouncing ball example discussed in `Section 2.2`, synchronization is almost as good as an auditory metronome.

`REWORD THIS`:! The capacity to entrain motor behaviors to a beat is predictive (i.e., on average, taps slightly precede event onsets when tapping to a beat) and flexible (i.e., synchronization to an auditory beat is accurate for inter-beat intervals ranging from 300 to 900ms, with the most preferred inter-beat intervals being approximately 600ms). [4]

This work will focus on the expansion of this claim into the tactile realm, hypothesizing that:

Chapter 2

Previous Work

2.1 Auditory Advantage

Decades of research into sensorimotor synchronization presents a clear advantage of the discretely timed auditory stimulus implying that the neural and evolutionary mechanisms underlying beat synchronization are modality-specific. [2] The stability of beat synchronization to visual modalities (a flash of light) has been shown to be less stable that its auditory counterpart.

Explain sensorimotor synch

Research paper disc.

Concrete examples/figures?

2.1.1 Rhythmic Perception

Though seemingly a separate realm of study, the field of rhythmic perception represents an important contribution to the overall understanding of sensorimotor synchronization. The work involves measurement of the ability to recognize different rhythmic patterns to different stimuli in a listen and respond type of fashion. Researchers from the human computer interaction group at the University of Tampere, Finland, conducted an experiment in 2008 to confirm that the instantaneous auditory modality dominates rhythmic perception. Tactile follows close suit with the visual modality being the least suitable for accurately perceiving rhythmic information as well as the most mentally demanding. Rather than the traditional tap based test, users were given two rhythmic sections and asked to determine whether they were identical or not across modalities as well as combinations of each. [3] Even though it yielded less correct results the tactile modality was, from the users point of view, almost as good as the auditory modality. Exploration of pulse length was called upon for further insight.

2.2 A Continuous Visual Metronome

In a novel advancement challenging the auditory advantage and perhaps paving the way towards a more meaningful gesture, researchers in the Psychology department at Sun Yat-Sin University in Guangdong found continuous motion of a bouncing ball to be as stable as synchronization to an auditory metronome.

Bouncing ball paper discussion.

Furthermore, an 2014 experiment by the Department of Psychology at Sun Yat-Sen University in Guangdong, China, explored tap synchronization to a visual of a bouncing ball and found that it was not less stable than to an auditory metronome [2].

2.3 The Tactile Modality

A 2016 study by the Department of Psychology at Ryerson University considered whether the auditory advantage persisted across the tactile modality. The experiment was a tap test of non musicians put through a series of simple and complex rhythmic sequences with a varied area of haptic stimulation. In conditions involving a large area of stimulation and simple rhythmic sequences, tactile synchronization closely matched auditory. They proved that if made salient enough, the accuracy of synchronization to a tactile metronome can equal synchronization to an auditory metronome, further challenging the idea of an auditory advantage over all other modalities for synchronization to discretely timed rhythmic stimuli. However, auditory won out for synchronization of complex rhythmic sequences. [1]

2.4 Commercial Introspection

Peterson tuner BodyBeat Sync ($140) seeks to revolutionize the traditional metronome through its extensive coverage of all three modalities with a wearable pulsing vibration unit which claims to allow musicians to easily internalize the beat and develop a note value relationship both audibly and physically. [Peterson Citation]

Ramp up/down as well as proof via quantification of this rhythmic internalization are missing.

The Soundbrenner ($99) is a vibration based metronome using an instantaneous pulse and claims that in freeing the ears, it has brought the rhythm closer to the body, making it more comfortable and natural to feel the beat and swing of the music instead of chasing the click. [Soundbrenner Citation]

Similarly, lack of ramp up/down as well as numerical proof.

Chapter 3

Haptic Design

3.1 Requirements

3.2 Design Challenges

3.3 Optimization

Chapter 4

Method

Previous studies have shown that periodically bouncing ball stimuli moving with a rectified sinusoidal velocity profile are the most effective moving stimuli in improving synchronization to a visual beat. [2]

The method which follows is a nature expansion of this ideology into the haptic domain.

4.1 Arduino

4.1.1 Tap Onset Latency Evaluation

A sensorimotor synchronization experiment was conducted to discover how auditory feedback to a tap onset could be presented with minimal latency and responses recorded with the most accuracy. It was found that not only was the auditory response latency the least for the Arduino system using a force sensitive resistor (mean = 0.6 ms, sd = 0.3), but it had missed the fewest taps and recorded the least superfluous responses as compared to a percussion pad with the FTAP and Max MSP systems [Tap Arduino, 1].

4.1.2 Beat Tracking

Max Patch based on `THIS RESEARCH`

does this
for the purposing of testing this

Chapter 5

Data Analysis

5.1 Motivation

I was motivated to write a Phd thesis because I did not want to work directly after finishing my study

5.2 Organization

This thesis is organized as follows, ...

Chapter 6

Conclusions

In conclusions, robots are the best.

Appendix A

Stuff I forgot

Robots are really, really great.

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