# Embodied Interfaces for Interactive Percussion Instruction

Thesis by

Justin R. Belcher

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Steve Harrison, Chair
Dr. Scott McCrickard
Dr. James Miley

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# Abstract

For decades, the application of technology to percussion curricula has been substantially hindered by the limitations of conventional input devices. With the need for specialized percussion instruction at an all-time high, investigation of this domain can open the doors to an entirely new educational approach for percussion.

This research frames the foundation of an embodied approach to percussion instruction manifested in a system called *Percussive*. Through the use of body-scale interactions, percussion students can connect with pedagogical tools at the most fundamental level—leveraging muscle memory, kinesthetics, and embodiment to present engaging and dynamic instructional sessions.

The major contribution of this work is the exploration of how a system which uses motion-sensing to replicate the experiential qualities of drumming can be applied to existing pedagogues. Techniques for building a system which recognizes drumming input are discussed, as well as the system's application to a successful contemporary instructional model. In addition to the specific results that are presented, it is felt that the collective wisdom provided by the discussion of the methodology throughout this thesis provides valuable insight for others in the same area of research.

# Acknowledgements

This project would not have been possible without the support of the many people who directly or indirectly helped me realize the *Percussive* interface. First of all I wish to express gratitude to my advisor Steve Harrison. Though this project has been in constant flux for many years, his constant support, perspective, and guidance has been invaluable to the difficult task of framing this work. I would also like to thank Dr. Scott McCrickard for taking me under his wing as a young CS graduate student, and showing me what the world of academia can really offer. He is a man who truly cares for the members of his troupe, and I always look back fondly on my time in 104 McBryde. Appreciation is also extended to Dr. James Miley, whose advice and direction has proven invaluable in strengthening this work.

I would also like to thank the Nintendo® Corporation, for their playful and innovative design work with the Wii® Gaming System—work that has afforded me one of the most novel input devices to hack around with in years. Also, the open-source community of WiiLi.org has been absolutely foundational in the success of this project.

To my fiancée Cassie, thank you so much for standing by me tirelessly as I worked to finish this thesis. I am sure you will be quite happy to have me back when all of this is said and done.

Lastly, I express my deepest appreciation to my parents John and Penny Belcher, who have always been nothing but supportive of my educational pursuits. Without their sacrifices and encouragement I would not be in the position I reside in today, and it is my sincerest hope that I will one day find a way to repay them for the love and support they have shown me through the years.

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# Chapter 1

# Introduction

This chapter severs to frame both the motivation for research, as well as the context it is placed in. Additionally, an interactive educational system for teaching developmental percussion techniques named *Percussive*is introduced.

## 1.1 Motivation

For the past fifteen years, percussion has been an integral component in my life. During this time I have performed at the highest level of marching and symphonic percussion, written and arranged for some of the most competitive percussion ensembles in the country, and taught percussionists of all proficiency levels ranging from private students to collegiate and independent ensembles. As an activity, percussion has seen a renaissance of sorts over the past decade. Pageantry activities such as Drum Corps International[1], Bands of America[2], and Winter Guard International[3] have elevated the exposure and accessibility of advanced performance techniques to students across the country. The role of percussion instructor, formerly occupied by the band directors themselves, has steadily been replaced with both full-time and consulting professional percussion instructors—instructors who come at a hefty price to music programs. Because of the cost of staffing professional instructors, many programs are forced to rely upon instructional media to supplement the development

[1]http://www.dci.org – A competitive independent marching circuit.
[2]http://www.bands.org – A competitive scholastic marching circuit.
[3]http://www.wgi.org – A competitive percussion-only indoor circuit.

of their students. This media unfortunately falls well short of one-on-one instruction, yet it provides a domain of research for interactive systems which can attempt to replicate these learning situations at a fraction of the price.

## 1.2 Percussion Instruction and Interactive Systems

Individual instruction still rests as the cornerstone of percussive development, as the seemingly simple act of striking a taut membrane with a blunt object requires a great deal of specialized technique typically only cultivated through close supervision [6]. Various supplemental teaching aids do exist however in the form of instructional booklets, DVDs, play-along CDs, and interactive CD-ROMs. Unfortunately, these interactive programs suffer heavily from the limitations of the input devices of typical computing systems as well as the primitive nature of Musical Instrument Digital Interface (MIDI) instruments. In both scenarios, input to these digital systems only comes in the form of an analog signal (and in the case of MIDI input, an accompanying velocity). As a analog signal, software can analyze the timing of the performance and the appropriateness of the volume, yet it cannot be made aware of how that input was entered in a mechanical sense—which is the very basis of technique.

## 1.3 Enter *Percussive*

*Percussive* is designed to engage students in a body-scale, embodied learning environment. Input to the system is filtered through a mathematical model of a "correct" drumstroke, which allows the system to reinforce proper technique through repetition and muscle memory. Because of the embodied approach to interaction, the system itself is made aware of complex performance data—including the spacial acceleration of the input device and its orientation in three-space. *Percussive* uses this data to form the criteria for a successful "hit," which consequently reveals an understanding of *how* the instrument was struck in addition to *when*.

With this method of input in place, software can be scaffolded to create peda-

gogical tools that possess a deeper understanding of the student's performance and context. For the scope of this thesis, *Percussive* features two interactive lessons that leverage this technology: one that uses repetition and modeling to reinforce a proper drumstroke, and another that teaches the fundamentals of rhythm by allowing students to perform basic exercises themselves. The two lessons represent the groundwork of a more feature-complete instruction system which could cover a myriad of beginning percussion topics including basic rudiments, music reading, and performance techniques.

# Chapter 2

# Related Work

## 2.1 Introduction

This chapter presents significant research efforts both peripheral and central to *Percussive*. They are separated into sections of increasing relevance—starting with foundational research and ending with related projects.

### 2.1.1 Foundational Research

One of the central claims behind the design of this project is that children and young adults learn best through an active process where their understanding is built on interaction with objects and situations in their environment. This claim is largely structured upon the work of cognitive psychologists such as Dr. Jean Piaget and constructivist theory.

Dr. Jean Piaget is largely attributed to be the father of constructivist theory, which outlines the basis of active learning. He suggested that through processes the of *assimilation* (aligning one's experiences with their internal representation of the external world) and *accomodation* (reframing one's mental representation of the external world to fit new experiences), individuals are able to learn and construct new knowledge from their experiences [16]. This approach is fundamental to the processes of learning to play percussion, as drumsticks themselves have many preconceived affordances (inherit uses) that students must overcome to become proficient [20]. It is

an important distinction, however, that this constructivist approach does not suggest a particular pedagogy, but instead describes *how learning should happen* which is the approach this project uses in its mission.

To ground the pedagogical approach of *Percussive*, I draw from several prominent musical education researchers who base their perspective on the need for engaged and embodied learning as part of the educational process.

Keith Swanwick, in his book *A Basis for Music Education* [26], describes the need for direct interaction with musical material and the incorporation of the student's innate musical perceptions as part of the learning process. Similar earlier work from Susanne Langer, Arthur Koestler, and Bennett Reimer echo this approach as well. George Odam further presents the need for an engagement of sensorimotor facilities during the education process in his book *The Sounding Symbol: Music Education in Action* [22], as it translates directly to both performance and creativity in the student.

Another foundation of the pedagogy of *Percussive* is based around muscle-memory. Muscle-memory (or implicit memory) is a phenomenon where previous experiences with an action aid in the performance of a task without conscious awareness of these previous experiences [25]. In particular, it has been shown that through a muscle-memory activity called *priming*, students may show improved performance on tasks for which they have been subconsciously prepared for [13].

### 2.1.2 Interactive Design Research

The design of *Percussive* itself is grounded in the domains of embodied interaction and user-centric design. Embodiment has surfaced as a popular research focus in the domain of Human-Computer Interaction (HCI), largely based on the work of Paul Dourish. Basing his theories on pheonomenologists such as Martin Heidegger, Alfred Schultz, and Ludwig Wittgenstein, Dourish establishes an approach that centers around the understanding a user creates and communicates meaning through their interaction with the system [9]. On the basis of that understanding, Dourish out-

lines a range of design principles that are reflected by systems exploiting embodied interaction.

Starting with the work of Don Norman, and later embellished by John M. Carroll, the domain of user-centered design and usability engineering are now deeply ingrained into HCI. This focus is largely based around the notion of both the designer and user having a mental model, and the interaction designer's goal is to close the gap between the two models through their design [23]. Carroll approached this design task through the use of scenarios and actors, later employing the notion of a "claim" (design artifact) as a piece of reusable knowledge [3]. Taking a related but opposing approach, Alan Cooper framed the use of a "persona," which is a reusable scenario centered around a potential user [7].

### 2.1.3 Related Projects

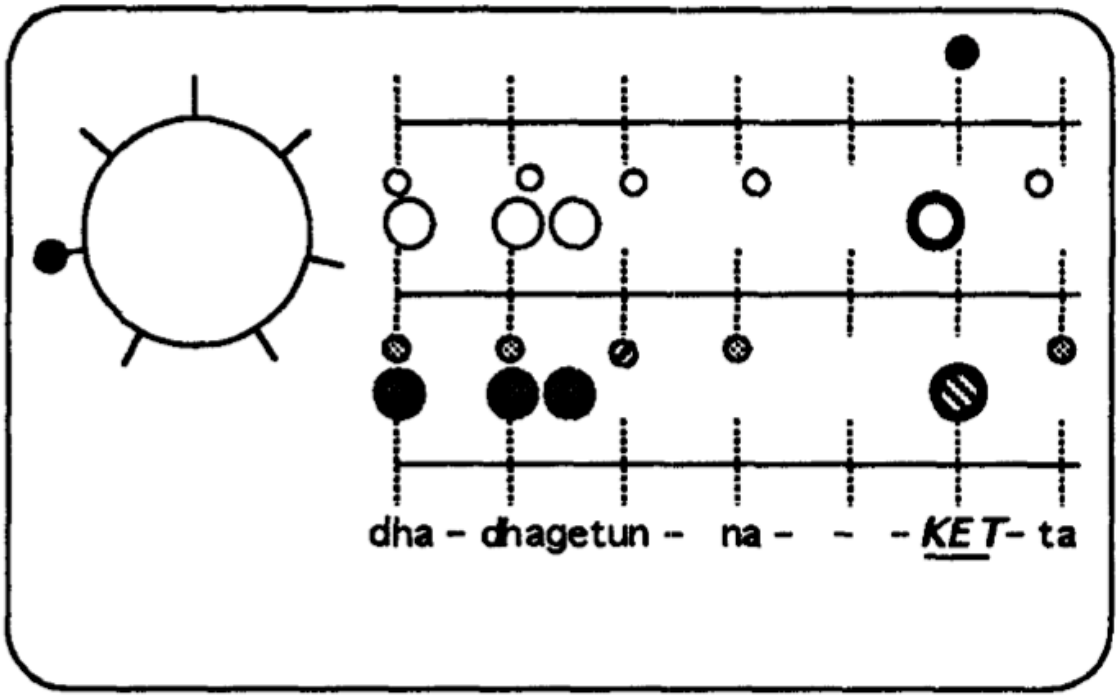
Though there have not been many projects charged directly in creating interactive percussion instruction systems, there have been many peripherally-related research ventures which merit discussion.

#### 2.1.3.1 Toy Symphony

Tod Machover's Toy Symphony [18] is project centered around the use of musical toys which enable children to engage in sophisticated listening, performing, and composing-activities that would normally be accessible only after years of study. These musical toys are essentially MIDI devices which interpret motion, pitch, and vibrations as interpreted music. An interesting approach of this project is the emphasis on social interaction with these devices, as they become more functional as more children participate nearby. In this way, the children can help one another to perform music more intricate than any of them would be able to create individually.

This interaction is still somewhat centered around play, contrasted to *Percussive*'s more traditionally instructional setting. Also, the project's primary demographic is children, while *Percussive* is aimed at students with a basic or non-existent knowledge of percussion.

#### 2.1.3.2 Exploring Tabla Drumming Using Rhythmic Input




Jae Hun Roh frames the beginnings MIDI percussion recognition in this 1995 work [24]. Rhythms are drummed onto two MIDI trigger pads, which are then mapped to tabla phrases using a hidden Markov model-based recognizer. This approach, however, is not a direct performance mechanism. The user is prompted by a metronomic click to which they drum a rhythm to. This rhythm is then transformed into a grammatically correct tabla pattern and played back for the user. Because of this, the user's creative input is limited to whatever preprogrammed patterns have been injected into the system.

The use of Markov models is worth noting, as it fits perfectly into trying to translate serial input into a recognized drumstroke—a vital component of an interactive drumming system.

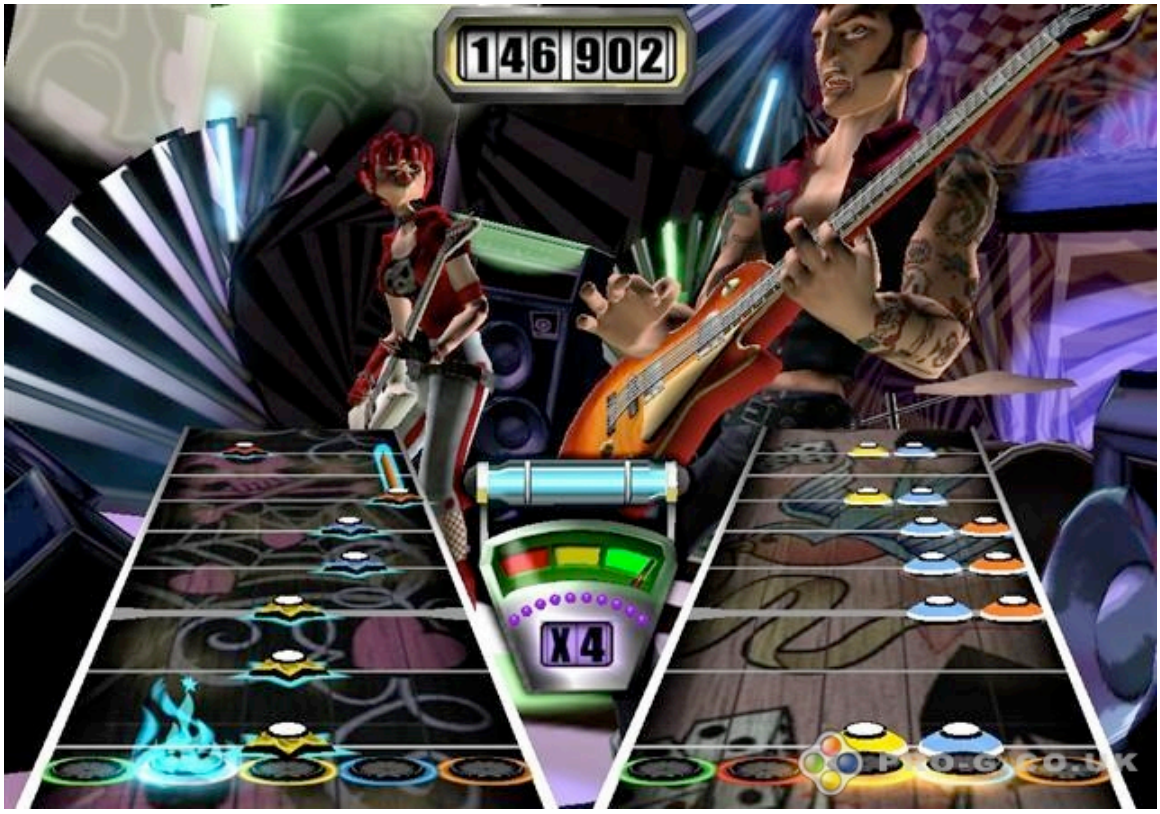
#### 2.1.3.3 Jam-O-Drum

The Jam-O-Drum [2] project is a collaborative percussion exhibit designed by Carnegie Mellon's Tina Blaine. This device features a table-top design with velocity-sensitive input devices and a top-down projected interface. This project is a direct contrast to the tabla project, as it is designed for real-time improvisation (often referred to as "jamming" in live music contexts). The velocity-sensitive input devices are nothing more than MIDI drum pads found in most electronic drumsets, but were coupled with a serial MIDI data protocol and a Macintosh computer to combine all aspects of the experience together. Like Machover, Blaine cites the social act of drumming as a fundamental design focus in her system.

#### 2.1.3.4 E3 Nintendo Wii Drum Demo


During the Electronics Entertainment Expo (E3) in 2006 [8], Nintendo developed an exhibit which allowed users to use Nintendo Wii controllers to play a virtual drumset. The response time of the instruments is quite accurate, down to 32nd notes played at a moderate tempo. While this project lends itself well to a performance setting, it still does little in terms of a precise educational tool. Using IR sensing, the devices can determine what virtual drum is struck based on the angle of the input device, yet these angles are quite exaggerated and uncharacteristic of conventional drumsets. The response of the system is also incredibly sensitive, which leads to it responding positively to any number of incorrect hand motions. This project was, however, the inspiration for the *Percussive* project, which draws from this free-space embodied interaction to form the basis of an instructional tool for percussion teachers.

#### 2.1.3.5 Dance Dance Revolution™, Guitar Hero™, and Other Commercial Rhythm Games




Dance Dance Revolution™(DDR), Donkey Conga™, and Guitar Hero™ all represent a class of commercial video games called "rhythm games." These games are popular in both their novelty and the implications of their interface design. They range from musical interpretation (DDR), to musical performance (Guitar Hero™) and engage users on different levels. While centered around play in a similar manner to Jam-O-Drum, these interfaces bring in new concepts of competition, feedback on individual performance, and the potential for mastery [5]. The last point is worth noting, as that is also a fundamental goal of traditional musicianship. The drawback of these interfaces as a pedagogical tool reside in their imprecise input recognition, which although is closely tied to the music they accompany possesses a latency too great for advanced recognition.

#### 2.1.3.6 StepMail and StepPhoto

StepMail and StepPhoto[19] are applications developed by Microsoft Research to explore their StepUI interface. This project is based loosely on DDR, but is more centered on bringing full-scaled body interfaces to traditional computer applications. In their 2006 CHI paper, they describe the benefits of such a large-scale system which include increased level of exertion over sitting at a desk, and a diversion from the typical office workspace. This work, however, does not pave any significant space for embodied interaction as a pedagogical tool, and in fact is nothing more than a novel foray into uncharted interactive territory.

#### 2.1.3.7 Hyperinstruments: Hybrid Percussion


The Hyperinstruments Project [17], headed by Tod Machover, represents some of the first and finest efforts at the merging of technology and music. To discuss all of the various projects from this research effort is beyond the scope of this thesis, but one specific project is of particular relevance to this work: Hybrid Percussion [1]. Hybrid Percussion takes a novel approach to digital interface design, by processing the raw acoustic output of a physical controller object to add the resonance of a sampled percussion instruments. In this way, the controller is made aware of more than the simple intensity of stroke. Such a system can produce the illusion of acoustic instruments in a digital setting, which certainly pushes the envelope of what digital systems are capable of. Unlike *Percussive*, however, this system does not meaningfully monitor the motion of the drumstroke so its pedagogical applications are limited to the performance end of the spectrum.

### 2.1.4 Discussion of Related Work

The aim of *Percussive* is to utilize the interaction design pioneered by many of these projects to create something unique to the research space. Rather than considering "any and all rhythmic input," *Percussive* is designed to only accept what it considers "correct" percussive strokes as legitimate input. In this way, the act of drumming in this interface primes the user to have a better fundamental understanding of a drumstroke before they even touch an actual drum. In contrast to other interfaces mentioned in this chapter, *Percussive* also structures its interaction through a linear progression of lessons—rather than the somewhat ad hoc "playful" approaches many of the other interfaces employ.

# Chapter 3

# Interaction Design

This chapter describes the process behind the interaction design for *Percussive*. It will cover a description of the problem space, several iterations of design work, and briefly discuss the design and purpose behind the final prototyping of the system.

## 3.1 Problem Space

This research began with the lofty goal of creating an interactive system where few currently exist. Although large-scaled interactive systems and tangible computing have been researched for decades, the implementation of many gross-motor interactions such as drumming has been somewhat dilatory [10]. These types of interactions are poorly simulated with conventional computing input devices, and as such require either the construction of customized devices or the purchase of expensive specialized equipment.

The need for innovation in this space is great, as digital percussion instruction has not advanced much further than it stood in the early 1990s. The necessity for specialized input coupled with the fact that accessible computing is still largely situated has stifled most attempts at bringing percussion instruction to the digital classroom. However, many musical programs who cannot afford to staff percussion specialists would greatly benefit from such a system.

## 3.2 Early Design Work

Adapting a meta-methodological approach to the design process [14], the refinement of *Percussive* has been free-form and highly iterative. All design work stems from a central hypothesis, which states: **"traditional percussion instructors could be largely replicated by a digital system developed as a body-scale embodied interaction."**

### 3.2.1 Design Methodology

With the hypothesis in place, exploration of possible solutions began as exercises in ideation. Early approaches involved brainstorming to find other real-world analogs of drumming for metaphorical correlation. Some examples include:

- Drumming is like...
  - Bouncing a basketball (requiring minute, fine-motor adjustments to stabilize its dynamic system).
  - Playing paddle ball (somewhat cadencial in both motion and effort).
  - Cracking a whip (motion is a transfer of energy from larger muscles to smaller muscles).
  - Driving a nail with a hammer (drumming features an aggressive downward acceleration to facilitate rebound from the instrument).

Delving deeper into the experiential qualities of drumming, a morphological box approach [14] was used to enumerate the sensational aspects of drumming—ranging from the quality and timbre of sound produced from the instrument, to the relative levels of vibration feedback from striking the instrument (see Figure 3.1).

Throughout this ideation, the problem of developmental percussionists' physical strokes surfaced as a design focus. Beginning percussionists often run into significant cognitive dissonance when learning proper technique as the affordances of the drumstick itself are familiar in other forms (a broomstick, a hammer handle, a baseball

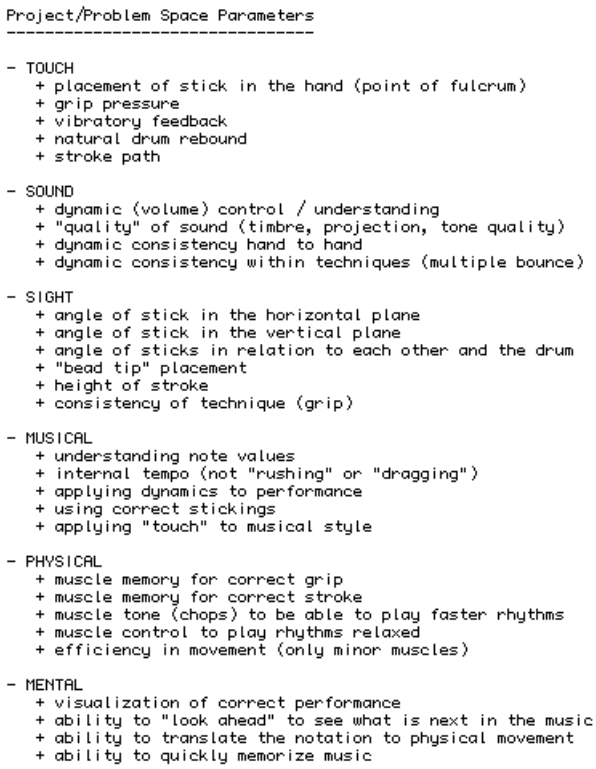



Figure 3.1: Morphological exercise with sensation

bat). One of the critical milestones in technical development involves overcoming this dissonance, by learning to move the stick in the proper—and initially awkward—way. This refinement in focus allowed for a more structured approach to the design, in the form of scenario-based design [12].

### 3.2.2 Scenario-Based Refinement

Rather than approach this entire design problem as scenario-based system design, scenarios were used as mutually-exclusive design tools for refining context and place within the problem space. An example problem scenario of a young student struggling with early drumstroke motion follows:

Cassie is a fifth-grader who has recently started beginning band at her elementary school. Since she has been a dancer from childhood on (and consequently has been surrounded by timing and rhythm), she choses the drum as her instrument. During her first lesson, she is given a drum and a pair of sticks and immediately bangs away at the instrument amused by the sounds she can make. This action feels quite natural to her, as there is really no thought to picking up a stick and banging something with it. As the instructor begins to teach her the basics of the drumstroke, Cassie becomes frustrated with the way she is forced to hold the stick and move. With her palms flat the the ground, she feels uncomfortable with the extra tension it puts on her hands. She finds that as she proceeds through her lesson that she has trouble maintaining this grip, since her hands typically want to revert to a more comfortable, upright orientation. Additionally, she finds that she has a hard time recognizing when she has shifted to an incorrect technique as she really can't tell the difference between the two. All Cassie really wants to do is bang away at the drum unabashedly, and she finds the amount of formality in the lesson somewhat boring. After her lesson is concludes, she approaches a classmate who seemed to be having way more fun on her "very cool trumpet."

Figure 3.2: Example problem scenario

From these scenarios, *claims*[1] were distilled to form the basis of a design criteria for possible solutions. Not only do claims give direction to the design, but they can be revisited throughout the design process. Consider two example claims from the above scenario:

[1]Recall that a claim is essentially a piece of reusable design knowledge.

| **Claim: Overcoming awkward motion indirectly.** |
|---|
| Upsides & Downsides |
| + Students do not need to maintain direct focus. |
| + Can be implemented through muscle-memory. |
| – Could establish bad habbits. |
| – Requires assumptions about retention of repetitive motion. |

| **Claim: Requiring correct motion.** |
|---|
| Upsides & Downsides |
| + Provides continuous maintenance of technique as cognitive load increases. |
| + Further reinforces stroke technique throughout lessons. |
| – Errors in execution or system failure could be difficult to discern. |
| – Users might be frustrated by the system not recognizing their efforts. |

Table 3.1: Example Problem Claims

From this criteria, story boards were used to provide potential task flows within the system itself, and system mockups and diagrams were drafted to establish structure to the interface. In the following section, we discuss early prototypes of the system and their inherent problems.

### 3.2.3 Early Prototypes

The initial system design consisted of an acoustic snare drum fitted with a ddrum MIDI trigger (see Figure 3.3) which captured strokes for processing. This input, coupled with media and a webcam that showed the user's hands side-by-side with virtual instructor's hands, provided a rich platform for developing interactive applications for percussion. This system design did possess many flaws, namely the expense of purchasing a MIDI console to process the MIDI signal, the complexity of processing the MIDI signal without appropriate patch software (such as Max/MSP), and the fact that the system could not be made intimately aware of how the strokes were made. This final point proved to be the deciding factor with this design, as throughout the various design iterations *how* the user struck the instrument was emerging as the key factor.

After noting the importance of motion recognition several implementations were


Figure 3.3: DDrum acoustic MIDI trigger

investigated. Image processing was the first avenue pursued, but latency and the processing power required were limiting factors for a percussion application. In the next design, the system was implemented using the Vicon system[2] which the human-computer interaction department at Virginia Tech owned. This approach was a significant step forward, as the system could be made to recognize drumsticks as tracked objects in 3D space. The drumsticks were tracked through position alone, so implicit readings such as acceleration would have to be computed mathematically from the matrices of the system. In addition to this, the system could easily be knocked out of calibration if any of the cameras were moved—which proved to be a frequent occurrence with the number of graduate students using Vicon in the lab.

The final iteration of the system utilized accelerometers attached to drumsticks to provide motion input to the system. By bracketing these readings, drum hits could be inferred from the motion itself (rather than the impact of the stick). This design provided an ideal arrangement of implementation, practicality, and functionality.

[2]http://www.vicon.com - A realtime motion tracking system based on reflective markers and several infrared cameras.

## 3.3 Thesis Prototype Discussion

The final thesis prototype began as a series of sketches and storyboards depicting accelerometers attached to drumsticks for input. While this design allowed the user to interact with the system using real drumsticks, it also required the sticks to be attached to wires. To decide if this limitation would hinder the experiential aspects of the system, a rapid prototype was made with drumsticks with USB cords attached. These wires indeed made the interaction somewhat awkward, so it was clear that a wireless implementation would be the only feasible approach.

Rather than attempting to build a homemade wireless device, pre-made alternatives were examined for prototyping. The Nintendo Wii® Remote (see Figure 3.4) emerged as an ideal device, as it features integrated Bluetooth, a three-axes accelerometer, IR sensor, vibration feedback, and several input buttons all for under $50. A unique quality of the remote is that its form-factor is close to a real drumstick—so it could be held in a similar manner. The remote was not designed to work with computers, however, which posed a unique engineering problem discussed in detail in chapter 4.


Figure 3.4: The Nintendo Wii® Remote

Using the remote required several design trade-offs. First, the device itself is rigid but could be damaged through any impact. This required the remote to only be operated in the air, which raises some confusion as to where the virtual drum exists on the vertical plane. Second, while the form-factor shares similarities with a drumstick, its buttons and bulkiness still requires a somewhat unconventional/unnatural grip. Lastly, for people who actually play video games, there exists some overhead in shifting their interaction model from "play" to "learning" with the device. Ultimately, these trade-offs were acceptable given the functionality and cost of the remote.

# Chapter 4

# System Implementation

This chapter describes the implementation of *Percussive*—touching on the software developed to interface with the device, the algorithms used to model and recognize input, and the design and implementation of the user interface.

## 4.1 System Overview

The prototype consists of a wireless remote which interfaces with an Apple Mac Pro through Bluetooth. The packets received from the device are intercepted by software which recognize the acceleration values from the packet and model that input as a potential drumstroke. If the interface receives a successful drumstroke, system-wide input messages are sent to the operating system which a Flash[1] user interface intercepts. This interface is projected as a large-screen display for the user to interact with (see Figure 4.1 for a complete system diagram).

*Percussive* is written in Objective-C and Cocoa for the Macintosh OSX operating system. It also employs several open-source projects discussed below.

[1]http://www.adobe.com/products/flash/ - A program which allows the creation of animated, interactive vector graphics and multimedia for digital, web, and mobile platforms.

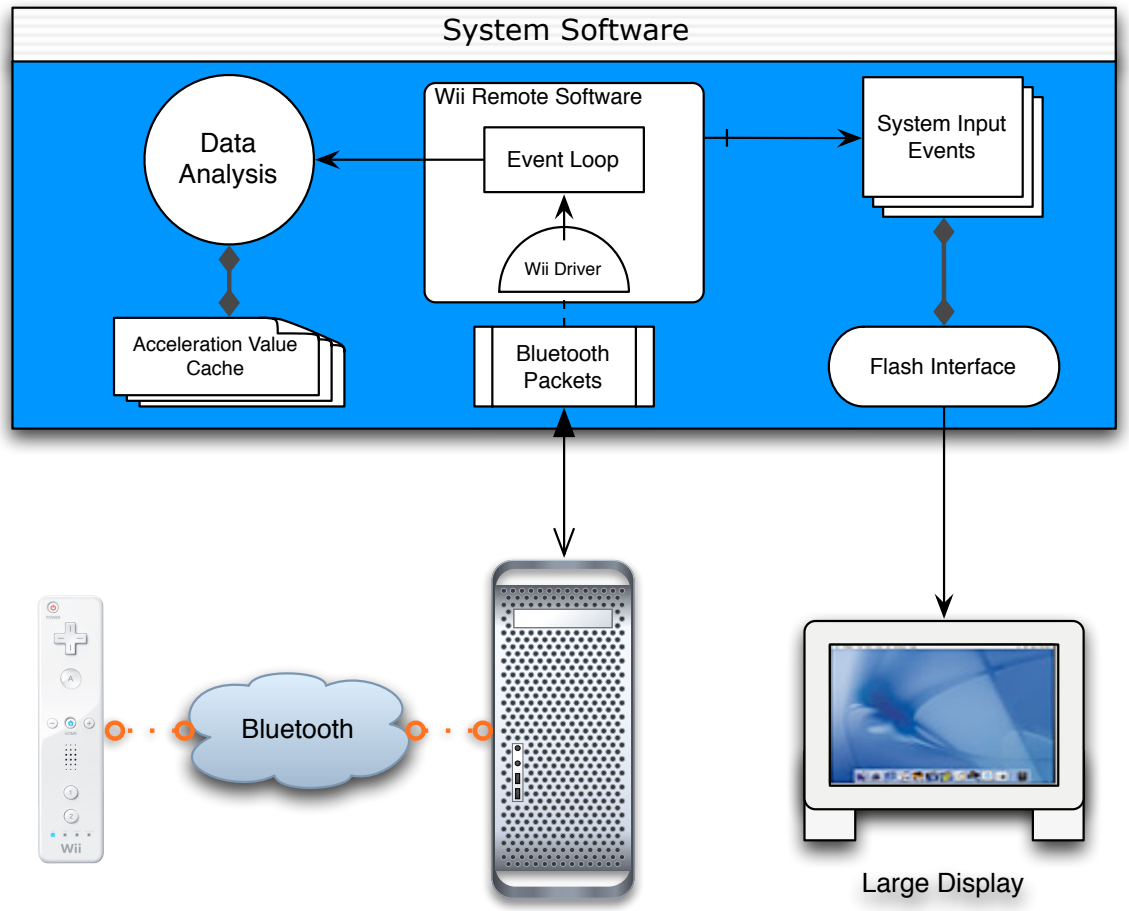



Figure 4.1: System diagram for *Percussive*

## 4.2 WiiRemoteFramework

The WiiRemoteFramework[2] is an open-source driver-level framework for developing applications that center around the Nintendo Wii® remote as an input device. This project is head up by a contributor named Hiroaki, and is a direct extension of other efforts to provide GNU/Linux ports to the Wii system through the WiiLi project[3]. This framework creates a data abstraction for the Bluetooth packets coming to and from the remote, as well as allow for the creation of callback routines to handle various events with the remote; for example: acceleration changes, button depressions, and tilt changes. In addition to these API functions, the framework also handles

[2]http://sourceforge.net/projects/darwiin-remote/
[3]http://www.wiili.org

connecting the remote to the operating system through discoverable Bluetooth.

## 4.3 Low-level Interaction Model

When the state of the remote changes, it beacons a Bluetooth packet to the device it is paired with. The remote has a maximum frequency of 100 reports per second. This packet uses the HID standard[4], which allows devices to be self-describing by using a HID descriptor block. This communication is unidirectional, as the device recognizes input and output through its descriptor block messages. Refer to the following table for a human-readable summary of the remote's HID descriptor block:

| **Report ID** | **Payload Size** | **Known Functions** |
|---|---|---|
| 0x11 (input) | 1 | Player LEDs, Force Feedback |
| 0x12 (input) | 2 | Report type / ID |
| 0x13 (input) | 1 | IR Sensor Enable |
| 0x14 (input) | 1 | Enable speaker |
| 0x15 (input) | 1 | Controller status |
| 0x16 (input) | 21 | Write data |
| 0x17 (input) | 6 | Read data |
| 0x18 (input) | 21 | Speaker data |
| 0x19 (input) | 1 | Mute speaker |
| 0x1a (input) | 1 | IR Sensor Enable 2 |
| 0x20 (output) | 6 | Expansion Port |
| 0x21 (output) | 21 | Read data |
| 0x22 (output) | 4 | Write data |
| 0x30 (output) | 2 | Buttons only |
| 0x31 (output) | 5 | Buttons — Motion Sensing Report |
| 0x32 (output) | 16 | Buttons — Expansion Port |
| 0x33 (output) | 17 | Buttons — Motion Sensing Report |
| 0x34 (output) | 21 | Buttons — Expansion Port |
| 0x35 (output) | 21 | Buttons — Motion Sensing Report — Expansion |
| 0x36 (output) | 21 | Buttons — Expansion Port |
| 0x37 (output) | 21 | Buttons — Motion Sensing Report — Expansion |
| 0x38 (output) | 21 | Buttons — Motion Sensing Report |
| 0x3d (output) | 21 | Buttons — Expansion Port |

Table 4.1: Wii HID Descriptor Block [27]

[4]http://www.usb.org/home/ - A standardized protocol for USB devices.

### 4.3.1 Motion Sensing

The Wii Remote tracks acceleration through a ADXL330 accelerometer[5], positioned slightly left of the large "A" input button. This accelerometer is rated to measure a range of $\pm 3g$ with a 10% sensitivity. Refer to Figure 4.2 for a diagram of the remote's coordinate system and its tilt-sensing. If at any time the WiiRemote-Framework parses a change in acceleration/tilt from a report payload, it will fire the `accelerationChanged:(WiiAccelerationSensorType)type` API function which is where our software hooks to analyze the incoming acceleration data.

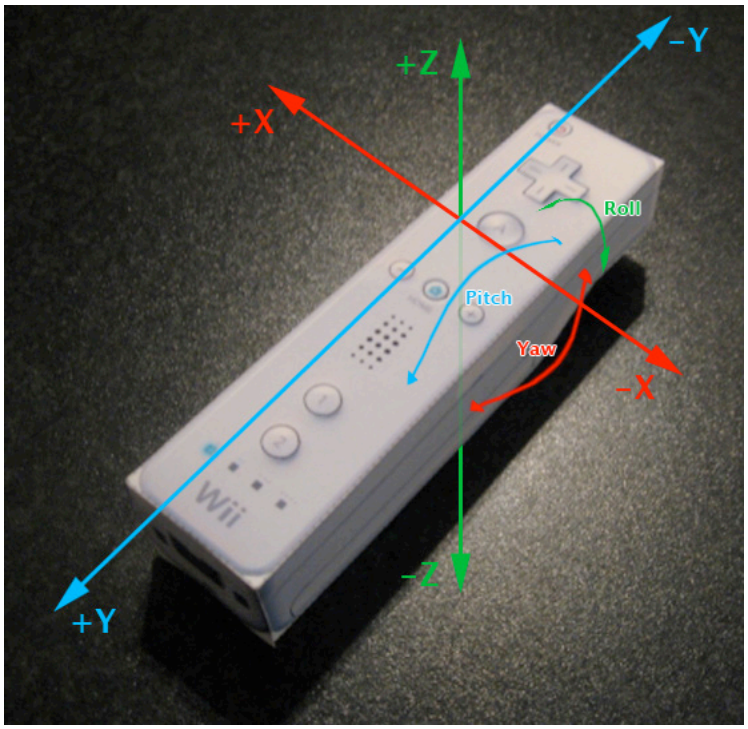



Figure 4.2: Wii Remote Coordinate System and Tilt-Sensing

### 4.3.2 Callback Performance

As mentioned above, the maximum frequency of the remote's HID packet reporting is 100 times per second. After some informal testing during the initial prototyping stage, this reporting was found to incur an average response time of 11ms for packet

[5]http://www.analog.com/en/prod/0%2C2877%2CADXL330%2C00.html

posting. The response time is particularly agile, allowing the system to handle the packet parsing, processing of motion, and system events for the GUI all within an average latency of 20ms. Expert evaluators commented on the latency of the system as "very responsive."

## 4.4 Drumstroke Recognition

Correct drumstrokes feature substantial downward acceleration which facilitates rebound of the drumstick back into playing position. In order for the system to recognize correct drumstrokes, some abstractions of a correct model were established. First, several experienced percussionists were asked to perform a series of basic drumstrokes. During this exercise, the percussionists' motions were graphed and the changes in acceleration tabulated. From those sessions, the following general graph of a correct drumstroke was created:

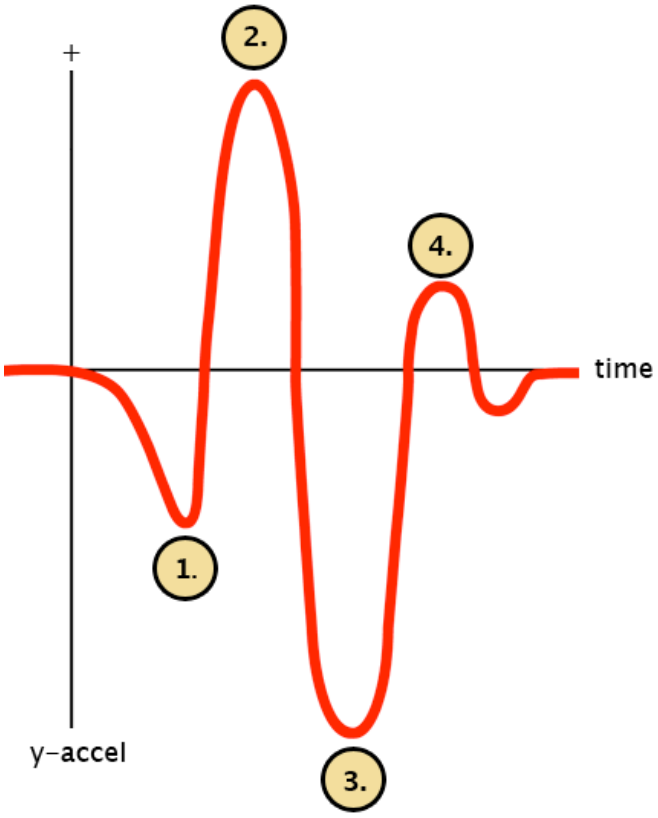



Figure 4.3: 1.) Preparation 2.) Upstroke 3.) Downstroke 4.) Stabilization.

Of particular note is how the Wii Remote's accelerometer operates in relationship to the user's hand. The values returned by the reporting are not characteristic of the acceleration of the remote, but rather the force exerted by the test mass on its supporting springs [15]. Because of this, the quantity reported represents the net force exerted by the user's hand on the remote—which is to say that at rest on a flat table the accelerometer reports a vertical force of $+g$, and when dropped reports a force of nearly zero (since it is falling at the same rate of the gravity that is acting on it).

Due to the fact that the remote measures exerted forces holistically, a proper drumstroke can be represented as a parabolic graph of y-acceleration over time. This allows recognition to be treated as a peak-detection problem.

### 4.4.1 Drumstroke Recognition Algorithm

```
function accelerationChanged(accelY, TIMEOUT_DURATION)
   const int SAMPLE_SIZE = 6;
   int y_samples[SAMPLE_SIZE];
   int count = 1;
   while (ticking())
      if (count <= SAMPLE_SIZE)
         y_samples[count] = accelY;
         count = count + 1;
      else
         if (allValuesOverTreshold(y_samples[]))
            RegisterHit();
            Timeout(TIMOUT_DURATION);
            count = 1;
         end
         for (i = 1; i <= SAMPLE_SIZE; i++)
            y_samples[i] = y_samples[i+1];
         end
         y_samples[SAMPLE_SIZE]=accelY;
      end
   end
end
```

Figure 4.4: Drumstroke Recognition Algorithm

Essentially, this algorithm establishes a threshold of a certain $g$-force value ($1.9g$ was found to be ideal) and maintains a sample of acceleration values read over time. If these acceleration values fall above the threshold for the duration of the sample, a drumstroke is registered. Once a successful drumstroke is registered, the callback will ignore successive updates for a set duration to avoid recognizing erroneous strokes. This timeout implicitly limits the frequency with which successive strokes can be executed, and consequently can be used to limit the system to simpler note units in early developmental stages (no quicker than a quarter note, for example). Rather than depend on callbacks to dictate the rate of acceleration samples, *Percussive* uses a 25ms "tick" to produce consistent sampling frequencies. This tick creates more accountability in sample errors, and makes the synchronization of the user interface more predictable in contrast to on-demand callbacks.

## 4.5 Remote User Interface

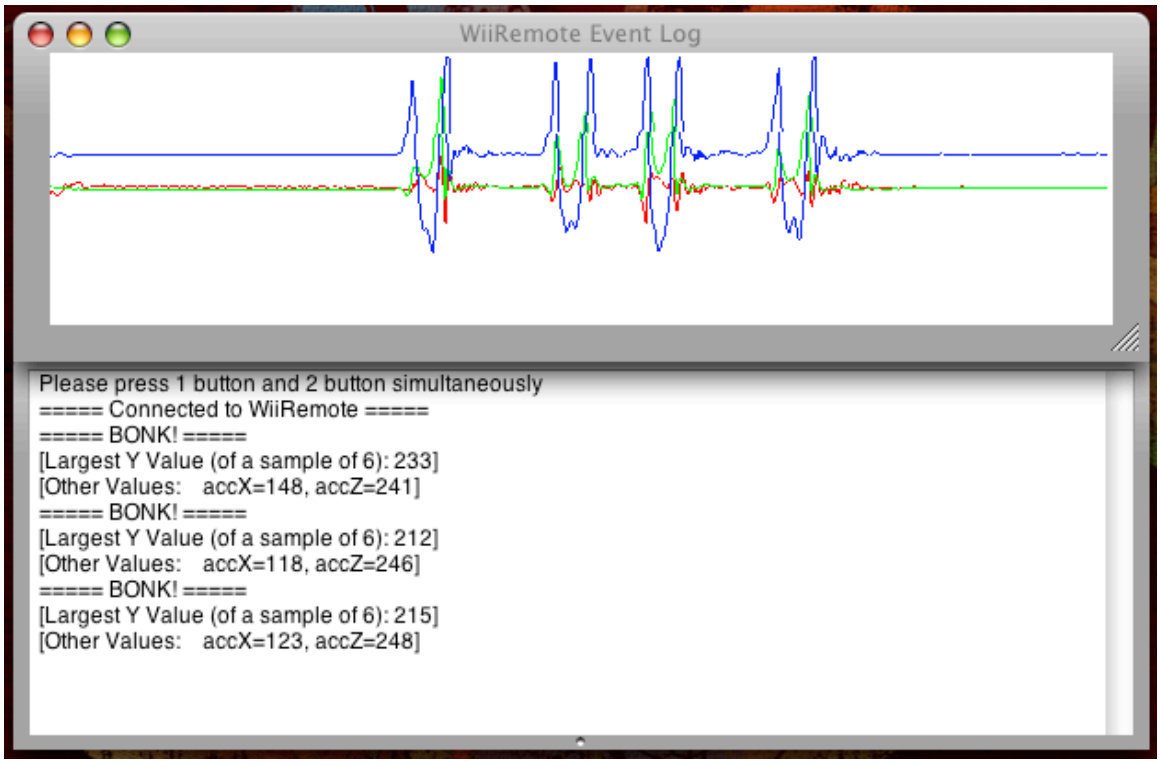



Figure 4.5: Wii Remote Event Log UI

*Percussive* features a separate user interface for remote motion monitoring and debugging. This interface was built on the WiiRemoteFramework as well as the DarwiinRemote distribution for OSX. As you can see from Figure 4.5, this interface is nothing more than a graph readout of remote motion and a console window for debugging purposes. This Cocoa[6] application uses a `GraphView` widget to display the remote motion, which was taken from an example in the O'Reilly *Cocoa Applications* book. Since this interface is used primarily for debugging and evaluative purposes, its design was simple and functional.

## 4.6 Percussion Lesson Interface

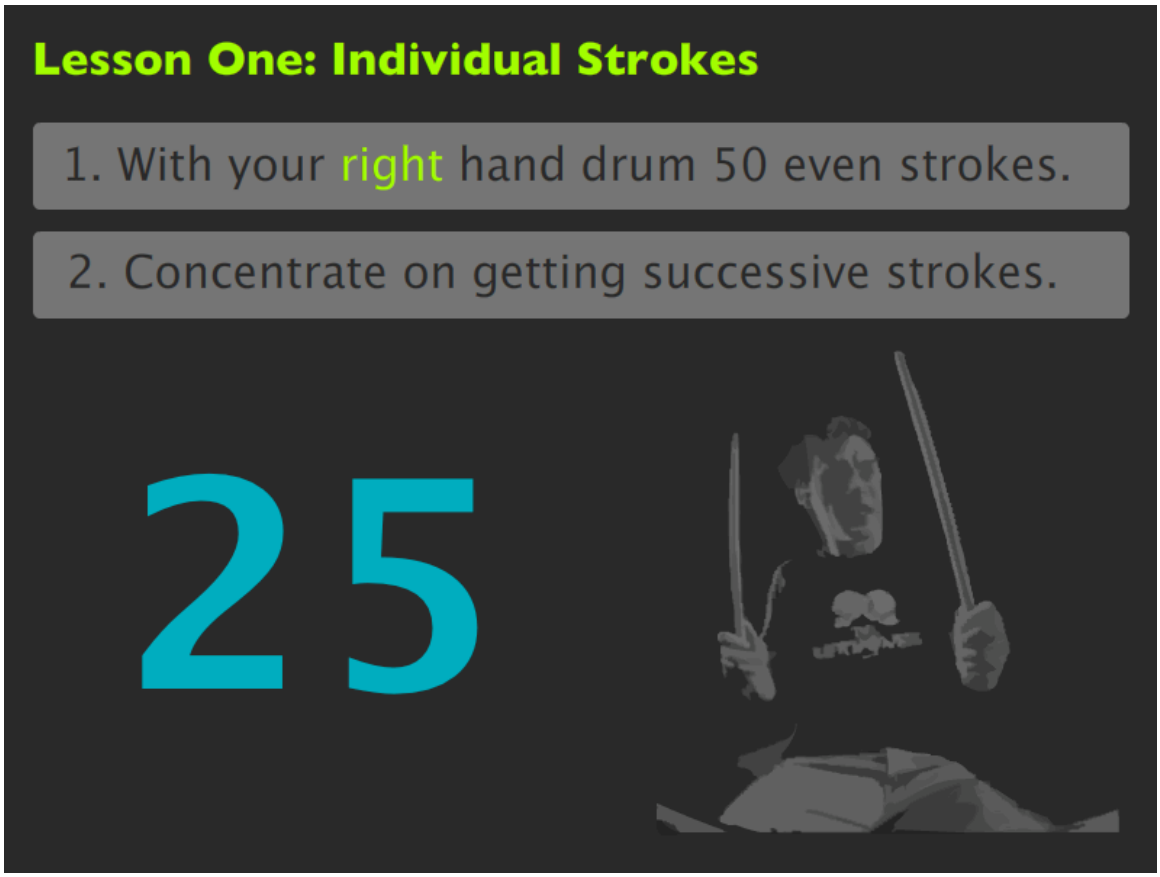



Figure 4.6: Example Screen From Percussion Lesson Interface

[6]http://developer.apple.com/cocoa/ - An object-oriented application environment for making native OSX applications.

The interface for the percussion lessons themselves was created using Adobe Flash®. Flash not only allows for rapid generation and modification of graphical elements, but also the convenient incorporation of rich media. Since *Percussive* was envisioned for use with large-screen displays, Flash's vector-based[7] graphic representation made it an ideal platform to develop on.

### 4.6.1 ActionScript

More than a simple graphics engine, Flash also features a powerful object-oriented scripting language called ActionScript[8]. ActionScript allows *Percussive* to communicate seamlessly between the two interfaces, as well as manipulate the on-screen elements of the interface programatically. In order to receive the system-wide input events from the Wii Remote Event Log program, an `Object.KeyListener` instance is created. This class allows the Flash file to capture and process input to manipulate the lesson interface. See the Figure 4.7 for a diagram of the *Percussive* event model.

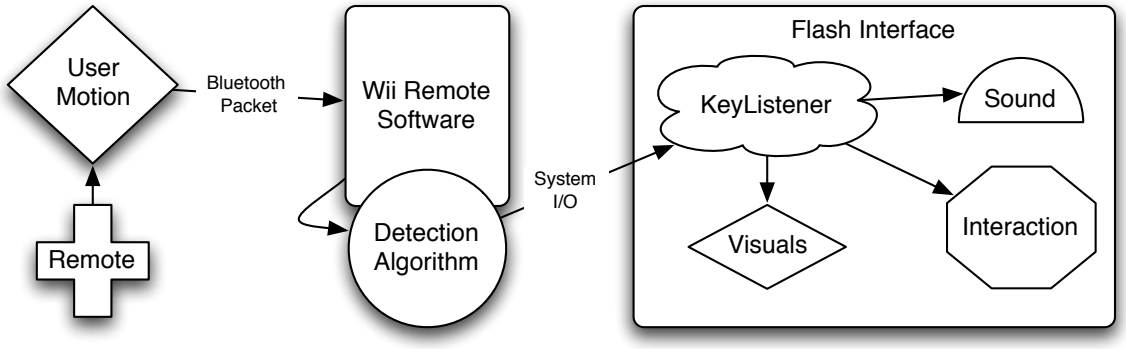



Figure 4.7: *Percussive* Event Model

[7]Vector graphics are created using scalable, mathematical formulas allowing them to be resized without a loss of quality.

[8]http://labs.adobe.com/wiki/index.php/ActionScript_3

### 4.6.2 Lesson Design

The prototype of *Percussive* implements two percussion lessons, one which is centered around the reinforcement of the basic drumstroke, and another which serves as an introduction to rhythm and percussion music. While the experimental rationalization for both of these lessons is described in chapter 6, the following sections outline the general design and implementation.

#### 4.6.2.1 Lesson One: The Drumstroke

In this lesson, users are oriented to the motion of a correct drumstroke. An exploratory exercise (Figure 4.8) opens this lesson, allowing users to test the remote recognition in a context-free setting. When the user executes a correct drumstroke,

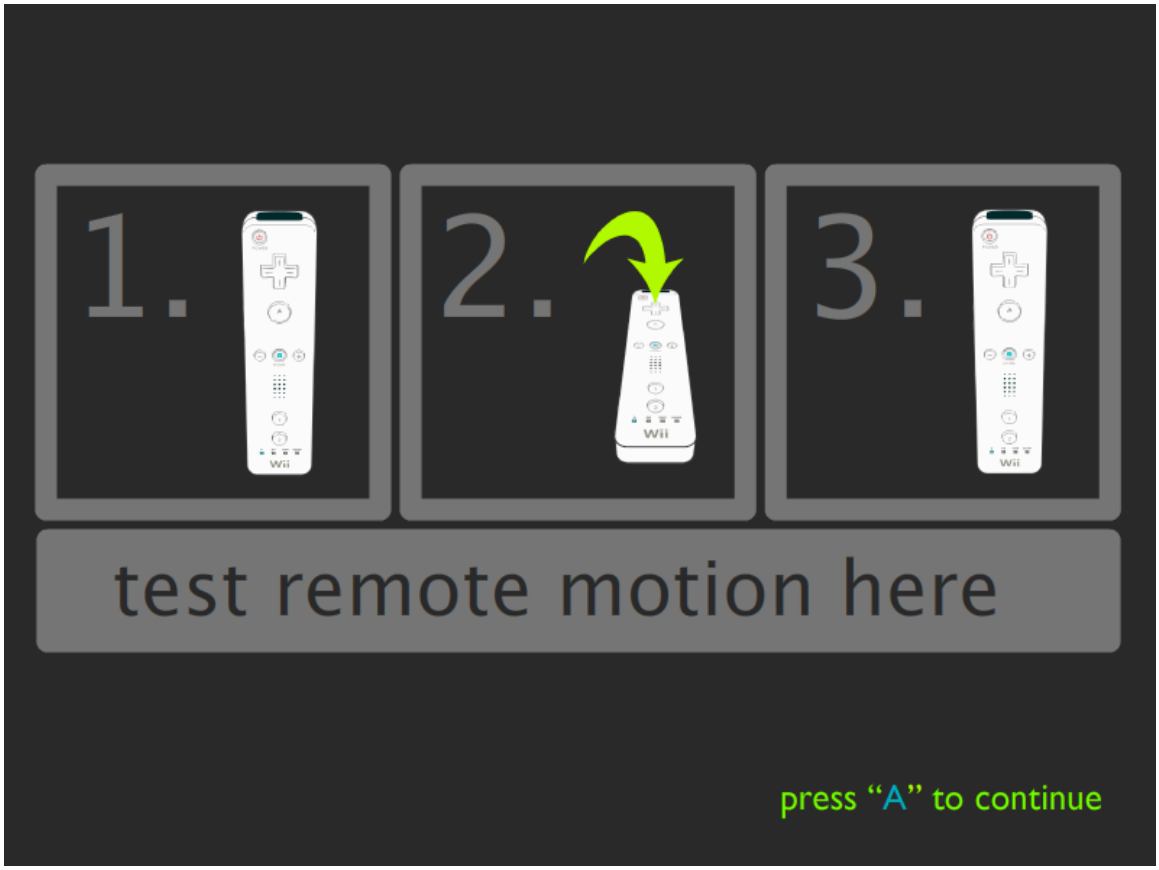



Figure 4.8: Orientation Screen

the remote will vibrate briefly in their hand to provide haptic feedback. A color

change in the interface serves as an additional visual cue to this recognition. Sound is also produced during a correct stroke, as the interface plays a sampled snare drum hit from the excellent Virutal Drumline 2[9] sample library.

Following this introductory exercise, users are asked to produce 50 strokes in each hand concentrating on consistency and successive correct strokes (Figure 4.6). This repetition puts the correct drumstroke in context (a counting exercise), as well as reinforces the motion to both short-term memory and primed muscle memory.

#### 4.6.2.2 Lesson Two: Rhythm and The Beat

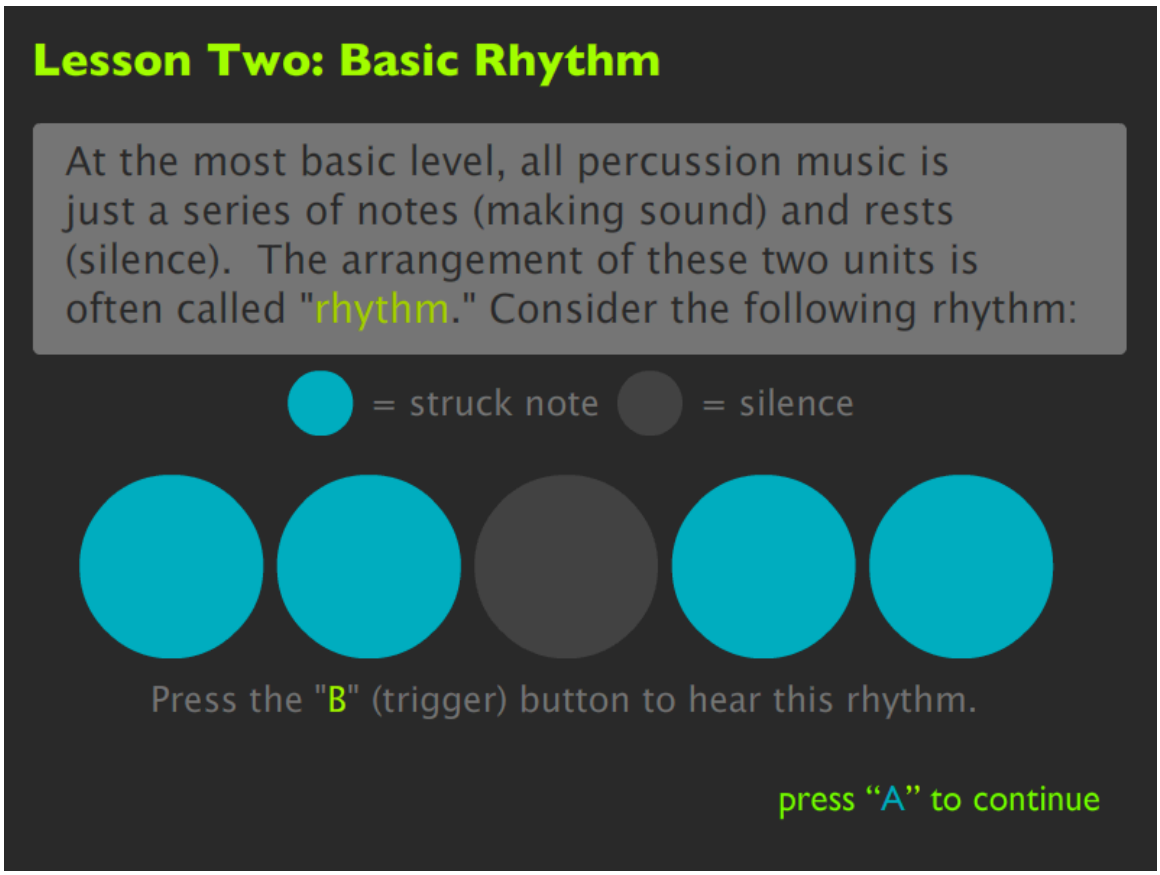



Figure 4.9: Introduction to Rhythm

In lesson two, the user is presented with the fundamentals of rhythm and percussion music. This is first done by setting up a representation of music through colored

[9]http://www.tapspace.com/vdl2/

circles (hits) and gray circles (silence). This abstraction is designed to reduce some of the cognitive load of understanding traditional musical notation. With this abstraction, *Percussive* introduces basic rhythm, relates that rhythm to a beat (Figure 4.10), and provides exercises for the user to drum along with those rhythms. To produce the sound files for each excerpt, layered recordings of Virtual Drumline samples were captured through WireTap Pro[10] and edited through Apple Quicktime Pro[11].


Figure 4.10: User Learn About the Beat

[10]http://www.ambrosiasw.com/utilities/wiretap/
[11]http://www.apple.com/quicktime/

# Chapter 5

# Pedagogical Design

Although the pedagogical charges behind *Percussive* are mentioned several times in other chapters, the true appropriateness of this interface lies in its application to existing instructional frameworks. In this chapter, we discuss such a framework and how *Percussive* fits into it at both the conceptual and functional levels.

## 5.1 A Fresh Approach to the Snare Drum

The book "A Fresh Approach to the Snare Drum" [28] by Mark Wessels is one of the most acclaimed beginning percussion methods in the past several decades. Instead of approaching beginning percussion as a brief introduction to holding drumsticks and then diving head-first into learning music, Mark pays careful attention to the development of fundamental techniques and muscle memory. This is all accomplished in a unique environment, where exercises are set to accompaniment through real musical ensembles covering several genres.

### 5.1.1 The "Approach"

Mark's method employs an instructional model centered around the reinforcement of motion. Rather than looking at technique as an exercise in decomposition and isolation, the lessons themselves are united with the common goals of muscle memory and developing "correct" motion on the drum.

At a higher level, this focus is related to the act of drumming itself—which is a building-block interaction. Bad habits propagate quickly, so it is of the utmost importance to not reinforce incorrect motion. By approaching muscle memory proactively, Fresh Approach sets students up to succeed.

Another facet of the Fresh Approach model is its use of play-along CDs. These recordings provide more than simple context for the student, as they are both engaged in the material as well as introduced to the responsibilities and excitement of playing within an ensemble. This highlights the importance of the social aspects of drumming, and introduces them to the student without their explicit knowledge.

## 5.2 Application of Model

Because of their similar pedagogical structure, *Percussive* can be easily adapted for use within the Fresh Approach educational model. The following steps outline this adaptation:

1. **Relate the input device to drumsticks** - Early exercises presented in the interface should closely correlate to actual drumsticks, so that students do not mistakenly seek mastery of the input device itself.

2. **Structure early lessons around motion reinforcement** - More important that simply producing correct strokes, consistency and repeatability are to be the main focus of early instruction.

3. **Encourage deep engagement from the user** - Because of the target age of the users, it is important to replicate the engagement found from the play-along CDs in the digital system. More than just simply providing similar recordings, the interface must cultivate a sense of social inclusion and enjoyment.

4. **Revisit rudimentary techniques** - In order for the muscle memory to be effective, the motion must be positively reinforced at every step of development.

## 5.3 Discussion

Fresh Approach is only one of many successful educational models in percussion, but it resonates well with the pedagogical model of *Percussive*. The interface itself is well-suited for the types of physical, abstracted exercises found in this method, and the level of engagement possible from an embodied system correlate well to that of Fresh Approach.

# Chapter 6

# Experimental Design

The evaluation of *Percussive* was carried out in two steps: a formal user study consisting of twenty Virginia Tech students, and an expert evaluation conducted by two prominent percussion instructors. This chapter discusses both the design and execution of both studies.

## 6.1 User Study

The user study for *Percussive* was conducted as an empirical field study, focusing on both the experiential qualities of using a digital instruction system and the transition of user expectations after interacting with the system.

### 6.1.1 Subject Base

College students were chosen as the primary user base for the evaluation of *Percussive*. Since *Percussive* was designed for users with little to no prior experience in percussion, college students provided a convenient and appropriate user pool to draw from. It was also decided that subjects with actual experience in percussion were desirable as well, since their expectations of a digital system for interactive percussion are valuable in evaluation.

### 6.1.2 Study Design

The choice of an empirical field study comes with several tradeoffs in usability evaluation. While it provides robust feedback from users and can ensure the validity of usability problems as they are discovered, their results are "extensive, qualitative, and difficult to summarize and interpret [4]." This was an acceptable compromise however, as this type of interface does not lend itself well to empirical evaluation through data collection.

The field study was structured around a post-facto questionnaire designed to evaluate experiential ephemera rather than user satisfaction. This ephemera includes several design questions, which are enumerated below:

1. The effect of cognitive load on short-term muscle memory.
2. The attribution of error in non-recognized drumstrokes.
3. The expectations of percussion as a discipline.
4. The qualification of an instructor-less learning environment.

#### 6.1.2.1 Questionnaire

The questionnaire itself is listed below in its entirety. Below each question you will find rationale for its inclusion in the survey.

1. **What is your experience with musical instruments? What about Percussion?** This question serves to qualify the user's assessment of system mechanics, as well as attribute experience as a factor in success with the system.
2. **Do you own or have you extensively played a Nintendo Wii®?** This question addresses success with the system through a familiarity with the input device: the Wii Remote.
3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** One of the goals of *Percussive* was to "demystify" percussion as an instrument, so this question establishes the user's preconceptions for playing percussion.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing (No Rhythm — Some Ease in Creating Rhythm — Comfort with Rhythm — Mastery)?** This question gains an understanding of the subject's perception of their own sense of rhythm.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** One of the lessons in *Percussive* involves finding the beat in a musical recording. This question indirectly gains an understanding of the subject's connection with the beat.

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** This question addresses how increased cognitive load affects the basic drumstroke.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** This question establishes the subject's postconceptions with percussion as an instrument.

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** It is important to examine whether the user felt they or the system was in error when a drumstroke is not recognized.

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** This question also relates to subject postconceptions.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** This question is aimed at the experiential qualities of learning from a digital system.

## 6.2 Expert Evaluation

For the expert evaluation, two prominent percussion instructors were introduced to the system, allowed to interact with it, and interviewed in an attempt to assess the validity of the system and its approach. Short vitas of both instructors follow:

### 6.2.1 Tim Bray

Tim Bray is the director of the Virginia Helmsmen from Danville, VA—a WGI independent-open class indoor ensemble. Under his direction, the Helmsmen have represented Virginia as the only independent ensemble in the state, participating in the WGI World Championships as a finalist seven times and taking home a silver medal in 1998. Through his 35 years of experience as a percussion instructor, Tim has worked with countless scholastic and independent groups and is a sought-after clinician and adjudicator across the East coast. Tim is a member of the WGI Rules Congress steering board, and an endorser for Vic Firth Sticks and Mallets, Evans Drumheads, and Dynasty USA Instruments.

### 6.2.2 Lenny Keesee

Lenny Keesee director of the Ledford Indoor Percussion Ensemble from Thomasville, NC. The ensemble is a four time Atlantic Indoor Association Percussion Scholastic A Class finalist and the 2005 PSA-2 Class Silver Medalists. He is also in his seventh season as the the battery percussion instructor and arranger for the Ledford High School Panther Regiment Marching Band. Keesee has also served as as the Assistant Director of the Virginia Helmsmen from Danville, VA in 2005. In addition to his work at Ledford and Helmsmen, Keesee has taught and arranged for numerous high school programs in Southside Virginia and within the Piedmont Triad of North Carolina. He is also an active judge at marching band competitions in Virginia and North Carolina. Lenny is an endorser of Dynasty USA Instruments and is a member of the Vic Firth Education Team.

# Chapter 7

# Results and Discussion

This chapter presents the preliminary findings of the user study. Both usability concerns and design issues are discussed within the context of the experimental design.

## 7.1 Study Sample

The study was conducted over the first two weeks of May 2007 and held in McBryde 102C, a multi-purpose research space. Fourteen college students participated in the study, and an overview of that sample is presented below:

| Description | Representation |
|---|---|
| Total Size | 14 Subjects |
| Male/Female | 21%/79% |
| Childhood Music Experience | 79% |
| Recent (3yrs) Music Experience | 14% |
| Percussion Experience | 21% |
| Wii Experience | 21% |
| Comfort with Rhythm | 57% |

Table 7.1: Sample Overview

## 7.2 Usability Issues

In his work with military test pilots, J.C. Flanagan outlined a concept called "critical incidents" which is defined as an episode of interaction that is remembered as

particularly successful or unsuccessful [11]. These episodes serve as checkpoints in the system for moments that are essential to the success of the interface. During the evaluation of *Percussive*, several of these incidents were noted and are described and discussed in the following sections.

### 7.2.1 Critical Incident - Failed Recognition of a Drumstroke

When an incorrect stroke is encountered in *Percussive* the response from the system is nothing. No sound or confirmatory feedback is given at all. When encountering this occurrence it was found that users are forced to establish responsibility in this failed action. Either it was an error on the part of the system (a bug in the code), or an error in the performance of the user (an incorrect drumstroke). Most subjects attributed this error to their own performance, while a few (3/14) subjects suspected system error instead. Subject 9 was quoted as mentioning it being "80% my fault, 20% the system's" while subject 11 adds that it is simply "an error in the system."

### 7.2.2 Critical Incident - The First Rhythm Performance

When the subjects were first asked to perform a rhythm, many froze not knowing what to do next. Even though the on-screen instructions indicated pressing one button to start the playback and drumming along, the shift from a participatory model of "observation" to one of "evaluation through performance" proved substantially dissonant in some subjects (4/14).

### 7.2.3 Heuristics

A heuristic evaluation is a process described by Jakob Nielsen where general usability "rules of thumb" are examined to discover breakdowns in user models [21]. It was apparent that many users suffered dissonance between their perceptions and the design of the system, and the following heuristics proved symptomatic of the system itself in many cases.

- **Preventing Errors** - Audio clips could be layered by pressing the play button twice, causing substantial dissonance in the user experience
- **Providing Good Error Messages** - All feedback from the system was implicit.
- **Provide Feedback** - "Correctness" of a performed rhythm was never presented to the user.

### 7.2.4 Questionnaire Concerns

In addition to the more formal evaluative methods expressed above, many users gave pointed feedback about different facets of the interface which are listed below. Proposed solutions to these concerns are also listed in parentheses following each quote.

- **Subject 1:** "I would have liked to ask several questions." (More thorough and focused directions must be given to dispel the need for clarification)
- **Subject 4:** "Some may not understand how to properly hold it." (Add additional demonstration about how the input device is to be held)
- **Subject 6:** "I think it would be better to see someone demonstrate the lessons first." (Use video examples to supplement more visual learners)
- **Subject 6:** "I think if you had titled each part in chapters and let your subject know how many chapters there are, it would be more user-friendly." (Support user spatial expectations through a timeline or breadcrumb display)
- **Subject 7:** "Seeing hand motions on the screen would be helpful." (Add an on-screen avatar to further extend the user model—it is worth noting that this action could potentially lessen the embodiment of the interface)
- **Subject 8:** "It would be cool to see a score on accuracy." (Add a display of the relative accuracy of a performed rhythm)
- **Subject 11:** "The computer can register your stroke as being incorrect, but not how or why it was incorrect." (Provide feedback for unrecognized strokes that are detailed enough to correct)

## 7.3 Observations

Hard data was gathered throughout the study in the form of acceleration graphs, video footage, and investigator comments. Although the study was largely qualitative, selected observations from this data is discussed in the following section.

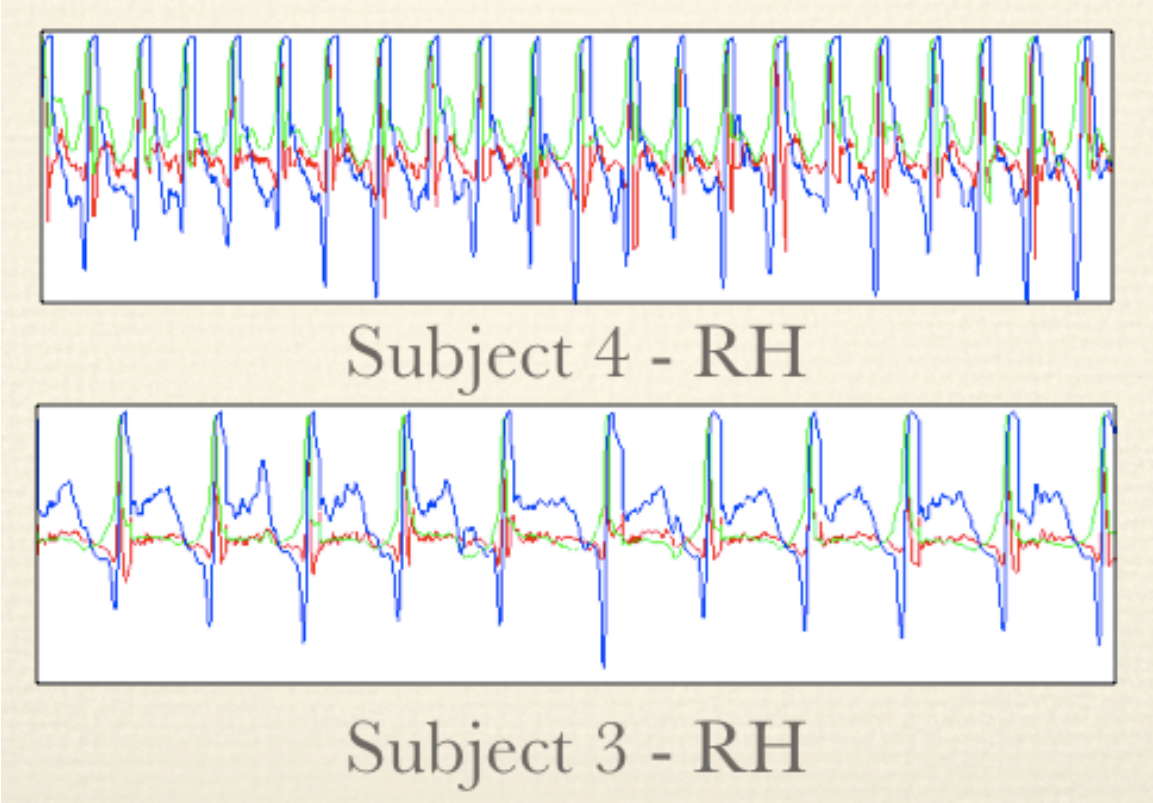



Figure 7.1: Graph Readouts of Two Subjects' Right Hands

In Figure 7.1, two subjects' right hand graph readouts are shown. You'll notice that while subject 3 (bottom) has a relatively even and consistent stroke, subject 4 performed extremely forceful and erratic motions. This exercise is the very first activity encountered after the orientation phase of the interface, which indicates that not everyone understood and applied the orientation. The orientation screen is open-ended to allow exploration of the motion, but it needs to be driven home that a grasp of that motion is necessary to progress throughout further lessons. In this way, it should become more of a required tutorial than an open-ended speed-bump in the overall task flow.

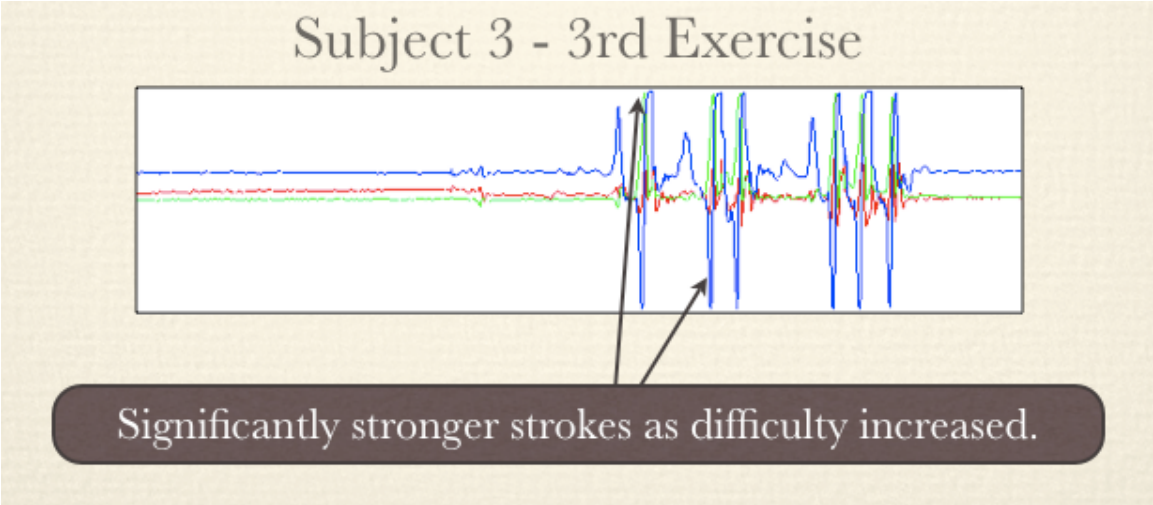



Figure 7.2: Graph Readout of Exercise Three

In Figure 7.2, the acceleration graph of the most complex exercise is shown. This exercise imparts the most cognitive load on subjects, as both the representation of the rhythms is changed (circles represented half a beat instead of a whole beat) as well as the frequency of struck notes. As subjects executed this exercise, their control of the basic techniques they developed through the course of the lessons significantly degraded. From this, it can be gathered that as discomfort increases so does overexertion. This is an observed phenomenon in coarse motor psychology, and it appears to manifest in this interface as well.

One particularly interesting finding in this study is that many subjects performed better with their non-dominant hands. In fact, 42% of subjects (1, 3, 4, 6, 7, 10) exhibited this phenomenon. Although the study itself did not explicitly identify the dominant hand in the subjects, they were allowed to use whichever hand was most comfortable in the exercises and all but one chose their right hand.

## 7.4 Study Conclusions

There are several key discussion points which arose from this study. Firstly, the exercises themselves need to combine the tasks of performance and stroke execution. This is because in the developmental stages, percussionists need to constantly reinforce the

motion of a correct stroke. While the system does this implicitly by its recognition algorithm, it is every bit as important to execute rhythms with proper technique as it is to play them with the right timing.

Next, non-dominant hand performance seems to be correlative to the overexertion phenomenon noted in Figure 7.2. Because the algorithm is a thresholded peak detection scheme, the overexertion from discomfort in non-dominant drumming results in more downward acceleration—which in the context of this system is recognized more frequently as a correct drumstroke.

Calibration is also an important activity in systems such as these, and it should be an essential step in the interface to ensure users have a fundamental grasp of the rudimentary motions before moving on.

It was found that the algorithm employed in *Percussive* to model a drumstroke was satisfactory. As one of the expert evaluators Tim Bray described, "It's about as close to playing on an actual drum as anything I've ever touched."

Muscle memory is an ultimate goal of percussion training, and appears to be closely tied to cognitive load. For introductory lessons such as these, the correct motion of a drumstroke must be revisited as cognitive load and discomfort increase.

On the whole, subjects perceived the system not as an educational interface, but as a drumming activity which facilitated learning. This is an important design success of the system, as its embodied approach aims to capture the experiential qualities of drumming in the system itself. As you'll find from user comments listed in Appendix B, this goal has been largely met.

Lastly, there is a place for technology such as this in the musical curriculum. Both expert evaluators resonate with this point, seeing its potential as applied to early developmental percussionists (primarily fifth and sixth grade drummers).

# Chapter 8

# Conclusions and Future Work

Throughout the scope of this work, an emergent approach to percussion instruction was examined. This system, *Percussive*, leverages embodiment with a traditional pedagogical approach resulting in an experience that closely mirrors that of learning to play a real drum. Advancement of this technology could certainly support the rigid demands of accelerated percussionists, but even in its infancy systems such as this are well-niched with young beginning percussionists.

This study found that not only can acceleration be used as an accurate modeling space for drumstroke motion, but also an interactive system utilizing such recognition could exist within a conventional instructional framework. This framework, based upon Mark Wessel's "Fresh Approach to the Snare Drum," describes how developmental milestones such as the rebound stroke, muscle memory, and technical application can all be replicated and enhanced by *Percussive*.

## 8.1 Future Work

There is much more investigation necessary on the issue discussed in Chapter 7 with non-dominant hand performance. While this phenomenon is not viewed as a false positive with regard to the accuracy of *Percussive*'s stroke modeling, it does warrant reinvestigation of the act of drumming as primarily coarse-motor. More supporting research into the cause of specific performance problems could also help refine the direction of the interface.

Investigation into other form factors for the input device could greatly benefit the system. Ring-shaped devices which provide the same Bluetooth and acceleration-measuring functions could be slipped onto conventional drumsticks—allowing students to play on a physical surface while still collecting input for the interactive system.

Various interface iterations are also needed, most notably in the area of user feedback. The system does not tell the user "how right" they were, but as exercise rhythms are predetermined, Markov Models could be employed to give users a quantitative reading of their accuracy. Iteration upon the way the lessons are presented to the user, how tightly coupled those lessons are to the pedagogy, and the level of interaction the user experiences from the interaction level are all needed.

Lastly, there is much work to be done to place *Percussive* in a context appropriate for young percussionists. Extensive user studies should be conducted to develop a greater understanding of the young user base and how their unique perceptions of this system could adapt the pedagogical approach. Truly, the "next step" of this project is to spend time with fifth- and sixth-graders to iterate the design of *Percussive* holistically.

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# Appendix A

# Installation and Operation of Percussive

## A.1 Installation

*Percussive* is designed to run on Macintosh OSX, and is compiled as a universal binary (meaning it will work with both PowerPC and Intel-based Macintoshes). *Percussive* also requires that your system has a built-in Bluetooth™ receiver. After obtaining the latest distribution of the *Percussive* interface[1], unzip its contents to your desktop and follow the proceeding instructions:

1. Open `DarwiinRemote.app`.
2. Depress buttons 1 & 2 on the Nintendo Wii remote to pair the Bluetooth device to the software.
3. Open up the file `thesis-interface.swf` in your preferred web browser.
4. Input to this interface is as follows:
    - *Moving the remote up and down* – perform a drumstroke to the interface
    - *The "A" button* – proceed to the next screen
    - *The "B" button* – trigger any example clips on the current page

[1]The current distro can be found at http://www.gravtiywins.com/percussive.

## A.2 Troubleshooting

- If `DarwiinRemote.app` returns a "Wii remote discovery error" upon pairing, open System Preferences → Bluetooth, go to the "Devices" tab, and delete the Nintendo entry. This happens sometimes mainly as a consequence of OSX's attempts to automatically pair the device upon its detection.

- If an error occurs during the course of the lesson, you can reload the lesson and skip ahead by pressing the "A" button repeatedly to return to your previous spot.

- If the vibration feedback from the device is not functioning (or is stuck in vibration mode), exit the `DarwiinRemote.app` application, unpair the device, and start over again.

- If the device is producing erroneous drum hits, take time with the initial orientation screen to become comfortable and consistent with the "correct" drumstroke that *Percussive* is made to model. This will greatly enhance your ability to perform through the interface later in the lesson.

- If the interface is not recognized in your browser, ensure that you have the latest version of Adobe/Macromedia Flash[2] installed.

- If the interface is unresponsive upon initial loading, allow it addition time to cache the music files needed for the lesson.

[2]http://www.adobe.com/products/flashplayer/

# Appendix B

# Study Questionnaire Transcripts

## B.1 Male

1. **What is your experience with musical instruments? What about Percussion?** Portion of elementary, middle, and high school with various concert and marching percussion ensembles.

2. **Do you own or have you extensively played a Nintendo Wii®?** Nah.

3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** Learning to read the music was difficult and getting the rhythm was hard.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Comfort with Rhythm.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Of course.

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** I definitely focused more on the beat and not the stroke, so it was easier.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** I feel like mastering the rhythm is most difficult.

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** I am uncertain. I feel as thought my stroke was correct, but experienced a delay in the auditory feedback it made my rhythm a bit off.

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** Indeed.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** I love everything interactive, but I'm also very picky when it comes to AI of sorts. Eg. frustration with automated corporate phone menus. I felt like this was a clean and simple system which was fun to use. It helped that I could pace myself and that you can incorporate multimedia into the lesson. It did hinder in the regard that there isn't visual feedback from an instrument, EG. am i stroking high or low enough, fast or slow? Where to stop is an issue. Overall it was very interesting and encouraged me to do more.

## B.2 Female

1. **What is your experience with musical instruments? What about Percussion?** 8 years of piano, 4 years of violin, percussion in elementary school.

2. **Do you own or have you extensively played a Nintendo Wii®?** No.

3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** difficult.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Some Ease in Creating Rhythms.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Yes. Especially when playing the violin.

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** It felt harder to control.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** Somewhat easier than what I originally thought. It was nice to be able to hear an example before you performed the strokes yourself.

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** Both. When performing the stroke I was unsure of where to stop hitting since there was no drum, so it felt as if there was an error.

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** I would like to.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** I would have liked to ask a lot of questions ("Am I holding it right? How could I improve?"). It's nice to be able to go about the program at your own pace and be able to repeat each lesson as many times as you wanted. The Wii remote was a little bit hard to grip.

## B.3 Female

1. **What is your experience with musical instruments? What about Percussion?** Flute, several years of percussion.

2. **Do you own or have you extensively played a Nintendo Wii®?** Played Wii.

3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** It is difficult but never unbearable.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Comfort with Rhythm.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Yes.

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** The basic motion was difficult at times with the controller.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** It is easy to break down and learn.

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drum-stroke motion) or an error in the system (the system failed to identify your drumstroke)?** It may have been both. My strokes were probably not consistent.

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** Yes.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** I liked it because I moved at my own pace. I can imagine that with more difficult rudiments, the ability to have endless repetition would be very helpful. But I think the lack of actually hitting something can hinder you. It is great for learning the basic stroke and rhythms with their exact values.

## B.4 Female

1. **What is your experience with musical instruments? What about Percussion?** Music Major – play piano/trumpet. Played around with percussion.

2. **Do you own or have you extensively played a Nintendo Wii®?** Yes.

3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** Technique takes time but basics are relatively easy if you can keep a beat.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Mastery.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Yes. Music major.

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** No, just the fact that the Wii remote is so much bigger than a drumstick made it slightly awkward, but not enough to affect performance I don't think.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** Wii remote seemed to beat erroneous beats – etc. 1 stroke would sometimes sound 3 taps. I think without the errors it would cause less frustration and streamline the learning process.

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** Sometimes I would misjudge the beat, and I know my stroke is more aggressive than most percussionists because I don't have technique.

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** If I was given a drumset or had access to one for free. Always wanting to learn new instruments.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** The on-screen explained really well to me, some may not understand how to properly hold it.

## B.5 Female

1. **What is your experience with musical instruments? What about Percussion?** Piano (10 years ago).

2. **Do you own or have you extensively played a Nintendo Wii®?** No, never.

3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** Not very hard for basic level.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Some Ease in Creating Rhythm.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Sometimes

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** Basic was comfortable, last step was not.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** Want to learn! Interesting!!

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** I did not create the correct drumstroke motion

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** Yes, if I have a chance.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** Some yes and no. Visually it helped a lot, but the motion I prefer to play actual instruments.

## B.6 Female

1. **What is your experience with musical instruments? What about Percussion?** None.

2. **Do you own or have you extensively played a Nintendo Wii®?** No.

3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** Difficult. I don't have a good sense of beat.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** No Rhythm.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Yes.

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** Uncomfortable. It could be because I am not used to the remote, and it is different from using real drumsticks.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** It's still difficult, but the study seems to be beneficial if I were to begin in learning lercussion.

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** I think it could be an error on my part, but I think it also depends on how sensitive the system is.

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** No, however I may learn it in the future.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** I felt frustrated when the system fails to read my motions. However, it was good to have something to interact with. The sound of the system projects when the motino is made is good. I think it would be better to see someone demostrate the lesson first, and I think if you had titled each part (in chapters), and let your subjects know how many chapters there are, it would be more user friendly. And it would be even better if the subjects can choose which part of the lesson they want to work on. But it was good overall.

## B.7 Female

1. **What is your experience with musical instruments? What about Percussion?** I played the clarinet and a bit of guitar–none in percussion.
2. **Do you own or have you extensively played a Nintendo Wii®?** Yes.
3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** I assumed that I would find holding the "drumstick" and stroke more difficult to grasp than rhythm.
4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Comfort with Rhythm.
5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Oh do I? Yes I do!
6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** As assumed, I had a bit of difficulty making the right stroke, but with practice I could. The program was very descriptive.
7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** The program broke rhythms down very well, so it would be much easier than I thought.
8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** I did not create the correct drumstroke motion (I think it was overexcitement).
9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** Yes, I would.
10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** I was not too frustrated because when I made a mistake, I could replay the beat and figure it out after a few tries. However, maybe seeing a hand motion on the screen would be helpful for visual learners. Also, it would be cool to see a "score" on accuracy to see how off or on you are.

## B.8 Female

1. **What is your experience with musical instruments? What about Percussion?** Played the guitar for 6 months.

2. **Do you own or have you extensively played a Nintendo Wii®?** No.

3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** Semi-hard.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Some Ease in Creating Rhythms.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Sometimes.

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** Became a little more uncomfortable.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** Still a little hard.

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** Error on my part.

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** Probably not.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** No, it was helpful but sometimes made it hard not knowing what my mistake was.

## B.9 Male

1. **What is your experience with musical instruments? What about Percussion?** I have played the bongo/timpani before.

2. **Do you own or have you extensively played a Nintendo Wii®?** No.

3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** Fairly hard, but not too hard with constant practice.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Comfort with Rhythm.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Yes.

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** It became harder to control.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** Same as before.

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** 80% my fault, 20% the system's fault.

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** Yes.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** Digital system was alright. I felt I could have done much better with a real drumstick and drum.

## B.10 Female

1. **What is your experience with musical instruments? What about Percussion?** None.

2. **Do you own or have you extensively played a Nintendo Wii®?** No.

3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** Moderately Difficult.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** No Rhythm.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Yes.

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** Uncomfortable.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** Pretty hard.

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** Error on my part.

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** No.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** Yes; made me focus more.

## B.11 Female

1. **What is your experience with musical instruments? What about Percussion?** None.

2. **Do you own or have you extensively played a Nintendo Wii®?** No.

3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** Difficult.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Comfort with Rhythm.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Yes.

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** yes.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** Difficult.

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** My error -¿ Discomfort with system.

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** No.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** As a semitechnophobe I was uncomfortable and afraid of the system–not rational but true–whereas an instructor would

provide encouragement and direction. The computer can register your stroke as incorrect but not why it was incorrect. Such a system would be great for music students to practice on to reinforce leraning or for the "new" generation who is more comfortable with a system or machine than another human being.

## B.12 Male

1. **What is your experience with musical instruments? What about Percussion?** Played percussion 3 years in middle school band.
2. **Do you own or have you extensively played a Nintendo Wii®?** No.
3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** Assumed it would be fairly difficult and time-consuming.
4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Comfort with Rhythm.
5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** yes.
6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** Not quite as easy, but not uncomfortable.
7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** Still believe everything involved is pretty difficult.
8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** Error in system.
9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** Would love to pick it back up, and the lesson piqued my interest.
10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** I feel like an in-depth, personalized lesson would be necessary for prolonged instruction, but for basic lessons the digital system was plenty adequate.

## B.13 Female

1. **What is your experience with musical instruments? What about Percussion?** 7 years clarinet, 3 years mallet percussion.
2. **Do you own or have you extensively played a Nintendo Wii®?** No.
3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** I thought a certain amount of skill went into learning percussion.
4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Comfort with Rhythm.
5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Yes.
6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** No, I found that it was quite easy to control once you find the center of the motion.
7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** I feel that it would be easier to pick up.
8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** I felt it was an error on my part by not getting the stroke correct.
9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** Yes.
10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** I felt that it helped because of the examples on the screen pairs with the sound. However, individual instruction allows for perfecting in a way that a digital system could not.

## B.14 Female

1. **What is your experience with musical instruments? What about Percussion?** I was in band in high school, played the clarinet, bass clarinet, and xylophone.

2. **Do you own or have you extensively played a Nintendo Wii®?** No.

3. **Before participating in this study, what was your opinion of how hard a musical instrument percussion was to learn?** Moderately Hard.

4. **Some people describe themselves as having "no rhythm." Which of the following describes your personal perception of rhythm and timing?** Comfort with Rhythm.

5. **Do you frequently find yourself tapping your feet or fingers when listening to music?** Yes.

6. **As the lesson became more complicated (more to think about), did the basic motion of the stroke become uncomfortable? Or was it just as easy to control?** Just as easy.

7. **What is your opinion of how hard a musical instrument percussion is after participating in the study?** Fairly easy once you get the hang of it.

8. **When something went wrong in the experiment, did you feel that it was an error on your part (you did not create the correct drumstroke motion) or an error in the system (the system failed to identify your drumstroke)?** Incorrect drumstroke.

9. **Given your short lesson in percussion, would you ever pursue learning the instrument?** yes.

10. **Describe the experience of learning through a digital system, did you feel frustrated by the lack of individual discussion or example? Where did it help? Where did it hinder?** I felt the program was easy to follow in general. There were a couple of glitches or spots where the system was uncleaer. For example, the rhythms were repeatable with the use of the B button but I did not know this until it was pointed out by the investigator. other than that minor detail which was easily fixed the program and its instruction were easy to use and follow.

# Appendix C

# Expert Evaluator Interview Transcripts

## C.1 Tim Bray

- **From your experience, what are some of the problems kids run into very early on in the developmental process?**

  Tim Bray: The first problem is getting a good control of the stick itself, 'cuz everyone wants to just bang really fast and be an instant rock drummer. So getting them to break it down to what an actual rhythm is, and having the patience to do that with a quality sound—anyone can make a noise, but not everyone can make a quality sound–so good grip, technique, and patience.

- **Have you brought technology into your programs at all?**

  TB: We've used DVDs, CDs, cassette recordings that are somewhat interactive, we've also used basic recordings, recording the students as they perform, and of course we've used electronic metronomes to learn to play in time.

- **As far as technology that's available for instruction goes, what's out there right now?**

  TB: It's really very limited. You have metronomes, headphones with metronomes built in, drum machines that you can program rhythms into and play it back, and there's interactive notation software that can play what you write back for you, but it's there's not there for the actual hands-on part–it's mostly just on the learning angle.

- **Why do you think that percussion technology has not advanced much over the past decade?**

  TB: I think it's an issue of both the technology and interest. Again, if you

go back to the initial problem of trying to teach a kid to play drums is patience. So technology would have to be fun and interesting to hold the attention of a kid so they could stick with it. The other thing is once you start to develop technique, the programs would have to be pretty advanced or have the capability of being advancible [sic] to keep the kids interested, which may be cost-prohibitive—if you couldn't develop more software to go with it.

- **Would you comment on the accuracy of the remote in this digital interface? Did the motion feel realistic? The recognition appropriate?**

  TB: I thought it felt good really. The stroke itself feels great. It's about as close to playing on an actual drum as anything I've ever touched. The difference being that it's a lot shorter in your hand, so the implement itself feels a little odd, but even as you start to work with it more it feels better for the grip because it creates more of a natural grip in your hand. Which is of course a developmental roadblock for early percussionists.

- **Would you rather see the form factor of this remote made into something more like a drumstick?**

  TB: I think an actual stick or something that felt like a drumstick would be a great enticement to the program. If you had something that you could actually pad onto at some point, a second level where you could actually take the technique to a drumpad with it that would definitely take it to another level.

- **Touch is an important thing when it comes to drumming, at what point do you think technology like this is limited to the point where you have to get on a real instrument to develop further?**

  TB: Heh, that's a good question. I think once you get past the understanding of rhythm and time and space, and how to create a quality of sound, you would need to move pretty rapidly to a pad or drum to get that stroke and muscle memory that you've developed realized. If you could somehow have this as an electronic pad, with an electronic implement—then the possibilities are limitless. Because you could play any rhythm imaginable and get instant feedback on the rhythm itself as well as the stroke, as opposed to playing the rhythm and it's close and not exactly knowing why.

- **What did you feel about the lesson design, how was it as an introduction to percussion?**

  TB: I think as long as you're using a device like this, the grip isn't as important since you're picking up the motion and in order to get this device to pick it up you have to have the proper motion. So you're eliminating the problem that you have with grip. I think that's right on target for where it needs to be. The lessons that you have, the samples of rhythm chosen, are on-track

with developing muscle memory which is step one–'cuz you have to develop the stroke. The second thing is learning the distance of space between the actual notes to create rhythms, so any changes to the rhythmic changes in the patterns you have and the ability to change those rhythms would be the only necessary step.

- **When the system fails to recognize a stroke it simply does not respond at all. Do you have any suggestions for an alternate implementation or cue that would perhaps allow users to tell the difference between a breakdown in their stroke, or a system error?**

  TB: Me personally, I like it just like it is. Because most everything we do competitively is all or nothing. When it comes to producing a drumstroke, I feel it either produces a quality sound or it's nothing. There's really no in-between; it's not a gray area. If you changed it to where there was some type of buzzer or beeper or some type of instant feedback for an incorrect stroke, rhythmically that would be making a noise while you're trying to create a rhythmic sound or pulse with your hands—you may find that students, especially at a younger age, would do it purposely incorrect just to create the sound. I think nothing is better myself.

- **Do you envision a place for technology like this in typical percussion curriculums?**

  TB: Absolutely. I think it would be extremely helpful in beginning percussion classes with the band director with the band director who is not a percussionist, because their understanding of technique is somewhat limited in many cases, and this would help them to teach the student the proper stroke which would make the next person's job—the private lesson teacher or percussion instructor—make their job a little easier. I think it would need to be, because of patience being one of our biggest issues, it would need to be used in conjunction with actual drums. We start our students on drum pads, we don't make them buy drums because we feel like it's a waste of money, and we have a hard time keeping them satisfied on the pads. We have to get them on the drums at some point because they're drummers, they want to make noise. I think as you move up the scale, it could be a definite program you could come back to as you're introduced to more advanced techniques to spot-check your basic stroke.

- **Do you have any closing comments about this technology?**

  TB: It's really cool, heh. It's really cool. I think this is a great start in developmental technology for the up-and-coming percussionist. It is by far more advanced than anything that is on the market right now, and certainly would have a place in the educational field if you could develop it to the point of affordability. I think it would be a great tool to have, and I would highly

recommend something on this format to any program that wanted to teach a percussionist, because of its recognition of a correct stroke, and a bad stroke, and the difference between them.

## C.2 Lenny Keesee

- **From your experience, what are some of the problems kids run into very early on in the developmental process?**

  Lenny Keesee: The biggest thing I see is kids have a lot of problems counting. You know, I end up going back and teaching the high school kids same things that I think they should have learned in the 6th or 7th grade, maybe earlier. The biggest things are basic rhythms, and how to count those rhythms. Another thing, I think it starts at the middle school or beginner level, is sight-reading capability and that goes hand-in-hand with being able to count rhythms. It's a building block process, percussion is. I think we try to teach new skills as the kids get into upper grade levels each year. Everyone has different techniques and approaches to the instrument, a lot of the times what I try to do is tell kids to play through the drum. For anyone that's never done it, that's basically to play the drum as if they were hitting the drumhead 2 inches below where it physically sits, which helps to produce a quality sound. I've got a unique situation where 70% of the students I teach are female, and they tend to not hit the drum as hard as male students do. So I really try to emphasize a good, solid stroke, and not what we call "feather tapping" which is barely holding on to the stick and letting the drum produce the sound rather than you producing the sound. One thing I try to do is play with weighted sticks, play with the back of the mallet since it's a little heavier, whatever we can do to produce a good strong stroke.

- **Have you brought technology into your programs at all?**

  K: Currently it really comes down to the arranging and music side of things. We do everything with music notation software, and one of the thing I've gotten big into recently is making MP3s of individual music parts so kids can hear what their individual parts sound like, as well as what it sounds like in relation to other sections as a practice tool. We setup a website where the kids can go out and get pdfs of their music because they're kids, and they lose music, as well as MP3s to practice with. That's currently the biggest aid I get from technology.

- **As far as technology that's available for instruction goes, what's out there right now?**

  LK: I have not seen anything for percussion, we have gotten into it a little bit with music theory as far as basics of music and rhythm. We've actually gone back more to using the book and teaching rather than sit the kids in front

of the computer. We've tried the lab environment and it didn't work out as well as we hoped, so we haven't gotten much benefit from that right now.

- **Do you envision a place for technology like this in typical percussion curriculums?**

  LK: I think something like this would be great, especially at the fifth and sixth grade levels where you can begin to apply them being able to hear the rhythms, and visually see what they're doing. Something like that were you can apply the rhythms would be huge. Another thing is that I see a lot of kids that are wind players and are learning percussion as a second instrument, and there's a lot of things where they may be a ninth or tenth grader but you're trying to train them on a sixth-grade level just to get them caught up. So any type of tool like this, especially that you could take home and work on your own would really be beneficial. The time that you see kids is limited, but the time they spend on a computer is immense, so software like this could be very helpful.

- **Touch is an important thing when it comes to drumming, at what point do you think technology like this is limited to the point where you have to get on a real instrument to develop further?**

  LK: Just in the demo that we did here, and obviously this is just a prototype, the feel of the instrument and the actual transfer of the stroke to a real drum would need to happen early on. A lot this we currently see in going from a drum pad to a drum, because the feel just isn't the same. It's as close as you can get, and it's a good practice mechanism without being obnoxiously loud, but I think that the feel of it would be the biggest roadblock of an interface like this. You could teach basic rhythms, but as far as getting into more complex rhythms or drum rolls, more advanced rudiments, that's where you're probably gonna have to be on a drum. If you can refactor the form of the remote to a real drumstick, that would be huge.

- **What did you feel about the lesson design, how was it as an introduction to percussion?**

  LK: I think the interface is good, I really like the approach of the open and closed circles for rhythms–I thought that was good for someone who hasn't drummed at all before, or doesn't really have any musical background. Being able to see and hear that together is great. One thing maybe to enhance that is maybe the circles could flash as the sound is being played, just so they could see themselves. It might be good to have some introduction to how to hold the stick, a video clip, something that might enhance what they get out of the whole package.

- **Do you have any closing comments about this technology?**

  LK: I think the sky is the limit, and it's surprising to me that nothing has really been tapped yet. I mean here we are sitting at 2007, and we've just now gotten decent percussion notation software. There's a lot of opportunity out there, and I'd love to be able to implement this in the classroom. Right now a lot of things seem to be geared to wind and brass players in technology, as well as things for keyboard and guitar, but as far as snare drum and marching instruments there could be all sorts of things where we could get digital lessons, and the market just hasn't taken off for it. This is just the tip of the iceberg, what you've done here, and the possibilities are huge. I'd love to see something like this come to market, and try to use it with my kids.