

Music-Movement Synchronization in Capoeira

by

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ABSTRACT

Previous literature on synchronization to music using finger tapping tasks in a laboratory or otherwise controlled setting has led to some invaluable, albeit dated, theories about time and synchronization. In an effort to modernize some of the approaches utilized in research on music synchronization, this study applies established theories of music entrainment to a fieldwork study. Specifically, this study focuses on the extent to which participants of Capoeira, a Brazilian martial art disguised as a dance, synchronize to external timekeepers by analyzing icti in several types of movements and comparing them to musical rhythmic beats.

Sports psychology studies have shown that the presence of music can have involuntary effects on exercise. For example, walkers and runners will spontaneously synchronize gait to auditory signals. However, runners do not normally focus on choreology, acrobatics, and environmental stimuli while exercising. This study contributes to this field of research by adding observations and analyzing degrees of synchronization in a martial art, which may be more cognitively demanding than running.

In Capoeira, participants are still expected to attend to music. The degree of synchronization that occurs in a Capoeira class can then be compared with synchronization in martial arts that have music solely as a background component. These future studies would be analyzing music entrainment in real-life environments with physical activities that are more cognitively complex than running. Moreover, these future studies can help to confirm or challenge current theories of attention and music entrainment and synchronization.

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ethnomusicologist” a.k.a. music educator. Second, I would like to thank Dr. James DeMars, who first suggested that I research the phenomenon of entrainment.

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TABLE OF CONTENTS

| | Page |
|---|------|
| LIST OF TABLES..... | vi |
| LIST OF FIGURES..... | vii |
| GLOSSARY OF TERMS..... | viii |
| CHAPTER | |
| I. INTRODUCTION..... | 1 |
| Capoeira..... | 5 |
| Toques..... | 9 |
| Entrainment..... | 13 |
| Beat Perception: Form and Function..... | 17 |
| Capoeira as a Motor-Synchronization Case Study..... | 20 |
| Fieldwork with UCA and Capoeira Topazio..... | 23 |
| II. METHODS..... | 27 |
| Participants..... | 27 |
| Materials..... | 29 |
| Procedure..... | 31 |

| CHAPTER | Page |
|--|------|
| Results..... | 34 |
| Survey Answers..... | 39 |
| III. DISCUSSION..... | 42 |
| IV. CONCLUSION..... | 51 |
| Potential Comparative Research: Krav Maga..... | 54 |
| BIBLIOGRAPHY..... | 56 |
| APPENDIX | |
| A. PHOTOS OF CAPOEIRA TECHNIQUES AND INSTRUMENTS..... | 62 |
| B. CONSENT FORM..... | 65 |
| C. PARENTAL CONSENT FORM..... | 67 |
| D. CHILD CONSENT FORM..... | 69 |
| E. CAPOEIRA SURVEY QUESTIONNAIRE..... | 71 |
| F. UNIVERSITY EXEMPTION..... | 74 |

LIST OF TABLES

| Table | Page |
|--|------|
| 1. Participant Age Range..... | 28 |
| 2. Video Duration and Participants..... | 29 |
| 3. Participant Synchronization Primary Threshold..... | 38 |
| 4. Participant Synchronization Secondary Threshold..... | 38 |
| 5. Participant Synchronization: Video 6 and Video 7..... | 39 |
| 6. Survey Answers..... | 42 |

LIST OF FIGURES

| Figure | Page |
|--|------|
| 1. Atabaque..... | viii |
| 2. Berimbau..... | ix |
| 3. Ginga..... | x |
| 4. Pandeiro..... | xi |
| 5. Negativa..... | xii |
| 6. Basic Capoeira Rhythm..... | 8 |
| 7. Embellished Attabaque Rhythm..... | 8 |
| 8. Berimbau Angola Toque..... | 10 |
| 9. Berimbau Banguela Toque..... | 11 |
| 10. Berimbau Regional Toque..... | 11 |
| 11. Berimbau São Bento Grande de Angola Toque..... | 12 |
| 12. Logic Pro X Waveform and Video..... | 32 |
| 13. Stop Motion Images of Armada..... | 33 |
| 14. Survey Answer Sample..... | 39 |

GLOSSARY OF TERMS

Agogo: Two bells attached by a metal wire.

Atabaque: Percussion instrument similar to a conga.



Figure 1, Atabaque

Au: Cartwheel.

Bananeira: Headstand.

Bateria: Musical Ensemble of Capoeira consisting of several berimbaus, a couple atabaques, one or more pandeiros, and occasionally agogos and reco-recos.

¹ Capoeira Connection, “Atabaque,” Accessed April 4, 2020, <https://capoeiraconnection.com/product/atabaque/>.

Berimbau: Single stringed instrument, attached to a large stick with a resonator. Performers use a stone to shorten the string to allow two separate tones to be performed. 3 different sizes are used: Gunga, the bass tone, Médio, literally middle tone, and Viola, the highest pitched berimbau.



Figure 2, Berimbau. From left to right, Viola, Médio, and Gunga.

Bautizado: A ceremony in which mestres from across the world come to teach masterclasses to students of a school, and during which students may advance to higher cordões.

Cordão: Cord worn around the waist; similar to a belt in other martial arts, the color indicates the rank of a Capoeirista.

Coro: The chorus of a Capoeira song.

Dobrão: A stone used to press against the string of a berimbau to raise the pitch of the tone produced.

² Capoeira Connection, “Berimbau,” Accessed April 4, 2020, <https://capoeiraconnection.com/product/berimbau-bateria/>.

Ginga: The basic movement pattern of Capoeira. The ginga consists of alternating stances with one leg back, almost like a lunge, while the same-side arm protects the face and the opposite-side arm points back.



Figure 3, Ginga

Groove: Repeating time events in music characterized by multiple contributing parts or musicians and reinforced by cultural norms which often encourage listeners to internalize a given rhythm kinesthetically.

Reco-Reco: Scraped instrument, similar to a Güiro.

Roda: Literally circle, Capoeiristas form a circle surrounding the two players, with the bateria located at the front of the circle from which Capoeiristas enter the game.

Role: A roll to the side, used to get up particularly from a ground position.

³ Abada Capoeira, "Improving Your Ginga and Cadeira," Last Modified March 4, 2016, <http://abadacapoeira.com.au/improving-your-ginga-and-cadeira-10/>.

Pandeiro: Percussion instrument similar to a tambourine.



Figure 4, Pandeiro.

Ladainha: Liturgy; the repertoire of songs used in a given Capoeira school.

Mestre: Master; a respectable title and rank of highly experienced Capoeira instructors.

⁴ Capoeira Connection, “Pandeiro,” Accessed April 4, 2020, <https://capoeiraconnection.com/product/pandeiro/>.

Negativa: Capoeira technique in which the user goes down to the ground to “negate” an attack.



Figure 5, Negativa

Role: Half-cartwheel, often used to return from a ground position to a more upright position.

Toque: “Rhythm” used in Capoeira songs, determined by pitch sequence in the berimbau.

⁵ Sport Life, “Negativa,” Last Modified September 25 2018, <https://www.terra.com.br/vida-e-estilo/saude/bem-estar/sport-life/6-movimentos-basicos-da-capoeira,153b7fc84f66441b1307a586d9da4fc9c4qujxta.html>.

Introduction

Previous literature on music entrainment primarily focuses on dynamic attention theory (DAT), which implies that some level of attending is required for synchronization to occur, at least initially. Many previous studies that have promoted DAT include finger tapping tasks in a laboratory or otherwise controlled setting.⁶ I contribute to the body of research on music-synchronization by studying musical entrainment in a real-life environment. I observed the extent to which synchronization to external timekeepers occurs in Capoeira, a Brazilian martial art disguised as a dance, by analyzing icti in several types of movements and comparing them to musical rhythmic beats.

Musical rhythm and isochrony have historically been of significant interest for many researchers. Some of these researchers cite dance as an activity relevant to musical rhythm studies. Dancers often must perceive qualities of music, particularly rhythm. After they have perceived musical rhythm, dance often involves physical application of this perception through embodiment. In other words, dancers reflect musical rhythm through their own bodies. Music perception has become a focal point for broader sports psychology research in the mid-twentieth century. Martial arts are less frequently studied than dance, but constitute an equally viable activity for these studies.

⁶ See, for example, Taiki Ogata, Takahiro Katayama, and Jun Ota, "Cross-Feedback with Partner Contributes to Performance Accuracy in Finger-tapping Rhythm Synchronization Between One Leader and Two Followers," *Scientific Reports* 9, no. 1 (2019): DOI:10.1038/s41598-019-43352-x; Takato Iwaki and Mira Komori, "Effects of Musical Rhythm on Finger Tapping" *International Journal of Psychology* 32, no.1 (2004); Simone Dalla Bella and Jakub Sowiński, "Uncovering Beat Deafness: Detecting Rhythm Disorders with Synchronized Finger Tapping and Perceptual Timing Tasks" *Journal of Visualized Experiments* 97 (2015): DOI: 10.3791/51761

Renier Plomp argues that acoustics research too often focuses on sinusoidal tones as opposed to sounds that are more commonly heard in everyday life.⁷ Similar to acoustics, research in music psychology tends to focus on specific sounds to which listeners attend.⁸ Often, study participants are asked to listen to a recording of music while doing nothing else or are asked to respond to the music with a specific task, such as tapping a finger. Other times, they might be asked to respond to music through a survey, or have their brain activity measured through functional magnetic resonance imaging (fMRI). Typically, these studies will take place in laboratories where study participants are only exposed to a single stimulus: music. While these studies are invaluable for learning about specific effects of music, this is not an environment that represents how individuals listen to music in the real world. Listening to music in ecological settings typically take place alongside other tasks. In fact, the car has become the most popular concert hall.⁹ Music is used for various functions in gyms, markets, and other settings. Fieldwork-based studies, as opposed to laboratory-based, can offer significant insights into music cognition and musical rhythm research. Through the combination of

⁷ Renier Plomp, *The Intelligent Ear, On the Nature of Sound Perception* (Mahwah: Lawrence Erlbaum Associates, 2002).

⁸ For example, the experiments in Mari Riess Jones, Heather Moynihan Johnston, and Jennifer Puente, “Effects of Auditory Pattern Structure on Anticipatory and Reactive Attending” *Cognitive Psychology* 53 (2006): 59-96 DOI:10.1016/j.cogpsych.2006.01.003; or Guy Madison, “An Auditory Illusion of Infinite Tempo Change Based on Multiple Temporal Levels” *PLoS One* 4, no. 12 (2009), DOI:10.1371/journal.pone.0008151.

⁹ Carin Öblad, “On Using Music – About the Car As a Concert Hall,” paper presented at the *Sixth international conference on Music Perception and Cognition*, Keele, UK, August 10th, 2000, <https://www.escom.org/proceedings/ICMPC2000/Thurs/Oblad.htm>.

ethnographic and empirical methods, studies can and have been designed to research music in fieldwork settings.

Ethnomusicology has evolved from early methodologies that compared musical works of distant cultures to Western Art Music, to encompassing a much broader field. Judith Becker, among other ethnomusicologists, believes that the future of ethnomusicology hinges upon collaborating with other fields, such as the neurosciences and evolutionary biology.¹⁰ Ethnomusicology is an interdisciplinary field by nature.¹¹ While methodology is not the only distinction between the two fields of historical musicology and ethnomusicology, perhaps ethnomusicology's greatest strength is in the variety of methodologies afforded to researchers as they embark on fieldwork journeys. By combining methodologies of different fields, such as using the scientific method in fieldwork, we can also contribute to other fields. Some examples of ethnomusicologists who have contributed to the sciences with the foci of their respective research include Michael Bakan, Martin Clayton, Joseph Jordania, and Udo Will.¹² Nevertheless, ethnomusicology's involvement with the sciences is fairly new territory.

¹⁰ Ted Solis and Margaret Sarkissian, *Living Ethnomusicology Paths and Practices* (Urbana: University of Illinois Press 2019), 407.

¹¹ For an example of an ethnomusicological survey from the approach of historical musicologists, see Rachel Wheeler and Sarah Eyerly, "Singing Box 331: Re-sounding Eighteenth-Century Mohican Hymns from the Moravian Archives" *William and Mary Quarterly* 76, no. 4 (2019), DOI:<https://doi.org/10.5309/willmaryquar.76.4.0649>.

¹² See, for example, Michael Bakan, "Ethnomusicological Perspectives on Autism, Neurodiversity, and Music Therapy" *Voices* 14, no. 3 (2014): DOI [10.15845/voices.v14i3.799](https://doi.org/10.15845/voices.v14i3.799); Udo Will, Martin Clayton, Ira Wertheim, Laura Leante, and Eric Berg, "Pulse and Entrainment to Isochronous Auditory Stimuli: the Case of North Indian Alap," *PLoS One* 10, no.4 (2015): DOI: [10.1371/journal.pone.0123247](https://doi.org/10.1371/journal.pone.0123247); Joseph Jordania, "A New Interdisciplinary Approach to the Study of the Origins of Traditional Polyphony," *Muzikologija* 2015, no. 18. (2015): DOI [10.2298/MUZ1518077J](https://doi.org/10.2298/MUZ1518077J);

Following the work of Martin Clayton and Udo Will in particular, I combine elements of ethnomusicology and fieldwork with beat perception in my research. In order to study beat synchronicity in ecological settings, there needs to be a greater body of studies to draw examples from. Therefore, I designed a pilot study analyzing movement synchronization in Capoeira. Rosa Abraham's method of motion tracking was modified to fit the purposes of this study, and movement icti (singular: ictus) will be used as an indicator of timing for whether a movement is synchronized or not.¹³ In addition to creating a model for future motor-synchronization studies in exercise settings, I aim to provide some initial data on the degree of synchronization that participants exhibit in a martial art that emphasizes beat perception.

Fieldwork studies can present unique challenges. One such challenge I faced throughout my research was the massive changes that the school I was observing underwent. While I have participated in multiple Capoeira schools in the past, I made the decision to work with United Capoeira Association (UCA) in Mesa/Chandler, Arizona, for this project. However, one week prior to beginning my pre-approved recordings of the group, the school changed from UCA to Capoeira Topaziao. And while they share certain features, others changed, including the *ladainha* (the set of songs for a specific Capoeira school) and *roda* (the game of Capoeira) etiquette which set Capoeira Topaziao apart from UCA.

¹³ Rosa Butler Abrahams, "Moving in Sacred Time: Metrical Interactions Between Body and Voice in Jewish and Greek Orthodox Liturgical Chant" PhD Diss (Evanston, IL: Northwestern University, 2017), 100.

Capoeira

Capoeira is a hybrid dance-martial art form, initially developed by black Brazilian enslaved people. The dance utilizes various attacking and defending simulations using the feet.¹⁴ This worried white authorities in Brazil, who feared that slaves were training in combat to rebel under the pretense of dance. During the Paraguayan War (1864-1870), black Capoeiristas were known for their skill in beating opponents in hand-to-hand combat.¹⁵ Even after Black Brazilians were freed from slavery, Capoeira street gangs were still associated with violence until the mid 20th century,¹⁶ when Mestre Bimba revitalized the art, combining the practice with the extinct African martial art, *Batuque*.

Mestre Bimba (1899-1974) is credited with the creation of *Capoeira Regional*, which is far more widely played today than *Capoeira Angola*. In the 1960s, as tourism spread throughout Brazil, Capoeira also began to spread outside of Brazil. Mestre Bimba's own students took the art outside of the country to places such as the US. One student in particular, Mestre Acordeon (born 1943), wrote the first book about Capoeira in English.¹⁷

¹⁴ Gerard Béhague, "Afro-Brazilian Traditions," In *Garland Encyclopedia of World Music*, 2, (New York: Garland Publishing Inc. 1998), 366.

¹⁵ Maya T. Chvaicer, "The Criminalization of Capoeira in Nineteenth-Century Brazil," *Hispanic American Historical Review* 82, no. 3 (2007): 525-547 <https://doi.org/10.1215/00182168-82-3-525>.

¹⁶ John J. Crocitti, Monique Vallenge, *Brazil Today: An Encyclopedia of Life in the Republic* (Santa Barbara: ABC-CLIO LLC 2012), 132.

¹⁷ Bira Almeida, *Capoeira: A Brazilian Art Form: History, Philosophy, and Practice*, (Berkeley: North Atlantic Books, 1986).

Traditionally, Capoeira was practiced only by men. However, women became prominent leaders in the art in the 20th century, in conjunction with Capoeira's spread across the globe as well as increasing feminist sentiment in South America. In fact, one of the three founders of United Capoeira Association (UCA) in was a female: Mestra Suelly, who, in 2000, became the first American woman to achieve the rank of *mestre*. The other two founders included Mestre Acordeon and Mestre Ra, who began teaching with Mestre Acordeon in 1988.¹⁸

The central role of music sets this martial art apart from others. Each Capoeira *roda* typically have a *bateria*, a group of instrumentalists who perform various Capoeira songs.¹⁹ These instruments include several *berimbaus*, *atabaques*, *pandeiros*, and sometimes *agogos* and *reco-recos*. The two most important instruments of Capoeira are the berimbau and the atabaque. The berimbau is seen as the symbol of Capoeira, and every *bateria* has at least one. The size of the berimbau determines the degree of embellishments performed in a given song, and range from *Gunga*, *Médio*, and *Viola*. The atabaque serves as a constant rhythmic center of the songs being performed, referred to as the “heartbeat” by Capoeiristas, and is rhythmically the most important instrument to the ensemble.

Capoeiristas playing in the *roda* focus not only on matching their movements and *ginga* to the *bateria*, but also to their partners. Capoeiristas often mirror or contrast their

¹⁸ Patrick “Galego” Hilligan, *Playing in the Light: My Journey with the Art of Capoeira*, (CA: Move! Studio Publishing 2, 2018)

¹⁹ This section includes many Capoeira terms that are in Portuguese. See the glossary for a definition of each of these terms.

partner's ginga. They respond to each move with an appropriate move of their own, whether by dodging a kick with a *negativa* or responding to an *au* with a *bananeira*. Koehne, Schmidt, and Dziobek describe this highly nuanced Capoeira partner synchrony as physical empathy.²⁰

Learning the music and performing in the bateria are essential skills as a capoeirista advances in *cordão* colors. Beginners especially may struggle with the basics of timing in the music. While not inside the roda playing the game, members of a Capoeira school are often expected to form a circle around the players, clapping a rhythm based on the given toque. They are also expected to sing the melody, if they can. If they cannot, students are expected to hum the pitches and guess the pronunciation of some words until they can get it right.

A Capoeira roda begins by the berimbau player playing a short excerpt of a few seconds, using the two possible notes the instrument can sound. The atabaque enters next, followed by the other instruments. After all of the instruments have entered, the Capoeiristas begin clapping, and finally a member of the bateria begins to sing. All of these instruments tend to feature a variant of an eighth-eighth-quarter rhythm, often containing improvised embellishments. The most common basic rhythm would appear as such:

²⁰ Svenja Koehne, Mirjam J. Schmidt, Isabel Dziobek, "The Role of Interpersonal Movement Synchronization in Empathic Functions: Insights from Tango Argentino and Capoeira," *International Journal of Psychology* (2015): <https://doi-org/10.1002/ijop.12213>.

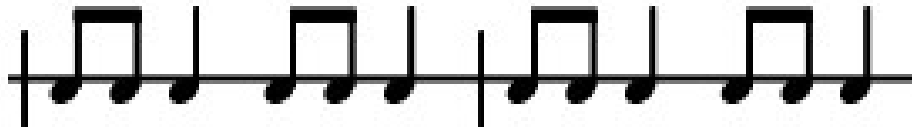


Figure 6. Basic Capoeira Rhythm

With embellishments, the atabaque rhythm would look more like:

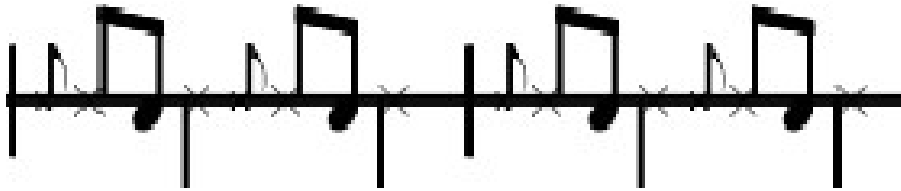


Figure 7. Embellished atabaque rhythm

The notes indicated by an “x” would likely be played on the edge of the atabaque, while the eighth-note head would indicate a slap in the center of the drum. After all of the instrumentalists have begun to play, the members of the roda clap the appropriate rhythmic pattern. Finally the leader will begin to sing a Capoeira song, which includes a responsorial part that the other Capoeiristas will sing. Unlike most Western music performances, the bateria does not just perform one song, stop, and perform another song. Instead, the bateria changes seamlessly. Likewise, when the bateria changes to a new song, the new tempo, toque, and lyrics that might be idiosyncratic of the new Capoeira song emerge seamlessly throughout a performance.

When a Capoeirista desires to play an instrument, they will move along the outer edge of roda to the instrumentalist they wish to replace. This should not be done to an

instrumentalist leading the vocals of a song. If the original instrumentalist permits, the instrument is passed on. While there is slight potential that these exchanges might create breaks and missing pieces in the music or groove, the other instrumentalists would not cease their rhythm, and this exchange should only happen with one instrument at a time.

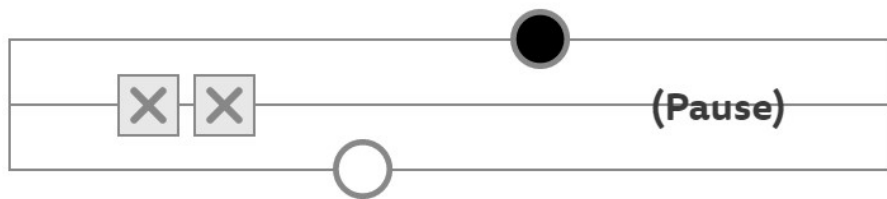
Toques

Capoeira *toques* are the rhythms performed by the bateria, and each toque tends to have particular games and etiquettes associated. Researchers often make the misconception that toques are tempi. Capoeiristas will quickly correct this, stating that toques are the rhythmic structure of a Capoeira song. A slower or faster tempo might be idiosyncratic of a toque, but is not a rule. Even referring to a toque as a rhythm is misleading. The actual defining factor of Capoeira toques is the organization of pitches.

In each of the diagrams to follow, the Berimbau plays three types of notes. An open string would produce the lower tone, and to play the higher tone the musician would touch a stone or coin to the string, effectively shortening it. If the stone or coin is partially touching the string, the unpitched tone, called a scratch, is produced, reflected by the box with an x.

There are 4 Capoeira toques that are commonly played: *Angola*,²¹ *Banguela*, *Regional*, and *São Bento Grande de Angola*. Angola games feature the following rhythm, with clapping occurring on the two pitched notes only:

²¹ Note there is some debate about the origin of the term Angola. Some reporters believe that the name indicates this style of game originated in Angola, on the southwestern coast of Africa. Capoeiristas dispute this point and argue that the term Capoeira Angola was conceived to pay homage to African origins



22

Figure 8. Berimbau Angola toque. The open circle represents playing on an open string, whereas the black circle represents playing the higher note, in which a dobrão is pressed against the string. The x boxes are scratches, in which the dobrão is slightly pressed against the string preventing the production of a clear tone.

Angola games emphasize trickery and are often played close to the ground. The movements in Angola games are slower, and while the accompanying songs are often also slower, this is not a requirement. This causes some of the misconception outlined earlier. It makes sense for a slower rhythm to accompany a slower game, but this is more of a guideline than a rule. Angola games also feature the *chamada* (a call to a break in the roda), which is unique to this toque. When players believe they outplayed their opponents, or believe their opponents are being too aggressive or otherwise disrespectful, they might make a *chamada*, in which that player will raise their hands as a sort of signal. The other player might respond to this, by slowly approaching the caller and placing their hands on the partner's hands. A stepping ritual then occurs before the game is resumed. However, the *chamada* is also a place where deception and trickery are encouraged.

of early Capoeiristas, many of whom did not know the African country of their ancestry. Angola was a likely origin for many of them since it was once under Portuguese rule and was a frequent place of origin for first-generation enslaved people.

²² "Toques de Berimbau," iangetz.com, Accessed March 21, 2020, https://iangetz.com/capoeira/toques_de_berimbau.html

Banguela games are among the most common games played across all groups. The banguela toque is perhaps more inclusive than others, facilitating a moderately paced “anything goes” roda. To many newcomers, Banguela games offer the safest place to demonstrate and work on any particular Capoeira technique, whether it is offensive, defensive, or aesthetic. The Banguela toque is as follows:

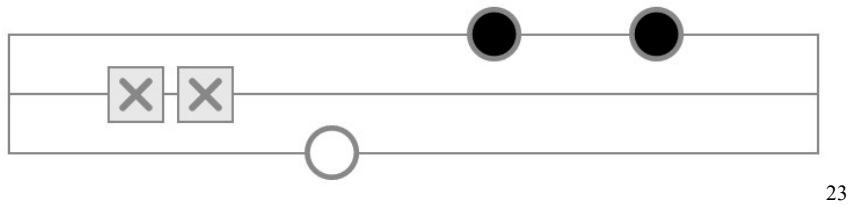


Figure 9. Berimbau Banguela toque

Regional games are more aggressive than Banguela, and are usually played upright. Banguela and Regional games features the standard clapping pattern of quarter-quarter-quarter rest (the same basic Capoeira rhythm as in fig. 6.) Kicks, sweeps, and takedowns are more common in this style of game, which features the following rhythm:

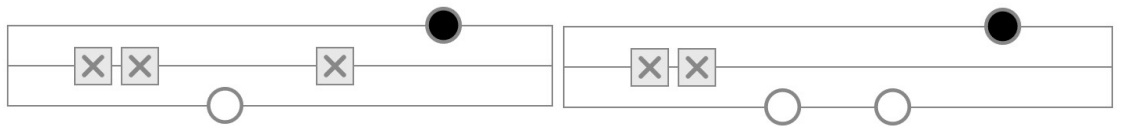


Figure 10. Berimbau Regional toque

²³ “Toques de Berimbau,” iangetz.com.

²⁴ “Toques de Berimbau,” iangetz.com.

Of the four Capoeira schools in the Phoenix Metropolitan area, three of them tend to emphasize games using the previous three toques. Banguela is the most common, followed by Regional, and finally Angola games. However, the Capoeira Topaziao group I observed in my study almost exclusively used São Bento Grande de Angola. These games are meant to be high energy, and even more aggressive than Regional games. In order to achieve this higher energy state, the clapping rhythm also changes drastically. The clapping pattern used in these rhythms is dotted quarter-dotted quarter-quarter. The berimbau rhythm is as follows:

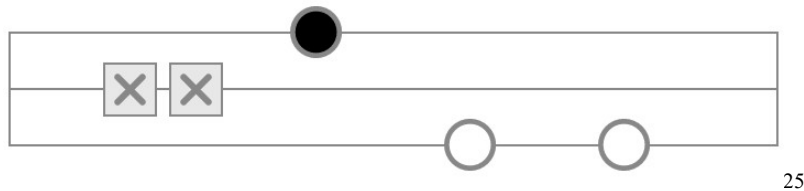


Figure 11. Berimbau São Bento Grande de Angola toque

There are several other well-known toques that are not as often played in classes or most rodas. These include rhythms such as iuna which accompanies games intended for more advanced students, and cavalaria, which was a traditional rhythm used to signal the approach of police in times that Capoeira was outlawed.

Game styles are also related to toques; however, the interplay between the two can be confusing. Capoeira schools usually self-identify into one of four styles: *Angola*, *Regional*, *Miudinho*, and *Contemporânea*. As the name might suggest, Angola schools

²⁵ “Toques de Berimbau,” iangetz.com.

will play Angola games. Similarly, Regional groups will play Regional games. Miudinho groups play a game considered by many Capoeiristas as more aesthetically pleasing because they feature more collaboration between partners and a significantly greater emphasis on acrobatics. Capoeira *Contemporânea* can refer to groups that practice a style of Capoeira that is neither exclusively Angola, nor exclusively Regional, and will often merge other martial arts into the art. Groups that practice both Regional and Angola games are the most common. Even UCA, a group that derived from Mestre Bimba's teachings and Regional style, can include both Regional games and Angola games. Labeling UCA and many other groups as either a Regional or Contemporânea can be problematic.

Entrainment

Entrainment is the phenomenon in which multiple autonomous processes phase-lock. In many instances, this occurs when our internal oscillators phase-lock to external oscillators. Humans exhibit many types of entrainment involving biological processes including gait, breathing, and heartbeat. Some of these processes may be under conscious control, while others are entirely automatic. For example, humans have little or no control over many forms of physiological entrainment, such as heartbeat. Others may be initially automatic but can be consciously changed. For example, human sleep cycles are loosely defined by the rise and fall of the sun, but we have intentionally shifted our day and night

cycle to adhere to numbers on a clock, regardless of whether they align with the sunrise/sunset.²⁶

A large body of research focuses on musical entrainment. This research can take many forms, though most concern studying the perception of musical rhythm. Conscious musical entrainment involves the anticipation of future events as a result of attending to the periodic elements in a stimulus. This anticipatory/reactive model takes place over a set of stages. First, listeners perceive music and make predictions about where a musical rhythm should fall. If our expectations are met, synchronization may occur. If our predictions are violated, then our brain will make adjustments to make new time-estimated predictions. This third stage is called adaptive response, in which our expectations are adjusted to assimilate the new time relationship.²⁷ Mari Riess Jones refers to this first model of entrainment as future-oriented attending.²⁸

Jones outlines a second mode of attending, analytical attending, to represent the way individuals focus on other musical aspects such as timbre and pitch. Edward Large notes that, while rhythmic entrainment predicts beats at a very specific time interval, entrainment involving prediction of pitch and global structures are more flexible.²⁹

²⁶ Anne Skeldon, Andrew Phillips, and Derk-Jan Dijk, “The effects of self-selected light-dark cycles and social constraints on human sleep and circadian timing: a modeling approach,” *Scientific Reports* 7, no. 45158 (2017): DOI: 10.1038/srep45158

²⁷ Martin Clayton, Rebecca Sager, Udo Will, “In Time With the Music: The Concept of Entrainment and Its Significance for Ethnomusicology,” *ESEM Counterpoint* 1, (2004) 15.

²⁸ Mari Riess Jones, and Marilyn Boltz, “Dynamic Attending and Responses to Time,” *Psychological Review* 96, no.3 (1989): 123. DOI: 10.1037/0033-295X.96.3.459.

²⁹ Edward W. Large and Caroline Palmer, “Perceiving Temporal Regularity in Music,” *Cognitive Science* 26, no.1 (2002): 33. DOI: 10.1207/s15516709cog2601_1.

Memory-based prediction, as opposed to rhythm-based prediction, seems to indicate a general idea of where beats are supposed to fall. An example of memory-based prediction would be predicting based on phrase length, or harmonic patterns.³⁰

Humans are inherently rhythmic, entraining to physical patterns of time. We organize time changes in ways that stem from either ratio transformations or additive time transformations. Additive transformations include changes in temporal velocity, such as the speeding up or slowing down of a period. Ratio transformations are changes in beat groupings, such as changing from 3/4 time into 4/4 time.

Beat perception of simpler rhythms occurs most easily; however, humans are able to adjust their attentional focus to different aspects of music. This is specifically useful when working with kaleidophonic music, a term coined by Paul Berliner to describe African music with multiple independent, yet interlocking, rhythms. While Capoeira music is an example of African Diasporic music, the rhythms do not reflect this phenomenon, and the rhythms used by each independent voice coincide with each other to create simple rhythms.

Madison and Merker argue that pulse attribution occurs within an 8.6% difference threshold of the inter-onset interval³¹ (IOI) of a musical isochronous rhythm.³² In other

³⁰ See Assaf Breska and Leon Deouell, “Neural mechanisms of rhythm-based temporal prediction: Delta phase- locking reflects temporal predictability but not rhythmic entrainment,” *PLoS Biology* 15, no. 2 (2017): <https://doi.org/10.1371/journal.pbio.2001665>, for a study on how rhythm based prediction violations incur greater behavioral costs and cognitive resource withdrawal than memory-based prediction.

³¹ The time difference between the onset of two consecutive notes.

words, to have a subjective experience of isochrony with an auditory stimulus, the auditory stimulus must not deviate from isochrony by more than 8.6% of the duration between beats. Madison and Merker's 2002 study was designed as a modern, empirical recreation of Wallin's 1911 study, and confirms the results in which listeners self-reported the accuracy of a rhythm given IOI deviations; specifically, an 8% deviation was considered "good" rhythm.³³ Non-temporal cues may also interact with temporal cues, such as pitch and volume, in beat finding.³⁴ And while beat perception occurs after only a few musical pulses, auditory priming can enhance beat perception tasks.³⁵

Finally, humans exhibit preference for specific rhythmicities. A natural rhythmicity of 2 hz (i.e. 2 cycles per second) has been theorized for some time by music theorists and psychologists. An overwhelming amount of music is composed at this tempo, which is equivalent to 120 beats per minute. Furthermore, it is exactly twice the speed of the average healthy resting heart rate, and exactly one half of a second. Askew, Abel, and Strüder inferred a potential attractor to a natural rhythmicity of 3 hz; heart rate

³² Guy Madison and Bjorn Merker, "On the limits of anisochrony in pulse attribution," *Psychological Research* 66 (2002): 201-207 DOI 10.1007/s00426-001-0085-y 205

³³ J. E. Wallin, "Experimental studies of rhythm and time. I. Qualitative limens or grades of rhythm, and the difference limen in the perception of time," *Psychological Review*, 18 (1911).

³⁴ Edward W Large, "On Synchronizing Movements to Music," *Human Movement Science* 19, no. 4 (2000): 529. [https://doi.org/10.1016/S0167-9457\(00\)00026-9](https://doi.org/10.1016/S0167-9457(00)00026-9)

³⁵ Jewel E. Crasta, Michael Thaut, Charles Anderson, Patricia Davies, and William Gavin, "Auditory priming improves neural synchronization in auditory-motor entrainment," *Neuropsychologia* 117 (2018): 110. DOI: 10.1016/j.neuropsychologia.2018.05.017.

at higher workload matches this rhythm, and electrocortical activity peaking at 3 hz has been reportedly increased after exercise.³⁶

In what follows, I outline two potential models of musical entrainment: conscious and subconscious. In the conscious model, entrainment to music occurs as the result of attending. Subconscious entrainment, however, occurs regardless of an individual's attentional focus. Whether musical entrainment can be subconscious is difficult to ascertain. By comparing settings in which music is in the foreground to settings in which music is in the background, we might be able to draw conclusions regarding the prevalence of conscious versus subconscious musical entrainment. Specifically, I argue for studying this foreground/background relationship through the analysis of motor actions.

Beat Perception: Form and Function

Researchers observe motor actions in participants to analyze beat perception. A number of rhythm studies involve participants' tapping rhythms. Motor actions are also often observed as a byproduct of a participant listening to music, spontaneously occurring in music listening tasks and beat perception tasks in particular.³⁷ In addition to the body's motor actions, neural oscillators can become entrained to music. Rhythmic stimuli, as well as music that is preferred by listeners, can increase delta, theta, alpha, or beta wave

³⁶ Stefan Schneider, Christopher D. Askew, Thomas Abel, and Heiko K. Strüder, "Exercise, Music, and the Brain: Is there a Central Pattern Generator?" *Journal of Sports Sciences* 28, no. 12 (2010) <https://doi-org.ezproxy1.lib.asu.edu/10.1080/02640414.2010.507252>

³⁷ Edward W. Large, "On Synchronizing Movements to Music" 528; Guy Madison and Bjorn Merker "On the Limits of Anisochrony in Pulse Attribution" 206.

activity.³⁸ In two separate studies, Pressing and Clayton draw connections between entrainment to rhythmic stimuli and pleasurable response.³⁹ It is likely that in these instances, synchronization to rhythmic stimuli increase theta wave production. While few studies involve analyzing motor actions beyond finger tapping, Abrahams developed a method for tracking motion by observing icti (singular: ictus), loci (singular: locus), and trajectories.⁴⁰ Locus refers to the origin of a movement, and trajectory its path through space. Icti are the points of rebound, and in the art of Capoeira, icti may best represent timing points in a motion that should synchronize to musical rhythm.⁴¹

Pressing describes entrainment to groove as a reliable prediction of time events bound and reinforced by repetition and engendered movement. This phenomenon is associated with a pleasurable state and has been shown to reduce anxiety.⁴² In gyms and other businesses, groove-based music can be used for a variety of functions. The presence of music has been shown to increase neuromuscular efficiency, as well as block negative

³⁸ Domante Kucikiene and Ruta Praninskiene, “The Impact of Music on the Bioelectric Oscillators of the Brain,” *Acta Med Litu* 25, no. 2 (2018): 101-106 doi: 10.6001/actamedica.v25i2.3763

³⁹ Jeff Pressing, “Black Atlantic Rhythm: Its Computational and Transcultural Foundations,” *Music Perception* 19, no. 3 (2002): 285–310. <https://www.jstor.org/stable/10.1525/mp.2002.19.3.285>; Clayton, Martin, Rebecca Sager, and Udo Will, “In Time With the Music: The Concept of Entrainment and Its Significance for Ethnomusicology,” 10.

⁴⁰ Rosa Butler Abrahams, “Moving in Sacred Time: Metrical Interactions Between Body and Voice in Jewish and Greek Orthodox Liturgical Chant,” 100.

⁴¹ For comparison, a finger tapping study would be looking at the icti in which a finger touches a surface and begins to return.

⁴² Jeff Pressing, “Black Atlantic Rhythm: Its Computational and Transcultural Foundations.”

signals.⁴³ Certain negative signals such as fatigue can be delayed by the presence of music, thereby allowing individuals to achieve a greater output in exercise. Background music is often used as a marketing strategy for business owners to keep certain demographics (such as elderly persons) away, or to influence spending habits.⁴⁴

One study that supports the subconscious musical entrainment model examined the role of slight tempi modification among runners. Runners were equipped with iPods as they ran, and musical pieces were selected to match the rhythm of the runners' chosen pace. The researchers found that if they modified the tempo of the audio tracks using a digital audio workstation (DAW), runners would spontaneously entrain to these changes. Dyck et al. believe that if running pace can be influenced, then music could be used to reduce step rate related injuries.⁴⁵ In another study, individuals walking spontaneously synchronized their gait to musical rhythm.⁴⁶ Du, Roberts, and Xu link therapeutic

⁴³ Xavier Sanchez, Samantha L. Moss, Craig Twist, and Costas I. Karageorghis, "On the Role of Lyrics in the Music-Exercise Performance Relationship," *Psychology of Sport and Exercise* 15, no. 1 (2014): 132-138, <https://doi.org/10.1016/j.psychsport.2013.10.007>.

⁴⁴ Dipayan Biswas, Kaisa Lund, Courtney Szocz, "Sounds Like a Healthy Retail Atmospheric Strategy: Effects of Ambient Music and Background Noise on Food Sales," *Journal of the Academy of Marketing Science* 47, no. 1 (2018): 37-55 <https://doi.org/10.1007/s11747-018-0583-8>.

⁴⁵ Edith V. Dyck, Bart Moens, Jeska Buhmann, Michiel Demey, Esther Coorevits, Simone D. Bella, and Marc Leman, "Spontaneous Entrainment of Running Cadence to Music Tempo," *Sports Medicine* 1, no. 15 (2015): <https://doi.org/10.1186/s40798-015-0025-9>.

⁴⁶ Jeska Buhmann, Frank Desmet, Bart Moens, Edith Van Dyke, Marc Leman, and Enrique Hernandez-Lemus, "Spontaneous Velocity Effect of Musical Expression on Self-Paced Walking," *PLoS One* 11, no. 5 (2016): DOI:10.1371/journal.pone.0154414

benefits to asynchronous music in Tai-Chi, including improvements in participant's Dynamic Gait Index.⁴⁷

Capoeira as a Motor-Synchronization Case Study

Capoeira may prove to be a useful case study of musical entrainment and music cognition. Unlike other martial arts, music is always playing in a Capoeira class and participants are expected to synchronize to it. While observing UCA in Chandler, I noticed that students often criticized each other's ability to synchronize their movements to music. Some comments included whether ginga steps or au landings synchronized with musical beats.

Familiarity with Capoeira movements may improve an individual's ability to synchronize to visual or auditory information in new ways. Stephens and Delamont noticed that British men were able to move with more flexibility after being sufficiently trained in Capoeira. Men who practiced Capoeira were more able to abandon their *cintura dura*, or rigid torso and hard waist.⁴⁸

Musical rhythms in Capoeira are multimodal: there are auditory, visual, and embodied stimuli. Auditory rhythms are produced by the *bateria*. A Capoeirista then receives visual stimuli from their partner in a *roda*. Finally, as Capoeiristas actively move

⁴⁷ Yan Du, Penny Roberts, and Qingwen Xu, PhD, "The Effects of Tai Chi Practice With Asynchronous Music on Compliance and Fall-Related Risk Factors in Middle-Aged and Older Women: A Pilot Study," *Journal of Holistic Nursing* 35, no. 2 (2017): 142-150 <https://doi.org/10.1177/0898010116636972>.

⁴⁸ Neil Stephens and Sara Delamont, "'I Can See it in the Nightclub': Dance, Capoeira, and Male Bodies," *Sociological Review* 62, no. 1 (2014): DOI: 10.1111/1467-954X.12062

multiple parts of their bodies at the same time, they generate sensory information through this movement. Sensory information drawn from limb movement and visual cues affects cognitive activity and perception of musical rhythm.⁴⁹ This finding parallels research that suggests listeners will often spontaneously move limbs when trying to perceive and track beats.⁵⁰

Visual stimuli can affect and enhance music synchronization⁵¹ and observers are more likely to attend to synchronized dancers than to asynchronous dancers.⁵² It is likely that in Capoeira too, asynchronous elements, such as other Capoeiristas who are out of sync with the bateria, will be backgrounded. Despite its dance-like features, Capoeira movements are reactive and improvised. Improvisational training improves musicians', dancers', and actors' abilities to synchronize during performances. Research on dancer synchronization suggests that this advantage usually occurs with long-term phrase structures of dance, rather than moment to moment synchronization.⁵³

⁴⁹ Udo Will, "Coupling Factors, Visual Rhythms, and Synchronization Ratios," *Empirical Musicology Review* 6, no. 3 (2011): OH: Ohio State University. DOI 10.18061/1811/52812

⁵⁰ Edward W. Large "On Synchronizing Movements to Music" 528.

⁵¹ Yi-Huang Su, "Audiovisual Beat Induction in Complex Auditory Rhythms: Point-light Figure Movement as an Effective Visual Beat," *Acta Psychologica* 151 (Sept 2014): 40-50. <https://doi.org/10.1016/j.actpsy.2014.05.016>.

⁵² Matthew Harold Woolhouse and Rosemary Elai, "Traces Across the Body: The Influence of Music-Dance Synchrony on the Observation of Dance," *Frontiers in Human Neuroscience* (2014): DOI: 10.3389/fnhum.2014.00965.

⁵³ Auriel Washburn, Mariana DeMarco, Simon de Vries, Kris Ariyabuddhipongs, R. C. Schmidt, Michael J. Richardson, and Michael A. Riley, "Dancers Entrain More Effectively than Non-dancers to Another Actor's Movements," *Frontiers in human Neuroscience* (2014): <https://doi.org/10.3389/fnhum.2014.00800>; Elizabeth Waterhouse, Riley Watts, and Bettina E. Bläsing, "Doing Duo – a Case Study of Entrainment in William Forsythe's Choreography 'Duo,'" *Frontiers in Human Neuroscience* (2014): <https://doi.org/10.3389/fnhum.2014.00812>

Musical expertise is equally relevant. Skilled listeners are more likely to effectively detect rhythms.⁵⁴ As Capoeira students progress to more advanced cordões (a belt system similar to those of many Asian martial arts), they are also expected to learn to play all of the instruments of the bateria as well as the ladainha for that school. The ladainha is made up of the songs that are a staple of that school. At first, Capoeiristas learn to play some of the more basic instruments, such as the pandeiro, and the coro (chorus) of the songs in the ladainha. Next, students will begin to learn to play the various toques on the berimbau, as well as the verses to the songs in the ladainha.

As Capoeira students become more advanced in their musical training, so too do they become able to move their bodies in ways that beginners are not able to. Most researchers often consider Western paradigms of musical training, which may differ from what Capoeiristas value from their musicians. Of all the instruments in the Capoeira ensemble, only the berimbau and the voice are capable of producing a range of pitches; the berimbau is often only used to produce two pitches and a scratch tone. Nevertheless, the berimbau is considered the “melody” instrument of Capoeira. Keeping a steady rhythm and being able to sing in Portuguese while simultaneously playing an instrument are the most important musical skills to a Capoeirista.

Because all songs in a ladainha are in Portuguese, Capoeira music may provide insight on the role of linguistics in music cognition. Learning the songs is often more

⁵⁴ Mari Riess Jones and William Yee, “Sensitivity to Time Change: The role of Context and Skill,” *Journal of Experimental Psychology: Human Perception and Performance*, 23, no. 3, (Jun 1997): DOI:10.1037/0096-1523.23.3.693

difficult for non-Portuguese speakers, as they cannot associate lyrics with meaning. However, non-Portuguese speakers may become enculturated to the music faster than a Portuguese speaker who has never been exposed to the martial art. Individuals listening to speech of a foreign language are more likely to have bilateral neurological responses indicative of music listening.⁵⁵

Fieldwork with UCA and Capoeira Topazio

More than ever, ethnomusicologists are doing fieldwork closer to home.⁵⁶ Doing fieldwork closer to home does offer several advantages. Expenses, such as travel costs, can be avoided and language barriers are less common in fieldwork that is close to home. Furthermore, because nearby fieldwork is more accessible, Titon's friendship model of fieldwork is more easily employed.⁵⁷ This model emphasizes that fieldworkers should be reflexive in their work through dialogue and including their collaborators and informants, or field partners. Furthermore, ethnomusicologists strive to practice "bi-musicality," a term coined by Mantle Hood to suggest that learning an unfamiliar tradition of music is similar to learning an unfamiliar language. To become truly fluent in a different musical tradition, researchers must participate and practice music in a similar manner to that of

⁵⁵Kankamol Jaisin, Rapeepong Suphanchaimat, Mauricio A. Figueroa Candia, and Jason D. Warren, "The Speech-to-Song Illusion is Reduced in Speakers of Tonal (vs. Non-Tonal) Languages," *Frontiers in Psychology* 7, no. 662 (2016): <https://doi.org/10.3389/fpsyg.2016.00662>.

⁵⁶See Bruno Nettl, "You Call That Fieldwork: Redefining the Field" from *The Study of Ethnomusicology, 31 Issues* (Urbana: University of Illinois Press, 2005); Bruno Nettl, "Essentials of Fieldwork," from *The Study of Ethnomusicology, 31 issues* (Urbana: University of Illinois Press, 2005).

⁵⁷Jeff Todd Titon. "Knowing Fieldwork," in Gregory Barz and Timothy J. Cooley, eds. *Shadows in the Field: New Perspectives for Fieldwork in Ethnomusicology*. (Oxford: Oxford University Press 2008) 33.

their field partners. My prior participation in United Capoeira Association and Capoeira Topaziao classes in Chandler, as well as my three years of experience with Capoeira in the Phoenix metropolitan area, indicates my bi-musical training within the traditions of these specific Capoeira schools.

Instructor Carlos “Primo” Herrera of UCA states that he has been to Brazil several times and has been personally given Mestre Acordeon’s blessing to teach his Capoeira school. Primo has been teaching in the Phoenix Metropolitan area for over a decade. He made an agreement with a Wado Karate school in Chandler to host his Capoeira classes, which he recently relocated from an arts studio in Mesa. At the time of this writing, Wado Karate is in the process of changing its business name to “Chandler Martial Arts Studio”, with the aim of incorporating other martial arts. Chandler Martial Arts Studio has matted, rather than hardwood floors, setting this particular studio apart from other Capoeira studios. This feature alone was a major factor in my personal choice to study at this school during my Master’s degree at Arizona State University. However, I do not believe this will influence study results. Despite Primo’s position as my instructor and my main contact for both my relationship with Chandler Martial Arts Studio as well as my listed contact with the IRB, he did not participate in this study.

In the few months following UCA’s 2019 Bautizado, Primo changed his class schedule from four days a week to three, and then again to only two days a week. Each time, the dates and times of classes changed as well. After reducing the number of classes available, Primo was offered some job opportunities in Chicago. He believed he was going to move there by the end of the year, so he tried to find a suitable replacement.

Instructor “Kino,” took over the classes at Chandler Martial Arts Studio. However, Kino is an instructor for a different organization: Capoeira Topaziao. After Kino took official lead of the group, the Capoeira group that practiced at Chandler Martial Arts Center changed from UCA to Capoeira Topaziao.

Primo allowed me to record classes, but I should note that some Capoeira schools, including other UCA classes, do not allow their classes to be recorded. This attitude relates back to the origins of Capoeira, when the art could exist as a combatant style only through the smoke and mirrors of appearing to be a dance form. Capoeira’s survival was dependent on the public’s not knowing the art form; many schools still carry on that tradition today. However, this historic holdover of secrecy is not ubiquitous, as many schools are also dependent on membership fees and want publicity so that more individuals will join the art and continue its preservation. One of my major concerns, which turned out to be for naught, was that the school change from UCA to Topaziao would entail a change of policy about filming, and I would not be permitted to record classes or conduct my research. My established relationships likely contributed to the fact that I was still permitted to record the classes.

Kino signed off on all consent forms and gave me his blessing to move forward with my research. However, Kino did request that any videos I took were to be released to the school for student analysis. One of the primary issues ethnomusicologists are concerned with is decolonizing fieldwork, or removing barriers to equal positioning of participants and observer. Addressing this concern often requires finding a common ground with field partners to provide compensation for allowing us to conduct fieldwork

with or about them. The practice of gathering information without compensating groups involved is increasingly viewed as exploitative.⁵⁸ Anthony Seeger's work with the Suyá native group in Brazil provides a good illustration of this potential.⁵⁹ The Suyá natives requested that Seeger help them record themselves to earn money for trade goods. While the recordings did not earn as much as the Suyá might have expected, what profits Seeger did make from the recordings he donated to the Suyá as compensation. After establishing the practice of fair compensation, Seeger remarks that now the Suyá tell others that their "anthropologist" (referring to Seeger, an ethnomusicologist) will pay them, and so they expect similar compensation from other groups as well. Kay Kaufman Shelemay remarks that an ethnomusicologist can reciprocate field partners by assisting in the transmission of their tradition.⁶⁰ By releasing the recordings I took to the school, I was able to offer a similar sort of compensation. While the recordings are not monetarily profitable, they can be used by the instructor and the students to improve on their Capoeira art. They are also free to use the videos as they wish in the future.

During the data collection period of this study, I learned that Primo's moving plans had changed, and he wanted to rebuild his Capoeira studio. He began to teach elsewhere in the Valley, which further split the number of study participants at Chandler

⁵⁸ Jeff Todd Titon, "Knowing Fieldwork," 33.

⁵⁹ Anthony Seeger, "Theories Forged in the Crucible of Action: The Joys, Dangers, and Potentials of Advocacy and Fieldwork," in Gregory Barz and Timothy J. Cooley, eds. *Shadows in the Field: New Perspectives for Fieldwork in Ethnomusicology*, (Oxford: Oxford University Press, 2008): 274.

⁶⁰ Kay Kaufman Shelemay, "The Ethnomusicologist, Ethnographic Method, and the Transmission of Tradition," in Gregory Barz and Timothy J. Cooley, eds. *Shadows in the Field: New Perspectives for Fieldwork in Ethnomusicology*, (Oxford: Oxford University Press, 2008): 143.

Martial Arts Studio since some of them left to train with him and others remained at Capoeira Topaziao with Kino. To reiterate, I recorded Kino's classes at the Chandler Martial Arts Center.

Methods:

Participants

All individuals who were participating members of United Capoeira Association/Capoeira Topaziao were recruited for this study as of October 29th, 2019. In keeping with all informed consent forms, no participant was required to attend any of the recording sessions. This meant that more participants were recruited than actually participated in the study.

Six male adults, two female adults, seven male children, and one female child consented to be a part of the study. Of these sixteen, only ten participants attended days that were video recorded, and only six participants chose to fill out surveys. Three of the consenting adults are experienced instructors, and all other adults hold verde, verde-amarelo, or amarelo cordões.⁶¹ However, only one instructor level Capoeirista attended class on days recorded. This means one participant has many years of Capoeira experience, while all the other adults have practiced for a few years only. None of the

⁶¹ Green, green-yellow, or yellow Cords. Similar to a belt system utilized in other martial arts, cords represent the experience level of the participants. In UCA's belt system, a green cord is the first cord given to a practitioner in a bautizado. This would normally mean anywhere from 3 months to one year's experience. The second belt given would be green-yellow, offered the following year, and then yellow which would be one to two years after that.

adults are complete beginners. Among the children, only three males have a cordão. The rest of the children are beginners.

The ages among all participants ranged drastically, due to familial relationships in the participant base, many of which are father-child or mother-child. While I did not ask the exact ages of the adults, table 1 represents my rough estimate of the age range.

| Ages: | Under 6 | 7-11 | 12-15 | 18-30 | 30-55 |
|--------------------|---------|------|-------|-------|-------|
| # of Participants: | 2 | 3 | 3 | 1 | 7 |

Table 1. Participant age range

A total of eight videos were recorded across a three-week period, however one video was discarded due to technical difficulties with recording. These seven videos included five rodas and two drills, in which participants practiced various Capoeira techniques. These drill videos had accompanying Capoeira music, as did the rodas.

Unfortunately, when United Capoeira Association transitioned into Capoeira Topaziao, student attendance dropped. The number of participants in each video reflects this low attendance, and the number of participants in each video are represented in Table 2.

| Video # and Type | Duration | # of Adults | # of Children | Total Participants |
|------------------|----------|-------------|---------------|--------------------|
| Video 1 (Roda) | 2:31 | 4 | 1 | 5 |
| Video 2 (Roda) | 6:33 | 3 | 4 | 7 |
| Video 3 (Roda) | 8:57 | 4 | 0 | 4 |
| Video 4 (Roda) | 1:33 | 3 | 0 | 3 |
| Video 5 (Roda) | 2:03 | 3 | 0 | 3 |
| Video 6 (Drills) | 2:05 | 5 | 3 | 8 |
| Video 7 (Drills) | 4:47 | 4 | 2 | 6 |

Table 2. Video duration and participants

To protect the identities of each participant they will be labeled by their level of experience. Therefore, the adult participants that have been recorded will be referred to as follows: Participant A, B, C, D, E, and the children will be referred to as Child A, B, C, D, and E. These letters indicate experience in Capoeira, with A being the most experienced and E being the least. Note that among the children, this generally reflects the order of age, with the oldest being A. Child C is the exception, being the youngest of the five.

Materials

As I have previously mentioned, it is customary that a Capoeira roda have an accompanying bateria performing Capoeira songs. However, many schools will use recorded Capoeira songs in lieu of this for particular reasons. Most often, recorded Capoeira songs are used when there are too few participants to form a roda and play in a bateria. When a Capoeirista takes an instrument, they will usually not be able to play in

the roda for a long time, until another Capoeirista relieves them of their instrument. In the case of the rodas I recorded, where there were only 3-7 participants, it would not have made sense to have a bateria of three berimbaus, two atabaques, and other hand held instruments. Sometimes, with a roda of 6 or 7 participants, the instructor may use a single berimbau. This was not the case for any of my recordings.

The Capoeira songs used in the roda had been recorded live. The songs were played from the instructor's smartphone through a small Bluetooth speaker, either a UE Boom 2, or a similar style. The speaker was placed at the front of the roda, where a bateria might normally be located. Participants begin their games from this point, usually performing an *au* into the center of the circle.

The studio has two unique features: first, the floor is made up of square mats and puzzle mats, rather than hardwood floor. Each square mat is placed in a way to minimize gaps or bumps in the floor; however, there is one slight bump in the floor that would have been crossed by some participants in video 6. The mats are cleaned daily, and no shoes are permitted on them. Second, mirrors covered the south wall, the same side that featured the front of each roda. In classes, participants would often be able to watch themselves or the people behind them. However, none of the videos I took were situations in which participants used the mirrors as a visual cue.

No other equipment or instruments were used in any of the recorded classes. Videos were recorded using a 2017 iPad 9.7". Videos were then analyzed using Logic Pro X. Surveys were constructed using Google forms. The survey included several

irrelevant questions in order to make it more difficult for participants to guess the purpose of my project. I wanted my recordings to represent a field setting, rather than a laboratory setting, as much as possible. Furthermore, if the observed participants knew the true purpose of the study, the role of attention on motor synchronization, the study results would be compromised.

Procedure

As previously mentioned, I started practicing Capoeira in 2017. Long before beginning this study, I had formed relationships with the other members, and learned about the art through participation. I started taking field notes several weeks before the recording sessions. These included comments between participants, constructive criticism from instructor to student, and methodologies employed by different instructors in teaching both movements and music.

Data collection in the form of surveys and recordings began after I received exempt status from ASU's Institutional Review Board (IRB, see Exemption Letter in Appendix F). Most participants' written consent was obtained the week prior to initial data collection. However, because some students were not present until mid-way through the data collection process, informed consent for these students was obtained the same day, prior to the beginning of the recording.

Following most days of recording, participants were asked if they would be willing to fill out surveys. On two occasions, however, the class ended so late that the school had to close. In these instances, participants were not asked to complete a survey

to avoid participants feeling obliged to fill out a survey in a parking lot at 10:00 pm. Eleven surveys were completed by the end of the data collection period.

Each video of each participant was then analyzed separately on Logic Pro X. Initial coding of participant movements was done without audio to avoid the potential influence of musical entrainment on the analysis of movement. Videos were marked at several sections to denote the ictus of a given participant's movements. The beats per minute of the audio were then aligned to the time markers set by Logic Pro X. Afterwards, I listened again to the audio to determine any locations where the beat deviated from the time markers. Because the audio stimuli used were live recordings, they did not consistently align to tick marks throughout the video. The waveform matching the video often, but not always, assisted in determining the location of a given beat. The figure below represents one example of the latter occurrence (Figure 12).

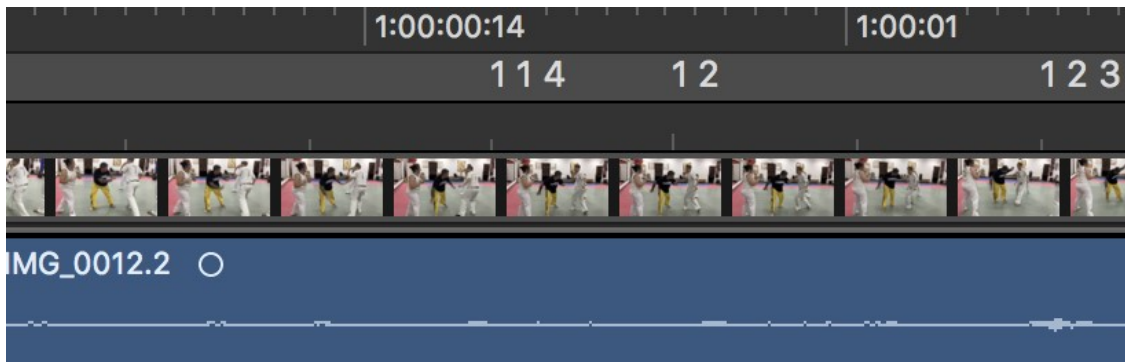


Figure 12. Logic Pro X waveform and video. The bumps at the beginning of the waveform represent downbeats, but they are not aligned with any marker in the black bar above the video. However, at 12 (measure 12, beat 1) the waveform is almost aligned to the ruler again.

In this figure, the blue box at the bottom represents the waveform. Each bump was an audio stimulus, so it was easy for me to determine which audio stimulus matched the rhythmic phase.

Sometimes, participant clapping did not match the audio, making the beat unidentifiable. Instances in which marked icti occurred at a point where the musical beat was obscured were discarded. After determining the exact location of the beat, I then needed to ensure the marker I placed was perfectly aligned with a movement's ictus. This was done through a process known as video scrubbing, in which I slowly moved the video to see stop motion images to determine when a movement finishes rising and begins to fall. Below I have presented an example of this process to demonstrate how a movement would show a given ictus in time (Figure 13). This is the point in its trajectory that the kick stops moving upward and begins its descent:

*



Figure 13. Stop motion images of an armada. Note the fourth image has no blur compared to the ascent/descent of the other images.

To determine whether a particular ictus was synchronized or not, I build upon Madison's study on pulse attribution. For a movement to be labeled as synchronized, it must fall within 10% of the inter-onset interval of the rhythmic beat. Madison's study suggests that 8.6% is a deviation threshold that allows for highly synchronized pulse attribution.⁶² While one may consider 10% to be arbitrarily wide, it falls short of a deviation percentage that would be described as "very jerky," which would exceed 15.2%

⁶² Guy Madison and Bjorn Merker, "On the Limits of Anisochrony in Pulse Attribution," 205.

of the inter-onset interval. The increase of 8.6% to 10% helped to account for conflicting rhythms and measurement errors.

I also marked a secondary threshold, which would categorize all movements between 10 and 15% of the inter-onset interval. This secondary threshold was less strict, to analyze how often participants would be somewhat synchronized. As a secondary measure to ensure accuracy of my measurements, I made eye measurements of each marker I placed. That is, I watched/listened to the video for each marker I made, and if I heard the beat at the same time as the ictus of the participant, I would consider that movement synchronized. My eye measurements corresponded very closely with the inter-onset intervals when I removed movements between the 10-15% deviation range. For example, if an individual was synchronized 10 times out of 20, but 2 movements were in the 10-15% range, then 10/18 would be the closest corresponding fraction to my eye measurements.

Results

Tables representing this section may be found after the discussion of video 5, below. Video 1 was the only one to feature an Angola rhythm. A slower tempo was used in the song than other videos: only 74 beats per minute. While this is not always the case, slower tempi tend to be typical of Angola games. Participants A, B, C, D, and Child A were all involved in this video. However, participant C did not play in the roda long enough to be examined. Because the song in this video features a much slower tempo, participants' movements needed to match the beat with no greater deviation than by 81

milliseconds to reach the synchronized threshold. I also marked any instance in which a participant was within another 40 milliseconds, still not reaching the 15.8% threshold listed as “very jerky” in Madison’s study.⁶³ Participant A was synchronized with 7 of the 16 movements recorded, with 3 additional movements falling within 40 milliseconds. Participant B had the highest synchronization in this video compared to all results across all videos and participants, with 9 of his 11 movements. Participant D was only synchronized for 6 of 20 movements, with 6 additional movements not exceeding the total 121 milliseconds. Child A was synchronized in 10 of the 22 recorded instances, with 4 being within the 50 milliseconds of passing the threshold.

Video 2 was taken during the children’s class, although the distinction between a children’s and adult’s class is blurred. Many children still take part in the adult’s class, including Children A, B, and C. Participants A, C, D, and Child C, D, and E participated in this roda. However, because most of the adults in this video participated in order to warm up for their following class, this was unlike the other recorded rodas for them. In a sense, they were not primed, and they were likely not taking this game as seriously as they would for their respective class. Three different songs were played in this video, at 92 bpm, 100 bpm, and 108 bpm respectively. Each song was faster than the prior. In this video, Participant A was synchronized in 7 of 12 movements with a threshold of 62 milliseconds. One additional movement did not exceed the secondary threshold of 30 milliseconds. Participant C unfortunately only had 4 usable recorded movements, as the clapping was not synchronized to the musical beat, and too many conflicting audio

⁶³Guy Madison and Bjorn Merker, “On the Limits of Anisochrony in Pulse Attribution,” 206.

signals were present for me to analyze where the beat was, much less for Participant C to synchronize to it. Nevertheless, of those 4 movements, half of them were synchronized. Participant D was synchronized in 7 of 12 movements. Child C was synchronized in 9 of 22 movements, with one movement not exceeding the secondary threshold of 30 milliseconds, and was an escape from the opponent's move, so the visual cues were likely higher order for motor synchronization. Child D was synchronized only 2 out of 10 recorded movements, however four of those were within the secondary threshold. Of those four, two were also escapes. Finally, Child C was synchronized 4 of 10 movements, again with 4 more meeting the secondary threshold.

Video 3 was over 8 minutes long; however, I only analyzed the first and last 2 minutes in this example. Four adults were present in this video, Participants A, B, C, and D. Participant A synchronized 11 out of 23 movements in the first section to a song with 110 bpm and a 54 millisecond threshold, and then 3 of 5 recorded movements with a song of 120 bpm and a 50 millisecond threshold; in total, Participant A was synchronized to 14 out of 25 movements, with 5 of those movements not reaching the secondary threshold. Participant B synchronized to only 4 of 17 recorded icti, with 4 additional movements not exceeding the secondary threshold. Participant B only played in the roda at the 110 bpm song. Participant C and D synchronized more frequently. Participant C synchronized to 6 of 20 movements at 110 bpm, and then 17 of 29 movements at 120 bpm. In total, Participant C was synchronized to 23 of 49 movements, with 11 movements not exceeding the secondary thresholds. Participant D was synchronized in

10 of their 16 movements synchronized. Participant D also only played in the roda with the 110 bpm song.

Video 4 was the shortest recorded video, and only featured Participant A, B, and D. Only one song of 116 beats per minute was present in this video. The primary threshold then was 52 milliseconds, and the secondary threshold was 26 milliseconds. Participant A had 7 movements not exceed the primary threshold, and an additional 3 movements not exceed the secondary, out of their 21 movements. Participant B was synchronized in 7 of 25 movements, with another 2 movements not exceeding the secondary threshold. Participant D yielded similar results, synchronizing in 9 of 23 movements, and 5 not reaching the secondary threshold.

Like video 4, video 5 was a roda at the end of a class with low student turnout. Those involved in this roda were the same as in video 4, and the roda had an accompanying song of 107 bpm. Participant A was synchronized within a 56 millisecond threshold 16 of 39 movements, with 6 being within another 28 milliseconds. Participant B was synchronized in 10 of 26 movements, with 7 movements not exceeding the secondary threshold. Participant D was synchronized in only 4 of 18 movements, with 6 being within the 28 millisecond threshold.

Because drills are very distinct forms of practice as opposed to rodas, data collected for these two types of activities were analyzed separately. The following tables show each participant's synchronization in rodas only.

| Participants | A | B | C | D | E | C.A | C.B | C.C | C.D. | C.E. |
|-------------------|--------|-------|-------|-------|-----|-------|-----|------|------|------|
| Roda 1 | 7/16 | 9/11 | N/A | 6/20 | N/A | 10/22 | N/A | N/A | N/A | N/A |
| Roda 2 | 7/12 | N/A | 2/4 | 5/12 | N/A | N/A | N/A | 9/22 | 2/10 | 4/10 |
| Roda 3 | 14/25 | 4/17 | 23/49 | 10/16 | N/A | N/A | N/A | N/A | N/A | N/A |
| Roda 4 | 7/21 | 7/25 | N/A | 9/23 | N/A | N/A | N/A | N/A | N/A | N/A |
| Roda 5 | 16/39 | 10/26 | N/A | 4/18 | N/A | N/A | N/A | N/A | N/A | N/A |
| Total | 51/113 | 30/79 | 25/53 | 34/89 | N/A | 10/22 | N/A | 9/22 | 2/10 | 4/10 |
| % Synchronization | 49% | 38% | 47% | 38% | N/A | 45% | N/A | 41% | 20% | 40% |

Table 3. Participant fraction of movements that were recorded as synchronized in each roda, as well as total synchronization percentages.

As I have previously outlined, my eye measurements corresponded more closely with each participant when I removed instances of near-synchronization; that is, when synchronization range exceeded the primary, but not the secondary threshold. The following table represents each participant's synchronization taking this into account:

| Participants | A | B | C | D | E | C.A | C.B | C.C | C.D. | C.E. |
|-------------------|-------|-------|-------|-------|-----|-------|-----|------|------|------|
| Roda 1 | 7/13 | 9/11 | N/A | 6/14 | N/A | 10/18 | N/A | N/A | N/A | N/A |
| Roda 2 | 7/11 | N/A | 2/4 | 5/12 | N/A | N/A | N/A | 9/21 | 2/6 | 4/6 |
| Roda 3 | 14/21 | 4/14 | 23/38 | 10/16 | N/A | N/A | N/A | N/A | N/A | N/A |
| Roda 4 | 7/18 | 7/23 | N/A | 9/18 | N/A | N/A | N/A | N/A | N/A | N/A |
| Roda 5 | 16/33 | 10/19 | N/A | 4/12 | N/A | N/A | N/A | N/A | N/A | N/A |
| Total | 51/96 | 30/67 | 25/42 | 34/72 | N/A | 10/22 | N/A | 9/21 | 2/10 | 4/10 |
| % Synchronization | 53% | 38% | 60% | 47% | N/A | 56% | N/A | 43% | 33% | 67% |

Table 4. Participant fraction of movements that were recorded as synchronized to the secondary threshold, as well as total synchronization percentages.

In video 6, students were practicing negativa movements followed by a *role* (a half-cartwheel to move sideways from a ground position to a more upright position), going from one side of the room to the other. Because participants were only in each video for a short amount of time, there were fewer recorded movements across participants. Only 7 of 25 movements were synchronized to music, however many participants would synchronize to other participants. For example, the back row might synchronize their movements with the person in front, or to the person to the side of them. The table below gives the total movements synchronized by each participant in this video.

Note that Child E’s participation in this video was impossible to analyze. In video 7, results were similar: only 12 out of 48 movements were synchronized.

| Participants | P.A | P.B. | P.C | P.D. | P.E | C.A | C.B | C.C | C.D | C.E |
|---------------------------------------|-----|------|-----|------|-----|-----|-----|-----|-----|-----|
| Video 6: Total Synchronized Movements | 50% | 33% | 17% | 33% | 33% | N/A | N/A | 0% | 33% | N/A |
| Video : Total Synchronized Movements | 33% | 25% | 18% | 43% | 33% | 0% | 33% | N/A | N/A | N/A |

Table 5. Video 6 and 7, participant degree of synchronized movements.

Survey Answers

The questionnaires given at the end of each class were anonymized and coded in order to meet IRB requirements, due to the presence of very young children in the study. I did this in a very conservative way to ensure protection of any identities of study

participants, and unfortunately cannot trace a particular survey to any particular participant. In total, 11 surveys were returned.

Survey answers for the participant coded PI50⁶⁴ wrote that they felt they matched the beat of each class with a 4 or 5 out of 5. PI50 does not play any other musical instrument, and was correct in identifying the type of Capoeira rhythm used in each class. They also wrote that they were very comfortable with the lyrics of all songs played, also with either a 4 or 5 out of 5 for each answer.

6. How did you feel you matched the beat in your game?
Mark only one oval.

| | 1 | 2 | 3 | 4 | 5 | |
|------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|----------------------------------|------------------------------|
| I do not think I matched the beat. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input checked="" type="radio"/> | I was very much on the beat. |

Figure 14. Survey Answer Sample

AR63 also does not play any musical instruments. They were correct in identifying the Capoeira rhythms, and self-reported that they were synchronized; always marking 4/5 as being very close to matching the musical beat. AR63 was more comfortable with the lyrics on some days rather than others, and their answers varied between 3/5 to 5/5, marking 3/5 on the class with an Angola rhythm.

⁶⁴ Because I cannot trace surveys to participants, individual surveys were coded differently than individual participants in the video data.

VV66 wrote that they are a singer, but only marked 2/5 when asked how they felt they were synchronized to the beat. They marked 3/5 comfort with the lyrics, and correctly answered that the musical rhythm was Angola. VV66 only filled out one survey.

MX65 filled out two surveys and is a guitarist. MX65 always marked that they were 5/5 synchronized with the beat, and 5/5 comfortable with the lyrics of songs used. MX65 was also correct in determining the musical rhythms.

AC03 and AM03 only filled out one survey each, and both wrote that they are guitarists. AC03 marked 4/5 in terms of being synchronized to a musical beat, and 3/5 comfort with the lyrics. AM03 only marked 2/5 on the synchronization question, and did not answer anything for the question regarding lyrics. AM03 also wrote a giant question mark when asked what type of Capoeira rhythm was being played.

The following table represents average answers to the survey questions, because individual answers cannot be traced to specific participants.

| Question | Participant Answers |
|---|---------------------|
| Total Musicians | 4/6 |
| Total injuries across all participants and surveys | 2/11 |
| Average physical state after class (0=tired, 5=not tired) | 4/5 |
| Average benefit of the class (0= no benefit, 5=benefited a lot) | 4.6/5 |
| Average Matched the beat (0=did not match, 5=matched a lot) | 4/5 |
| Average difficulty understanding the lyrics (0=more difficult, 5=more ease) | 4.2/5 |

Table 6. Survey answers. 4 out of 6 participants that answered surveys claimed to be musicians. Out of the total 11 surveys, 2 injuries were recorded. The following 4 scores were averages taken across all 11 surveys.

Discussion:

It would appear that as a general rule music-motor synchronization occurs between 40 to 60% of the time with movements among Capoeiristas studied. However, there are many nuances that make findings difficult to generalize. Participant A had the most consistent scores across all video examples as well as the highest scoring degree of synchronization, excluding a few exceptions. This may be related to Participant A being the most experienced participant.

Using eye measurements were more likely to result in ratios similar to the second data set (see Table 4). However, Participant A, who had the most experience, exhibited the least amount of change between the two data sets shown in Tables 3 and 4. This

means using the secondary threshold did not significantly increase the number of movements determined to be synchronized by Participant A, as opposed to the other less experienced participants. If experience is a defining factor of the degree of synchronization, the secondary threshold may not be as reliable in tracking motor synchronization as initially hypothesized, as Participant A did not score significantly higher using the secondary threshold.

Strangely, the instances (specific participants in specific videos) with the highest degree of synchronization occur among participants with the lowest overall synchronization scores. Note Participant B's unusually high synchronization score in roda 1, as compared to Participant B's lower overall score in Table 3. This instance was reviewed several times to ensure the analysis was accurate. One factor that might have played a role is the toque of the game. Roda 1 was the only Angola rhythm played. There are two important consequences of this: first, Angola games tend to be slower paced, closer to the ground, and lend themselves more to tricking the opponent into mistakes, rather than outpacing them in one's own movements. Therefore, analyzing one's partner, and perhaps even synchronizing to them may be more common in this type of game. Furthermore, the Sao Bento Grande de Angola rhythm is more often played by Capoeira Topaziao, and Angola rhythm is more ubiquitous across other Capoeira organizations. Perhaps students that were coming from several years of UCA training were more familiar with Angola than with the Sao Bento Grande de Angola rhythms used in other rodas. However, there is a problem with this rationale. While Participant B had the highest synchronization score in roda 1, the other participants scored lower than their

averages. Participant D also scored very high in roda 3, contrasting greatly with Participant B's very low score.

If the toque is not the major factor behind a participant's significantly high score, then other explanations must be considered. Perhaps specific attentional foci were given to the music of the roda on certain days by different participants. London suggests that a listener's attending process generates certain aspects of rhythm perception that facilitates entrainment, such as metrical accents.⁶⁵ One might assume then that attentional focus is required for synchronization, at least initially, which is implied by the Dynamic Attention Theory, which suggests that attentional oscillators entrain to isochronous rhythms.

Scores between 40-60% indicate some level of music-motor synchronization. It is possible that participants allocate a certain amount of cognitive resources to synchronizing to the music, and the amount of resources allocated varies in different contexts. This explanation aligns with Dynamic Attending Theory. An alternate explanation is that auditory stimuli are given cognitive resources without an attentional prerequisite, but attending can expand upon the resources allocated. Richard Kunert and Suzanne R. Jongman argue that auditory entrainment affects only auditory-motor

⁶⁵ Justin London, "Meter as a Kind of Attentional Behavior," in *Hearing in Time: Psychological Aspects of Musical Meter*. (2004) NY: Oxford University Press, 19.

systems⁶⁶, an argument that aligns with other theories that implicate motor planning in the auditory entrainment process.⁶⁷

Finally there are issues that are presented by the drill videos. I only was able to observe a few movements from each participant and the overall scores were very low. However, I noticed synchronization occurred to stimuli other than music, such as to other participants. Several studies suggest that when there is a rhythmic disconnect between auditory and visual cues, participants tend to look to visual cues for synchronization.⁶⁸ Sometimes, the entire class would appear to move identically. Other times, three or four would move together, with mirroring *icti and* trajectories, while a few individuals would break the trend. While in a *roda*, participants would be required to react to a partner's movements; under normal circumstances in a drill, there is no reason a participant would not be able to mirror another's movements. This attunement is described as a joint body schema. Researchers at Arizona State University argue that joint body schema support heightened sensitivity of the mirror neuron system, which enhances motor learning.⁶⁹

⁶⁶ Richard Kunert and Suzanne R. Jongman, "Entrainment to an Auditory Signal: is Attention Involved?" *Journal of Experimental Psychology* 146, no.1 (2017): DOI:10.1037/xge0000246

⁶⁷ Aniruddh Patel and John Iverson, "The Evolutionary Neuroscience of Musical Beat Perception: the Action Simulation for Auditory Prediction (ASAP) Hypothesis" *Frontiers in Systems Neuroscience* (2014): <https://doi.org/10.3389/fnsys.2014.00057>

⁶⁸ Udo Will, "Coupling Factors, Visual Rhythms, and Synchronization Ratios;" Yi-Huang Su, "Audiovisual beat induction in complex auditory rhythms: Point-light Figure Movement as an Effective Visual Beat;" Matthew Harold Woolhouse and Rosemary Elai, "Traces Across the Body: The Influence of Music-Dance Synchrony on the Observation of Dance."

⁶⁹ Tamer Soliman, "Joint Action Enhances Motor Learning," PhD Diss, (2015): Tempe, Arizona: Arizona State University, 11; Brenna Renee Goodwin, "Joint Action Produces Super Mirror Neurons" Master's Thesis, (2015) Tempe, Arizona: Arizona State University.

However, Gelsy Torres-Oviedo and Amy Bastian offer contrasting evidence, arguing that the removal of visual cues facilitates increased adaptive learning for motor actions.⁷⁰

Children also played a unique role in this research. Unfortunately, each child participant performed in one or zero rodas, so I do not have sufficient data for comparison. However, it appears as though the children with cordões exhibit similar degrees of synchronization as the adult participants, despite the difference in age. Certain children such as Child A and, to a lesser extent, B play in the roda in a style very similar to that of adults. They connect their subsequent movements and play with good flow;⁷¹ they stay upright and show a high level of control with their own body. The younger children often fall over after certain moves, continue spinning around after performing an armada, or roll around on the ground after a negativa. There are two factors that might explain this difference in bodily control. First is maturity, which corresponds with the age difference between Child A and B, compared to C, D, and E. Participants A and B are adolescents, whereas Child C, D, and E are pre-pubescent or just entering puberty. The second is the actual body. Participant A, in particular, has a relatively mature body, taller

⁷⁰ Gelsy Torres-Oviedo and Amy J. Bastian, “Seeing is Believing: Effects of Visual Contextual Cues on Learning and Transfer of Locomotor Adaptation” *Journal of Neuroscience* 30, no. 50 (2010): DOI: <https://doi-org.ezproxy1.lib.asu.edu/10.1523/JNEUROSCI.4205-10.2010>.

⁷¹ Flow in Capoeira represents performing movements in sequence without a disjointed break. For example, if a person kicks an armada, they land in a way that their body is already primed to go into a negative, or turn and kick a queixada. If a person has to stop after a movement, or return to their ginga immediately after finishing a movement, that person is not playing with good flow.

and broader than many of the adult male participants. These results are inconsistent with Mitchell's claim that puberty results in a loss of co-ordination.⁷²

Child C, therefore, is perhaps the most interesting child to study for two reasons. Child C has participated in many adult classes, and has more experience than Children D and E, but Child C is also the youngest of all 5 children recorded. Child C participated in only one roda, with a 41% synchronization. This means that despite body size and maturity/age, Child C maintained synchronization percentages similar to many of the adults with similar experience. However, in drills, children, including child C, were the only participants who had 0 synchronized movements. When talking about the roda, Capoeiristas refer to it as "the game." In contrast, drills have no special title, and are more likely to be perceived as exercises or work. Therefore, a child might be more likely to "play a game" correctly than "work" correctly, particularly at their maturity level.

Expertise appears to impact two aspects of synchronization in Capoeira. First, experienced individuals appear to have more consistent scores. Second, expertise appears to narrow the margin by which synchronized movements deviate from the exact timing of the beat. However, while experience in Capoeira might shape a participant's ability to synchronize movements to music, there is another possible factor that might explain why certain participants synchronized to a higher degree than others. Four out of six surveyed participants wrote that they play musical instruments. Perhaps playing music outside of

⁷² Siobhan Mitchell, Anne M. Haase, Sean P. Cumming, and Robert M. Malina, "Understanding Growth and Maturation in the Context of Ballet: a Biocultural Approach," *Research in Dance Education* 18, no. 3, (2017): 291-300.

Capoeira facilitates motor-synchronization. This is an application of Jones and Yee's theory that skilled listeners are better equipped to detect and subdivide rhythms.⁷³ However, as an individual becomes more experienced in Capoeira, they are expected to become musicians in the tradition. Therefore, even though Participant A may or may not be a musician outside of Capoeira, they are certainly skilled at all of the instruments of Capoeira, and it can be assumed that at least they are adept at skilled listening and can be attributed a musician title.

Remarkably, almost every participant wrote that they had little difficulty with understanding the lyrics of the Capoeira songs, that they were not tired after completion of the class, and that they perceived themselves to match the beat very closely. The only participants to report that they were not as synchronized to the beat as they could have been were musicians. However, in most instances, participants were between 40-60% synchronized, so while they were synchronized to a degree, they were not consistently matching all of their movements.

More participants expressed discomfort⁷⁴ with the Angola lyrics than the Sao Bento Grande de Angola lyrics. Angola rhythms and games are less common, both in UCA as well as Topaziao than other rhythms, and feature a strikingly different style of game. It's possible that the responses expressing discomfort with the lyrics actually

⁷³ Mari Riess Jones and William Yee, "Sensitivity to Time Change: The Role of Context and Skill."

⁷⁴ There may have been ambiguity with this term. The survey question asked participants how comfortable they were with the lyrics, but this could have been interpreted in different ways by each participant, such as how well they remembered the lyrics in the roda, or how comfortable they were with the toque.

meant participants were uncomfortable with playing Angola style games, as opposed to being a response to the specific lyrics of each song. Despite being an active participant, I was unfamiliar with the specific lyrics of each song used, as they had not been songs that the class had practiced and learned prior to my involvement with either group. If any participants did know these lyrics, they had learned them from other contexts. While possible, I suspect it is more likely that the participants responded to the *toque*, rather than the lyrics, in this survey question, due to the fact that these songs had not been played in any of the prior UCA classes in the year prior.

When analyzing movements, I noticed one particular movement whose profile makes it difficult to define an *ictus*: the *au*. At least one *au* was almost always present in each participant's game. Because the *au* is a cartwheel, there are different points that could have been defined as an *ictus*: when one leg reaches maximum height in the trajectory, when the second leg reaches maximum height in the trajectory, when one foot plants onto the ground, or when both feet plant onto the ground. I discarded any annotated movements with multiple *icti*, such as *aus*, and continued to the next marked movement.

Another issue that is unique to this study compared to other music synchronization studies is the role of live music. Ordinarily, a Capoeira class would have a live *bateria*, but as I had already mentioned, these classes were small and used recordings of *baterias*. Nevertheless, these recordings still featured the same types of nuances a live performance would have, most notably tempo irregularities. It is more difficult to find a beat with recorded Capoeira songs than with popular music recorded in

a studio, as recorded bateria often speed up or slow down slightly. Regardless of whether the song tempo changed, participants should be able to adjust to the new tempo through adaptive response.⁷⁵

Despite its strengths, there are several limitations with this study. First, there are very few participants in each specific video. Furthermore, many of the participants did not appear in multiple videos. Participant C, for example, only had a large number of recorded movements in one roda, with a small number recorded in another roda. This was due to the camera either starting to record just as they finished their games, or issues with clapping among the participants obfuscating the rhythmic beat during their games.

One of the major benefits of ethnomusicological fieldwork is that we can participate in the music culture we study, and practice bi-musicality. However, when UCA changed to Capoeira Topaziao, things such as the new clapping etiquette made the rodas more foreign to me, as well as other students. Such changes also generally require an adjustment period, so performance among the participants might yield lower results.

The large gap in ages among participants likely created specific situations that are hard to measure. Because there were many young children in this study, surveys had to be anonymized and were therefore impossible to link to specific participants, so only conjectures about answers could be proposed. For example, 2 injuries were reported in the 11 collected studies, and there may be a link between injuries and lower, or higher, degree of synchronization. If a participant could not outperform their opponent due to an

⁷⁵ Martin Clayton, Rebecca Sager, Udo Will, "In Time With the Music: The Concept of Entrainment and Its Significance for Ethnomusicology," 25.

injury, they might focus on making their game more accurately synchronized to a musical rhythm. Or, flowing their game and maintaining synchronization might aggravate an injury, and a participant would prioritize playing the roda in as safe a manner as possible.

Conclusion:

In Capoeira, synchronization to music tends to occur with 40-60% of movements among participants. Experience appears to correlate with consistency of synchronization, and higher degrees of synchronization. Children tend to score lower, and music synchronization occurs more frequently in rodas than in general drills.

Despite its limitations, the main purpose of this study was to provide a model for future ethnomusicologists and music researchers alike to study movement synchronization in the field, rather than a laboratory. To that end, this project functions as a pilot study of motor-synchronization in martial arts. However, the individual components are not entirely novel. Abraham's research involved tracking movement in an ecological setting in 2017,⁷⁶ and Du et. al. have published research studying the effects of music in martial art settings.⁷⁷

⁷⁶ Rosa Butler Abrahams "Moving in Sacred Time: Metrical Interactions Between Body and Voice in Jewish and Greek Orthodox Liturgical Chant."

⁷⁷ Yan Du, Penny Roberts, and Qingwen Xu, PhD, "The Effects of Tai Chi Practice With Asynchronous Music on Compliance and Fall-Related Risk Factors in Middle-Aged and Older Women: A Pilot Study."

This study would have been impossible to design without a bi-musical approach to fieldwork.⁷⁸ Knowing not only the terms, toques, and movements, but also having the insight on which movements could be analyzed, the significance of certain movements, and even the fact that Capoeira emphasized music-motor synchronization in the first place would have been impossible without bi-musical understanding of Capoeira. This project outlines all of these elements to those who may not be as familiar with the art, and demonstrates that there are art forms other than music performance and dance that feature music-motor synchronization. Capoeira provides a unique contrasting point for music-exercise studies, as no other martial art to my knowledge has such an emphasis on music. Therefore, Capoeira is uniquely situated as an art that can be compared with a control group⁷⁹ to analyze music and exercise in a martial art setting.

There are at least three types of studies that can draw upon this pilot study. Foremost, given the limitations with this study design, this study should be replicated. The participant base was too small, children create situational problems, and the shift from UCA to Capoeira Topaziao one week before I recorded the videos may have affected results in unpredictable ways. Furthermore, schools differ from one to another, including how topics like music are approached, so even if this study had none of the outlined flaws, replicating it in different schools may still yield varying results.

⁷⁸ See Gregory Barz and Timothy J. Cooley, eds. *Shadows in the Field: New Perspectives for Fieldwork in Ethnomusicology*. (Oxford: Oxford University Press, 2008).

⁷⁹ Any other martial art can be used to serve this function

Future researchers can expand on some of the concepts I could only touch on in this study. For example, because the surveys were randomized, connections between the surveys to the participants can only be made through conjecture. The role of musicianship in motor-synchronization is already of particular interest to researchers. Research on the role of musical expertise can be expanded upon by comparing the effect of musical training in Capoeira to traditional Western Art Music. The role the toque had on motor synchronization could also be investigated further. Finally, a host of questions and study designs can be made focusing on the Capoeirista children, perhaps focusing on the role of puberty and maturity on enculturation of movement and motor synchronization.

Another question that plagued this study was how visual synchronization affected study results. I have alluded to many studies throughout the course of this paper that implicate visual synchronization over auditory synchronization. However, the actual data analysis was fairly limited in examining this. While real-time notes allowed me to point out specific instances where visual synchronization occurs in conjunction with or against an auditory beat, data was analyzed with the specific aim of looking primarily at auditory synchronization. Therefore, I recommend a similar study design with a focus on analyzing visual synchronization, and comparing the results to this study's focus on aural synchronization. To analyze both visual and auditory stimuli both separately and simultaneously was beyond the scope of this research.

Capoeira, with its emphasis on music synchronization, can also be contrasted with another martial art. While I am an active participant in Capoeira's music culture, I too am a skilled practitioner of Krav Maga, and believe a similar study design could be made

pertaining to Krav Maga movements. Comparing the two would allow researchers to examine the roles of music attending and the dichotomy of background and foreground music in a martial arts setting.

Potential Comparative Research: Krav Maga

In my final remarks, I will highlight features of Krav Maga that would make it suitable for a comparative study with Capoeira. Krav Maga has no musical component, but music is often used in classes as they would be played in a gym. The martial art is fairly recent: it was developed in the mid 19th century by Imi Lietchtenfeld, initially for use by Israeli soldiers. Over time, it was adapted for civilian use and has been incorporated into military training. Due to its focus on ruthless efficiency and practicality for use on the streets, Krav Maga has become a favorite fitness activity, and schools have been established all over the world. As of the beginning of 2019, the Phoenix metro area alone has over 15 schools for various Krav Maga systems. Because Krav Maga is so common, a much larger sample size could be used.

Krav Maga is also a sort of cosmopolitan martial art. Many of its defenses draw from other martial arts, and better instructors would often clarify changes in a technique accordingly. For example, there are alternate options a defender might take when mounted, based on whether the assailant has no training, Brazilian Jiu Jitsu training, or other variables. And because music can be used freely according to a gym owner's decisions, any music-cognition/sports-psychology findings that pertain to Krav Maga can be potentially generalized to other gym settings.

As with Capoeira, analyzing icti should be sufficient in gathering data about possible music synchronization. The icti of many Krav Maga techniques are similar to the types of icti observed in Capoeira moves. This is one of the benefits of studying martial arts as a gross-motor study. Just as a Capoeira kick will stop extending and start returning, most Krav Maga strikes will also have a point at which the motion of a punch or kick end extension and begin return. Many Krav Maga defenses have a point of contact before a second type of motion occurs, which helps determine an ictus. For example, when a participant is escaping a headlock, the ictus point might be the simultaneous moment in which the defender's shoulder strikes back and the defender's hands pull on the attacker's grip.

If a comparative study were to be done between Krav Maga and Capoeira, similar fieldworking methods can be used in both environments. The same concepts of participatory fieldwork, informant relationships, and bi-musicality are relevant to both. While it is true that Krav Maga has no accompanying musical tradition, usage of popular music in Krav Maga and other gyms is all too common, and worthy of attention by musicologists and ethnomusicologists.

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APPENDIX A

PHOTOS OF CAPOEIRA TECHNIQUES AND INSTRUMENTS



Figure 1, Atabaque



Figure 2, Berimbau



Figure 3, Ginga



Figure 4, Pandeiro



Figure 5, Negativa

APPENDIX B

CONSENT FORM

Capoeira Research Study

Dear Reader,

I am asking you to take part in a research study at Arizona State University that I am conducting in order to learn more and document phenomena that occur among Capoeira practitioners.

***Note that if you are under the age of 18, you will need to have your parent sign a permission form as well.**

If you agree, some exercises and your game in the roda will be videotaped on three separate occasions between November 5 through November 22. You will also be asked to fill out a 2 minute survey at the end of each class that was videotaped.

At your request, I will distribute copies of the videos I take for your own practice/study.

There are no risks or benefits associated with this study

While names will not be disclosed in my research and possible publications, you will be identifiable to classmates in video recordings that are distributed.

My own master recordings will be destroyed two years after completion of the study.

Your participation in this study is voluntary, and you can choose not to answer any or all of the questions on the survey.

Signing here means that you have read this form or have had it read to you and that you are willing to be a part of this study. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

Signature of

Subject _____

Subject's printed name _____

Signature of investigator _____

Date _____

Alex Rossi
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APPENDIX C

PARENTAL CONSENT FORM

Capoeira Research Study

Dear Parent, I am asking you and your child to take part in a research study at Arizona State University that I am conducting in order to learn more about and document phenomena that occur among Capoeira practitioners. If you agree, I will seek verbal assent from any child under the age of 8, and written consent for any child 8 and older. If your child is under 8 years old, please check the bolded box at the bottom once your child has agreed to participate in this study. If your child is 8 years old or over, I will have a separate form for them to sign.

If you agree, some exercises and you and your child's game in the roda will be videotaped on three separate occasions between November 5 through November 22. You will also be asked to fill out a 2-minute survey at the end of each class that was videotaped. You may help your child fill out a survey, if you wish. At your request, I will distribute copies of the videos I take for your own practice/study. There are no risks or benefits associated with this study.

While names will not be disclosed in my research and possible publications, you and your child will be identifiable to classmates in video recordings that are distributed. If you wish, I can edit out your child from any video recordings that I distribute. My own master recordings will be destroyed two years after completion of the study. You and your child's participation in this study is voluntary, and he or she can choose not to answer any or all of the questions on the survey.

Signing here means that you have read this form or have had it read to you and that you are willing to be a part of this study. If you have any questions about you or your child's rights as a subject participant in this research, or if you feel that your or your child has been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

Sign below for your own participation in this study

I agree to participate in this study (name) _____

Signature _____

Sign below if you allow your child to participate in this study

I agree to allow my child (name) _____ to participate in this study Parent

Signature _____

Signature of investigator _____ Date _____

My child has given verbal assent

I would like to help my child fill out the survey

I would like my child to be edited out of any distributed videos

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APPENDIX D

CHILD CONSENT FORM

School of Music



Capoeira Research Study

My parent has agreed that I can participate in a research study about Capoeira.

I will be video recorded, and asked to fill out a very short survey at the end of a few classes. I can ask my parent to help me fill out the survey, if I need to.

My participation in this study is voluntary. I know I can stop being in this study at any time

My name _____

Signature _____

Date _____

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APPENDIX E

CAPOEIRA SURVEY QUESTIONNAIRE

Capoeira Questionnaire

For today

1. Write the first two letters of where you last attended school and the last two digits of your phone number. For example, if I went to Arizona State University and my phone number is 5106044961, I would write AR61

2. Do you play any music outside of Capoeira? If so, describe.

3. Are you injured? If yes, how?

4. How was your physical state during class (Tired, sore)

Mark only one oval.

1 2 3 4 5

Very sore Feeling great!

5. How much did this class benefit you as a Capoeirista

Mark only one oval.

1 2 3 4 5

No benefit Amazing class!

6. How did you feel you matched the beat in your game?

Mark only one oval.

1 2 3 4 5

I do not think I matched the best. I was very much on the best.

7. How difficult were the lyrics to sing/understand?

Mark only one oval.

| | | | | | | |
|-----------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|--|
| | 1 | 2 | 3 | 4 | 5 | |
| I struggled with the lyrics | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | I was very comfortable with the lyrics |

8. What toques were played during the roda? Check all that you remember:

Check all that apply.

- São Bento Grande de Bimba
- Banguela
- Iuna
- Cavalaria
- Angola

9. How likely are you to come to another class at this school?

Mark only one oval.

- I will come to the next available class
- I may come to another class in the future
- I will not come to another class at this school

10. Do you have any additional comments?

APPENDIX F

INSTITUTIONAL REVIEW BOARD EXEMPTION



EXEMPTION GRANTED

[Kay Norton](#)
[HIDA: Music. School of](#)
480/266-0690
Kay.Norton@asu.edu

Dear [Kay Norton](#):

On 10/31/2019 the ASU IRB reviewed the following protocol:

| | |
|---------------------|---|
| Type of Review: | Initial Study |
| Title: | Music-Movement Synchronization in Capoeira (a Brazilian Martial Art/Dance Form) |
| Investigator: | Kay Norton |
| IRB ID: | STUDY00010873 |
| Funding: | None |
| Grant Title: | None |
| Grant ID: | None |
| Documents Reviewed: | <ul style="list-style-type: none">• Approval Letter, Category: Other;• A. Rossi Capoeira Consent Form [For 8-14 year old children], Category: Consent Form;• A. Rossi Capoeira Recruitment Script, Category: Recruitment Materials;• A. Rossi Capoeira Survey Questionnaire, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);• A. Rossi Capoeira Combined 15-17 Assent Form and Adult Consent Form, Category: Consent Form;• A. Rossi Capoeira Consent Form and Parental Permission, Category: Consent Form;• A. Rossi Capoeira Social Behavioral Protocol, Category: IRB Protocol;• A. Rossi Point-By-Point Response Letter, Category: Other; |

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 on 10/27/2019.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator

cc: Alex Rossi