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

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To my favorite robot.

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 the upcoming onset? Can the gestural motion of the conductor be justified scientifically?

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.

The work hypothesizes that although rhythmic accuracy is proven to be most effective through discrete audible means [source] there will be improvement shown when the interstitial beat is occupied with a continuous wave across the modality of touch at slower tempo, when 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 and silent gestural system key towards future entrainment studies in expressive performance.

Acknowledgments

First and foremost to my advisor and the original inceptor of this work, Professor Stephen Neely. Our weekly discussions kept me on the right path. Thank you for the guidance and experience you brought to this project. I hope this proves to be exemplary to your design research as well as the framework for future work to come.

Tom,

Riccardo, support

To my roommates and close friends, Mike and Craig. For those long nights of brainstorming possibilities and troubleshooting. Thank you for not only being my think tank but for keeping me inspired and grounded.

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Chapter 1

Introduction

Introduction.

1.1 Installation instructions

This template was tested with TeX Live 2017, which includes all required packages [1]. Mac users: this is included as part of OSX and TeXShop. After successfully installing TeX Live, compile the PDF file using your favorite build tool (we tested with `make` on OSX).

1.2 How to use this template

Write each chapter as a separate LaTeX file and include them in `thesis-main.tex`. Edit the abstract, acknowledgments, background, title, dedication, and funding files as necessary. Include additional packages in `thesis-packages.tex` and define helpful macros in `thesis-macros.tex`.

1.2.1 Algorithms

Define each algorithm as a separate LaTeX file in the algorithms folder using either the `algorithmicx` or `algpseudocode` packages. For example, see Algorithm 1.

Algorithm 1 Longer caption

```
1: procedure Do it(N)
2:     Initialize all the things!
3:     for t = 1 to N do
4:         Do it!
5:     end for
6:     return N
7: end procedure
```

1.3 Motivation

Eurythmics, Prof Neely

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

Consequentially, the following assumptions arise:

From the work of Jacques Dalcroze,

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.

Chapter 2

Background

In a traditional sense, the audible click of Maelzel's metronome minimizes the space with an instantaneous impulse signal though the pendulum motion exhibited seeks to convey meaningful rhythmic information, 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]

Chapter 3

Previous Work

3.1 Auditory Advantage

Extensive research into sensorimotor synchronization has proven that there exists a clear advantage of the discretely timed auditory stimulus as opposed to the visual and tactile counterparts.

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. Instead of the common 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. [Crossmodal rhythm perception, 3]

Tactile was personally preferred during the test over the other modalities but exploration of pulse length was called upon for further insight.

Research paper examples/discussion

3.2 A Continuous Visual 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. [Synchronization to a bouncing ball with a realistic motion trajectory, 4]

3.3 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 discretly timed rhythmic stimuli. However, auditory won out for synchronization of complex rhythmic sequences.

3.4 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. [6]

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. [7]

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

Chapter 4

Haptic Design

4.1 Motivation

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

4.2 Organization

This thesis is organized as follows, ...

Chapter 5

Method

5.1 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].

Chapter 6

Data Analysis

6.1 Motivation

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Chapter 7

Conclusions

In conclusions, robots are the best.

Appendix A

Stuff I forgot

Robots are really, really great.

Bibliography

[1] TUG. TeX Live, 2017. URL https://www.tug.org/texlive/. 1.1