WIRELESS AUDIO STREAMING TECHNOLOGY AND

APPLICATIONS IN MUSIC COMPOSITION AND PERFORMANCE

by

CODY BROOKSHIRE

(Under the Direction of Peter Van Zandt Lane)

ABSTRACT

SynkroTakt is a technology created by myself and two others that synchronizes tracks of audio being streamed to a multitude of web-enabled devices. I have used this technology as an integral part of several compositions that I have written during my doctoral studies. In these pieces, the audience is asked to get out their web-connected devices and connect to a server to receive and play back audio as part of a live performance. The audio coming from each audience member's device is composed in such a way that it musically interacts with other audience members' devices, as well as live music being performed on stage.

This convergence of electronic media, live performers, sound spatialization, and audience interaction presents a little-explored area of research, as well as fertile new ground for composition in the 21st century. By asking the audience to take part in the performance, greater levels of engagement between them and the performance can be attained. Additionally, harnessing the power of each audience member's very own digital instrument (their smartphone with its own speaker) can easily change what a live music experience can be, with sound potentially coming from every corner and spot of a performance space. Thus, new music composed for this combination of media, live performers, and concepts stands to transcend being a novelty and experiment.

Chapter 1 of my dissertation examines previous experiments, projects, and works that set a precedent for musical pieces of this sort. Chapter 2 details the technology of SynkroTakt, describing how it works and evaluating the advantages and disadvantages of its method of audio track distribution in comparison with the technology from the works of others. Chapter 3 overviews several of my own composition that utilize this audio-streaming technology, noting the pros and cons of each piece, as well as important compositional strategies learned from the creation and performance of each piece. This chapter reviews these pieces in chronological order, while also detailing the development of improvement of the technology. A conclusion reviews the progress made while also looking forward to other implementations of the technology along with possible feature additions.

INDEX WORDS: wireless, audio, streaming, technology, music, composition, performance, internet, synchronize, synchronized, synchronicity, track, tracks, web, connected, connection, device, phone, smartphone, tablet, laptop, computer, immersive, immersion, electronic, spatialization, spatialized, audience, engagement, engage,

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INTRODUCTION

Since the proliferation of the smartphone beginning in the late 2000s, imaginative uses of these devices have been pursued by programmers, marketing executives, and end-users alike. Being essentially a computer in one's pocket, a myriad of additional uses for smartphones beyond merely calling or texting someone have been dreamt, designed, coded, tweaked, packaged, priced, and distributed as an "app" in digital stores. Many of these apps, or at least the most notable and widespread, fall in the category of social media apps, which thrive on and exist for the sake of user-generated content, and are created by networks of people, groups, organizations, and corporations that broadcast and then re-broadcast both trivial and important information to one another. It is estimated that 70% of the population is a member of at least one social media network in Northern America, with Northern Europe and Eastern Asia slightly behind at 66% and 64%, respectively.[1] The advent and mass-adoption of social media apps and a rise in digital crowdsourcing phenomena coincide with (and perhaps are because of) the evolution and now near-universal presence of the smartphone. This confluence has created a globally shared set of ideals and practices pertaining to digital connection, entertainment, and interaction. Whether or not such ideals are truly the zeitgeist of this time is arguable, but their pervasiveness is surely undeniable.

While social media applications are ever-present on smartphones across the globe, the transmission and reproduction of sound is still at the very heart of the phone. Music and sound-

[1] "Social Media: Worldwide Penetration Rate 2018 | Statistic," Statista, accessed July 11, 2018, https://www.statista.com/statistics/269615/social-network-penetration-by-region/.

related apps hold stable footing in the collection of apps that are built into the phone's operating system or come pre-installed, as well in as virtual app marketplaces, perhaps the most ubiquitous of which comes in the form of a simple sound file player and organizer. A notable early example of such an app is the Music app or "iTunes" app found in Apple's first iPhone model that launched in 2007, a key feature that helped function as a bridge from the company's prior success in the iPod, which was a music-playing device only.[2] Since the iPhone's launch, sound file storage, organization, and playback are extremely commonplace and are now considered to be a fundamental feature to all smartphones, along with simple sound recorders and alarm buzzer programs. Apps aimed at music creators and sound production, while not usually built-in, are still readily available for interested users, and possible app types range from tuners and metronomes, to on-screen pianos and drum machines, to code-driven sound synthesis. But perhaps the most significant of all music and sound-related apps are those that stream music to users for their own recreation and consumption, such as Pandora, Spotify, iHeartRadio, Apple Music, Amazon Music, Google Play, and Tidal.[3] By 2017, such on-demand streaming services accounted for the bulk of end-user audio consumption in the United States, and with actions by tech-giants such as Apple and Amazon that poise themselves to continue expansion and promotion of these apps, streaming-related services are only going to become more prevalent and more widely-used.[4]

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[2] Ryerson Review of Journalism, accessed July 11, 2018, https://web.archive.org/web/20070303032701/http://www.rrj.ca/online/658/.

[3] "10 Best Music Streaming Apps and Music Streaming Services for Android," Android Authority, March 10, 2018, accessed July 2018, https://www.androidauthority.com/best-music-streaming-apps-for-android-213818/.

[4] Sarah Perez, "On-demand Streaming Now Accounts for the Majority of Audio Consumption, Says Nielsen," TechCrunch, January 04, 2018, accessed July 2018, https://techcrunch.com/2018/01/04/on-demand-streaming-now-accounts-for-the-majority-of-audio-consumption-says-nielsen/.

Inspired by the extra-musical ideals of connection, entertainment, and interaction that are omnipresent in today's culture, and the seemingly obvious use of the now ever-present phone as a device that (with respect to its historical usage and significance) recreates sound from another place and/or time, I began forming ideas about musical works and performance situations that could utilize many smartphones and similar devices in tandem, for both audience members and performers alike. By leveraging the capability of a smartphone to continuously receive and rapidly manifest information wirelessly in the form of streaming audio, their ability to produce localized sound, and the fact that they are plentiful in audiences at nearly any music performance, I could tap directly into these permeating notions of connection, entertainment, and interaction by creating music that purposefully utilizes groups of the very device that is responsible for the ubiquity of these notions in the 21st century. In some ways, and for some people, it seems as if the smartphone is an extension one's self (given how personal and attached many people in developed nations are to these devices), and it seems possible that this could be used to create a type of compelling and engaging art which incorporates these personal devices into a performance.

Since these initial thoughts in the Fall of 2015, I have focused much of my research and compositional output on the intersection of electronic music, live ensembles, spatialization, and audience engagement. Along with a group of other musically-inclined technologists, I have created SynkroTakt, an audio streaming technology to be used for musical performances. SynkroTakt synchronizes the same or different tracks of audio being streamed to a multitude of web-enabled devices.[5] While we developed this technology, I used it as an integral part of several compositions that composed as part of my doctoral studies. In some of these pieces, the

[5] "SynkroTakt," SynkroTakt, accessed July 2018, http://synkrotakt.com/.

audience is asked to get out their smartphone (or a tablet or a laptop) and go to a specific web address to receive and play back audio on their device as part of a live performance. The audio coming from each audience member's device interacts in controlled synchronicity with other audience members' devices, as well as with live music being performed on stage. A few other pieces use SynkroTakt exclusively as an assistive tool for the performers, conveniently allowing them to wirelessly and privately stream several click tracks of the same or different tempi to their earbuds without the use of a potentially expensive audio interface and unsightly cables across a stage floor.

This convergence of electronic media, live performers, sound spatialization, and audience interaction presents a timely and fertile ground for music composition in the 21st century. In an age when audience members struggle to keep their eyes and fingers off their phones during performances, new music composed for this combination of media and live performers using technology that is easily set up and implemented stands to transcend being a novelty and experiment. I envision that by harnessing the power and capabilities of each audience member's smartphone and turning it into what is essentially their very own "digital instrument," such technology has the capacity to profoundly change what a live music experience can be, with synchronized sound quite literally coming from every corner of a concert hall, black box, bar room, or other live music setting. This spatialization of sound created by a group of audience devices, with the placement of specific sounds either tightly controlled or even semi-random, can create a completely immersive and possibly very complex and nuanced aural environment. While similar experiences can only currently be had at highly-specialized concert halls, high-end movie theaters, or specific art installations and the like, this technology offers the possibility of such enveloping sonic experiences becoming more widespread by exploiting the devices that are already in everyone's pockets.

There are, however, drawbacks and limitations to performances and implementations involving a smartphone-wielding, internet-connected audience. Performances like these are invitations for irrelevant sounds emitting from devices as text messages come in and notifications go off, creating a somewhat trivial and sporadic annoyance that can either be accepted and ignored; however, these intrusions can be potentially eradicated if an audience is willing to temporarily change settings on their devices. More notable difficulties in the successful execution of a piece in this new genre are the inherent unpredictabilities in the audience’s connection to a local network or direct connection to the internet, unknown factors regarding the operational state of their devices, and how they operate their devices (meaning, have they connected properly and are they following the instructions). These difficulties can create problems with audio synchronicity, sound clarity, and potentially a failure for a phone or group of phones to produce any sound at all, but with proper planning, these difficulties can be largely mitigated or outright eliminated. Yet, a single significant hindrance remains, with the primary downside being that the actual sound quality and sound volume coming out of a smartphone will be much lower than that of normal electronic sound reproduction coming out of larger loudspeakers that would be typical of any given concert. While pre-compositional considerations can be taken into account in designing music for this performance medium to maximize what such speakers can do best, these two aspects will remain an impasse that is intrinsic to the nature of the genre itself.

In spite of these troubles and disadvantages, I believe the primary benefits and advantages are too great to ignore, as creating music in this modified genre offers accessibility and affordability for implementation, the potential for portability and modularity in sound localization and speaker placement, and perhaps most importantly, audience interaction and participation. The sort of audience interaction that this genre offers straddles the line between the traditional completely passive audience that makes up the vast majority of musical performances of any type, and a completely active audience in which they would be substantially removed from their role as observers only.

In some regards, this particular type of "communal music-making" isn't new. From the simple act of an audience clapping their hands in rhythm with a performance, to responsorial singing in folk and religious music alike, an audience taking part in and contributing to a musical performance has been a part of music in general for a very long time. However, the musical contributions that audiences make in this regard tends to be very simplistic. Additionally, the western art music tradition has generally steered away from audience involvement and focused more on specialists presenting the music in the form of instrumentalists, vocalists, and directors/conductors.

But, by asking the audience to use their phone's sound-creating ability (which offers the possibility to playback much more complicated music and sound than a human is capable of) so that they may become a part of a performance without asking them to necessarily "perform" or to do too much, a compelling blend of engagement, entertainment, and fulfillment can be achieved. With such technology, it might be possible to recover the traditions of audience involvement and inject them back into the western art music tradition. In concert experiences such as these, a special sense of a shared communal experience can be had amongst the audience, yet each listener will still have their own unique perspective on the music they hear from their position relative to the distribution of sound in the performance space.

CHAPTER 1

Experiments, Projects, and Works of Other Musicians and Technologists

While the concept of a music performance that incorporates many music-playing devices in the hands of the audience into that performance is unquestionably non-typical in the western art music tradition, there are certainly prior examples and attempts at such performances. Additionally, similar projects and works are being developed and implemented concurrent to my recent compositions and the advancement SynkroTakt technology. Although very rare on the whole due to the young age of the cellular phone technology (and even portable consumer sound-playing devices in general), there are a handful of prominent audience-involved performances involving technology for immersive sound that have been attempted with varying degrees of success, most of which are very recent. Because of the troubles in testing such pieces prior to performance (namely, in having hundreds of smartphones readily available), many of these unorthodox performances have been billed or advertised as "public experiments," or with other similar phrasing.

A notable early example of similar work that is technologically different than the rest of the smartphone-driven examples is a group of tests known as the "Parking Lot Experiments" and later, the "Boom Box Experiments" carried out by the experimental rock band known as The Flaming Lips.[6] In his adolescence, Wayne Coyne, the frontman of the band, had an experience in a parking lot before a concert in which he noticed that, while everyone had their car radios on

[6] "Flaming Lips Parking Lot Experiments," The Flaming Lips Parking Lot Experiments, accessed May 2018, http://janecek.com/parkinglot.html.

and their windows down, the radios were all playing the same songs at the same times. Inspired by this, Coyne spent several months making a multi-channel sound composition in the style of *musique concrète* to be performed by gathering a large group of cars equipped with tape players, and simultaneously playing over 300 unique cassette tapes through the car stereos.[7] In the spring of 1996, the band organized the first experimental performance of the work, handing out cassette decks to family, friends, and as many others as they were able to recruit in a mall parking garage in Oklahoma City.[8] Joe Janecek's website documenting the Parking Lot Experiments offers a recount of the coordination this experiment required:

> At the events, Wayne directs the cars into position, wearing his now-ubiquitous yellow rain slicker with a ratty old patch on the back bearing his name, barking orders through his super bullhorn. Each car is given a "test" tape. If all goes well, and all tapes are started simultaneously, the garage should hear each tape count off its number. If done correctly, the numbers should be in order. Almost every time, however, someone messes up and the count is off. After a second test, which works better as folks get the hang of it, the test tapes are then exchanged for the real thing. Finally, Wayne barks out one more instruction "mingle amongst the cars after your tape has started," and gives the countdown. It's do or be damned time. Once the decks start there's no turning back.[9]

I presume that counting down to have everyone attempt to press play at the same time in an attempt at synchronization was perilous and fraught with human error and tape machine inconsistencies, but it was likely the best they could do in the mid-nineties as an avant-garde rock band with presumably very little to no funding. Nevertheless, it would seem that they were able to get the timing good enough to cause them to pursue this concept further.

The Flaming Lips held two more similar events in Oklahoma City before taking this work to the Austin, Texas music festival, South by Southwest, in 1997.[10] There, it was estimated that

[7] Ibid.
[8] Ibid.
[9] Ibid.
[10] Ibid.

as many as 2,000 people attended their performance and it was recalled by the Austin American-Statesman, the major daily newspaper for Texas' capital city, as "the event" of that year's festival.[11] After this, Wayne Coyne and The Flaming Lips took this concept and tried to have fans at home recreate such an experience. They made an album called *Zaireeka*, which was a 4-CD set; interested listeners would gather four CD-playing sound systems and play each of the four CDs simultaneously, essentially creating an 8-channel surround sound experience in their home.[12] For the tour of this album, however, they returned to a concept that was pioneered in the "Parking Lot Experiments." Nicknamed the "Boom Box Experiments," these concerts were held in traditional indoor rock-venues, and thus boom boxes were used instead of car stereo sound systems, these experimental concerts put musical material from the individual tracks of *Zaireeka* on cassettes and had Coyne and The Flaming Lips' multi-instrumentalist Steven Drozd working in conducting roles, directed choirs of listeners with boom boxes to adjust the volume during the performance.[13] The Flaming Lips are no strangers to experimentation and have continued to push boundaries and try new angles at music creation and performance, but this would be their last experiment of this type.

Well into the era of the smartphone, Sébastien Piquemal of Aalto University, along with Tim Shaw and John Bowers of Newcastle University, created a new electronic composition that uses audience members' smartphones called *Fields* in 2014.[14] Performances of *Fields* have been powered by a web server application built by Sébastien Piquemal called Rhizome, which serves

[11] Ibid.
[12] Ibid.
[13] James Sullivan, "Lips' `Experiment' Smacks of Novelty / Band Headlines Sixth Noise Pop Festival," SFGate, February 13, 2012, accessed June 2018, https://www.sfgate.com/entertainment/article/Lips-Experiment-Smacks-of-Novelty-Band-3310553.php.
[14] Tim Shaw, Sébastien Piquemal, and John Bowers, proceedings of International Conference on New Interfaces for Musical Expression, Baton Rouge, LA, USA, accessed June 2018, https://nime2015.lsu.edu/proceedings/196/0196-paper.pdf.

as the link between the audience's devices and the music-making laptops of the performers.[15] In a performance of *Fields*, audience members can, using their device, join a Wi-Fi network at any time, then enter a web address to be routed to a specific page set up by the performers.[16] On screen, a map of the performance space appears and the user is prompted to touch the area on the map in which they are located, approximating their position in the performance space so that specific sound may be transmitted to their device to create a sense of spatialization.[17] With a properly set up system and a sufficient number of connected devices the performance situation can be described as "an omni directional, multi-locational sonic output, with each connection individually contributing to the overall composition… the connected devices create a spread of sound across the environment, with the sound diffusion being directly informed by each audience member's location."[18] Additionally, the artists state that most performances have supplemented the mass array of many phones' tiny speakers with a regular sound system, somewhat for spatial interplay between primary speakers and audience speakers, but also to provide low-frequency content which is not usually possible with a typical device that an average audience member may bring to a performance.[19] Recently, the authors have changed the name of the piece from *Fields* to *Murmurate*, but it has sustained numerous performances across the Europe and one in the United States, at the 2015 International Conference on New Interfaces for Musical Expression, in Baton Rouge, Louisiana.[20]

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[15] "Rhizome, Interactive Performances and Network Topologies," Funktion.fm, August 25, 2015, accessed June 2018, http://funktion.fm/news/network-topologies.
[16] Shaw.
[17] Ibid.
[18] Ibid.
[19] Ibid.
[20] "Murmurate," Funktion.fm, accessed June 2018, http://funktion.fm/projects/murmurate.

A second work by Sébastien Piquemal, joined by collaborator Miki Brunou, *New Weave*, creates a performance environment in which small clips of sound are captured from each audience member's device and the performers then improvise with those clips.[21] This creates a two-way relationship between the performer and the audience that the composer describes as "a fragile equilibrium, held together with glitchy rhythms and deep pulsating pads."[22] While *New Weave* does use Rhizome to connect the performers' devices to the audience's as *Fields* did, it is unclear whether or not sound emanates from audience member's smartphones. In a short video with some footage of a *New Weave* performance, it would seem that the sound is coming from normal concert speakers and not the audience's smartphones, with perhaps the recording capabilities of the audience devices were used rather than their sound playback.[23] Beyond these two works, there is some evidence that Rhizome has been successfully implemented for performances of other musical works, including a collaboration with Stratos Bichakis, Jonas Hummel, Sébastien Piquemal, and Thomash Ghzegovsky titled "The Projectionist Orchestra"; an untitled piece for sound and visuals by artist Kun Jin; and an untitled performance by Léon McCarthy.[24] However, like *New Weave*, it does not appear that these works use the technology to diffuse sound through the audience's phones. Instead, they seem to be using the technology primarily to send data to a main computer directly involved in sound or visual manipulation that is output in a more traditional manner.

Other precedents for similar work include a project by electronic German house duo Booka Shade, and a trio of more classically-oriented works by composers Eric Whitacre, David

[21] "New Weave," Funktion.fm, accessed June 2018, http://funktion.fm/projects/newweave.
[22] Ibid.
[23] Ibid.
[24] Sébastien Piquemal, "Gallery," GitHub, accessed June 2018, https://github.com/sebpiq/rhizome/wiki/Gallery.

Baker, and Ng Chor Guan. These four precedents all have a commonality in their method of synchronization: audience members trigger the sound playback themselves upon seeing simple visual cues. The project by Booka Shade was to take their 2005 breakthrough hit *Body Language* and several other songs, and recreate them for this new audience-involved genre, technologically assisted by the company Vodaphone as part of its “Firsts Program.”[25] In a 2014 concert in Berlin, Booka Shade performed their new arrangements in a 45-minute concert, instructing fans to hold their phones into the air when prompted at various points throughout the performance.[26] After the concert-goers downloaded an app prior to performance, Diane Tamulavage, describes that they “were instructed by large screens around the venue when to hold up their devices and hit ‘Go,’ transforming their phones into ‘synchronized projectors of sound and light that worked in tandem with the music being played from the stage’.”[27]

After initial testing, however, Booka Shade appeared to be concerned about the low sound output of the phones, even as a large group. Their concern was justified of course, as the sound levels of any typical house sound system for a music concert can be overwhelming and enough to drown out yelling at face-to-face proximity. Late in the development, of the project it was decided that a small device would be created and given out prior to the concert that attaches to the phones, essentially amplifying the sound in order to compete against traditional sound system forces.[28] It would seem that, with Booka Shade’s project, some compromise was struck in order to compensate for one of the major downsides of composition for this performance

[25] "Booka Shade Talk," The Ransom Note, accessed June 2018, https://www.theransomnote.com/music/interviews/booka-shade-talk-2/.
[26] Ibid.
[27] Diane Tamulavage, "Get Your Phones Out - Booka Shade's Interactive Fan Experience," Your EDM, May 16, 2014, accessed June 2018, https://www.youredm.com/2014/05/15/get-phones-booka-shades-interactive-fan-experience/.
[28] “Booka Shade Talk”.

medium, the volume level of smartphones. Between creating a new arrangement of the piece with more quiet moments for the phones to cast sound, and crafting a device to amplify the phone's output, they were able to have enough moments in which normal amplitude levels of the house music concert can be delivered and yet, the audience could still be meaningfully involved with sound diffusing from their devices at adequate levels.

A series of experimental pieces by Ng Chor Guan, the artistic director at Toccata Studios, uses several large lights of different color, directed in a way to change the overall hue of the performance space, to inform the audience members of which pre-determined tracks to play on their built-in sound file players.[29] The lights not only provide and transform the visual ambience of the concert space, but serve as a sort of conductor for the audience's participation.[30] Indiana University professor of music, David Baker, also uses lights to cue the audience to play the ringtone of their cell phone, whatever it may be, for his 2006 work, *Concertino for Cell Phones and Orchestra*. In a review of Baker's piece, Daniel J. Wakin of *The New York Times* describes how the cueing device and the cueing assignment was "similar to a traffic light signaled the audience members to activate their rings — red for the balcony, green for the orchestra seats," to create large antiphonal choirs.[31] However, a conflicting review by Cynthia Martens of *Time Magazine* states that "Green light means turn your phone on and/or play your ringtone; red means let the orchestra take charge."[32] It was unclear whether or they happened to review the same performance, or different performances with different instructions. No matter the exactness

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[29] "Mobile Phone Orchestra – Toccata Studio – The Creative Incubator," Toccata Studio The Creative Incubator, accessed June 2018, https://www.toccatastudio.com/productions/mobile-phone-orchestra/.
[30] Ibid.
[31] Daniel J. Wakin, "Horns Up. Bows Ready. Cell Phones On.," *The New York Times*, October 3, 2006, accessed June 2018, https://www.nytimes.com/2006/10/03/arts/music/03cell.html.
[32] Cynthia Martens, "A Symphony for Cell Phones," *Time Magazine*, September 28, 2006, , accessed June 2018, http://content.time.com/time/arts/article/0,8599,1540442,00.html.

of the situation regarding what musical forces play in which moments, Baker's work, alongside Guan's work, shows that using lights can be a natural and direct way to trigger the audience's involvement.

The approach that Eric Whitacre employed for his May 2015 premiere of *Deep Field*, inspired by pictures of the far corners of the universe as captured by the Hubble Space Telescope, was somewhat similar. However, rather than lights, Whitacre employed a much more traditional conductor cue for the audience. Towards the 18-minute mark of a 23-minute piece, the conductor turns toward the audience and gives a cue – somewhat a traditional-looking downbeat – for the audience to push a start or play button in an downloadable app on their device.[33] As the atmospheric sounds begin emerging from the crowd of phones, vocal choirs placed throughout the audience close out the work alongside the audio tracks.[34]

While these projects by Booka Shade, Ng Chor Guan, David Baker, and Eric Whitacre have received substantial funding and publicity, the approach of having the audience trigger the playback of sound from their device is extremely simple. In practice, however, it is known that asking a group of people, especially those untrained in the criticality of musical timing, to all do a particular thing at a very precise moment will entail varying degrees of accuracy in the timing of that action. Timing problems can arise due in part to operator error, such as not triggering sound at exactly the right moment because a person pushed the button too late or too early, but perhaps the more pertinent source of timing problems can be found within the devices themselves. Surprisingly, many devices have varying degrees of latency (sometimes up to a

[33] Deep Field - Eric Whitacre, August 19, 2015, accessed June 2018, https://www.youtube.com/watch?v=FFiZVIoj5j.
[34] Ibid.

second, as I have noticed in my own personal observations and early experimentations with these ideas) between a person triggering playback of a sound and that sound actually starting,

Naturally though, this unpredictability may be taken into consideration ahead of time by composers or sound designers, and used to their advantage. While it is unclear and sufficient evidence or documentation could not be produced concerning what sort of musical material was coming out of the phones for Booka Shade's project, there is ample information regarding the other three precedents' approaches to musical content for phones. In the case of David Baker's *Concertino for Cell Phones and Orchestra*, cacophony and chaos were expected by the composer, as he asks the audience to play whatever their ringtone is at particular moments, which will predictably be a mix of off-timed stock cellphone ringtones with a dashing of popular songs converted to ringtones.[35] In both Ng Chor Guan's work and Eric Whitacre's work, however, a more ambient approach is used. While traditionally conducted or timed musical elements come from the stage or elsewhere, the sound coming from the smartphones in the latter two works has a sense of "beatlessness" and is void of any strong rhythmic identifiers or cohesive pulsation. This ambient and aleatoric approach allows the sound coming from the conglomeration of the crowd to appear unified as a slowly developing mass of sound, regardless of whether there is operator error or device latency in the triggering or playback of audio.

Most recently, two ventures that are being developed at the same time as my work with SynkroTakt are "Close Call" by Arthur Wagenaar and a project titled "The Smartphone Orchestra." With "Close Call," Arthur Wagenaar, a composer and music technologist with a theatre background, has created an evening-length piece that draws in themes of technology, social media, uniformity and individuality, interaction, and makes the audience ask the question:

[35] Wakin.

"Do you play your phone - or does your phone play you?"[36] The work is scored for a ten-piece big band with three drummers and audience participation via their cellphones, with a degree of theatricality required of the musicians.[37] In a video call I had with Wagenaar, he described that he and a team designed and built a stand-alone app for the audience to download to their iOS or Android devices.[38] The app itself has three main modes of operation or "instruments" that all work with a circular interface: one is a rhythmic instrument, one is a melodic instrument, and one is a recorder that plays back sound recorded by the user.[39]

I spoke with Arthur just shortly after the initial experimental performance of the work, where the actual concert was preceded by a workshop session in which the audience was trained in using the app. Wagenaar thought that it would be a good idea to make sure, at least for this initial performance, that the audience would be able to understand the app and how their "instruments" worked.[40] In regards to "Close Call," the work the app was built for, Wagenaar described the overall arch of the piece as being "very diverse in sound initially, but becoming more the same as the work continues;" in addition, the audience has more control over their digital instruments at the beginning of the work, but their control narrows towards the end - an allusion in Wagenaar's mind to the privacy and rights of content posted and stored on social media.[41] When asked about his approach to orchestration for the work, he responded that there was a "need to keep things simple."[42] Given that a big band and a large crowd of phones would need to somehow work together, Wagenaar's solution was to have a call-and-response

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[36] "Close Call," Culturele Zondagen, accessed June 2018, http://www.culturelezondagen.nl/zondag/2017/utrecht-centraal/programma/item-4222.
[37] Ibid.
[38] Arthur Wagenaar, "Video Call with Arthur Wagenaar," online interview by author, June 2017.
[39] Ibid.
[40] Ibid.
[41] Ibid.
[42] Ibid.

relationship present throughout much of the performance.[43] Also playing into the dichotomy and the extramusical motivations of the piece, he designed the work to have large blocks of chaotic sound coming from a seemingly disorganized and less restricted audience while tightly coordinated and more simplistic music was played by the live ensemble.[44]

"The Smartphone Orchestra" has received some press after several "experimental" concerts and a "premiere" performance on August 21st, 2016. While reports about the size of the audience have varied widely, from as many as several hundred to 5,000 people, the premiere at the Dutch Lowlands Festival has been called a success, with the main role for each audience member with a smartphone being to come together to form a single large and immersive piece of music.[45] The team for this project consists of Steye Hallema as the creative lead and a composer, Marieke Nooren as a producer, Eric Magnee as a composer and sound designer, Adrien Jeanjean as a creative technologist and co-founder, and Hidde de Jong as a creative technologist.[46]

The project's press release states that the specially composed work is "a musical piece with every smartphone making its own unique contribution, thanks to sophisticated technology and an entirely new method of composition."[47] Elsewhere in the press release they speak of their new method of composition as being inspired by minimalism, "in which various patterns form a bigger whole when put together."[48] Timbrally and gesturally, they note that ringtones and notification beeps make up the primary content of the music.[49] To power and make possible this

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[43] Ibid.
[44] Ibid.
[45] "The Smartphone Orchestra," Fonds21, accessed June 2018, https://www.fonds21.nl/nieuws/160/the-smartphone-orchestra.
[46] WildVreemd, "The Smartphone Orchestra Celebrates World Premiere at Dutch Lowlands Festival," news release, The Smartphone Orchestra, accessed June 2018, https://smartphoneorchestra.com/presskit/smartphoneorchestra_pressrelease_21aug_EN.pdf.
[47] Ibid.
[48] Ibid.
[49] Ibid.

piece, the team relied on what they called "TimeSync" technology created by the production studio Ambassadors.[50] On the Ambassador website, they describe TimeSync as "a web technology that allows devices and web browsers to accurately sync it's time to a server with millisecond accuracy, regardless of the type of internet connection.[51] Once a sync is established, instructions can be broadcasted from one device to the other allowing them to act like one synchronised network of devices, or in this case: one large orchestra."[52] The web page goes on to claim that the Ambassadors lab has "perfected the service and stress tested it to a whopping 2000 devices."[53]

In a video call with both Eric Magnee and Hidde de Jong, I was able to ask them for more background on their project, musical pieces, and how their technology works. Both Magnee and Jong agreed that they consider "The Smartphone Orchestra" to be a project with five people all playing equally important roles, and that all five contributors put the utmost importance on "telling the story" of each piece. This main goal is supported by three pillars: the composition, the technology, and "the arena" as they put it, meaning, the interaction of working with the audience.[54] Magnee stated that the music they create "must have an impact on the audience," and that with the experience, "being present and being part of something bigger than yourself" was what they sought for the audience to feel.[55] The Smartphone Orchestra has created eight pieces so far, and with each piece, they have tried to advance the technology or try a new compositional approach. One of their more recent works, referred to as "Remembrance of the Dead," named for

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[50] Ibid.
[51] "Lowlands | The Smartphone Orchestra," Ambassadors, accessed June 2018, http://ambassadors.studio/portfolio/lowlands-smartphone-orchestra/.
[52] Ibid.
[53] Ibid.
[54] Eric Magnee and Hidde De Jong, "Video Call with Eric Magnee and Hidde De Jong," online interview by author, June 2017.
[55] Ibid.

the May 4th Netherlands holiday commemorating deaths from wars, incorporated recordings of voices of people who had passed away alongside more traditional musical elements for great "emotional impact."[56]

Their most recent work, simply referred to as "The Lowlands piece" since it was premiered at the Dutch Lowlands Festival in the summer of 2016, was their biggest undertaking thus far, forming what Ransom Note digital magazine called a "staggeringly large orchestra" with the audience's devices.[57] The magazine describes the artistic intent of the work thusly: "Rather than staring blankly into their illuminated screens at festivals and club nights and rarely taking part, it attempted a cultural riposte to the criticism so frequently uttered against smartphone use today. Loosely inspired by minimal music, the ringtones and notification beeps were used to structure the composition…"[58] In the video call, the two collaborators confirmed that they wanted to "take each audience member away from their device by using their device," and wanted to "make them aware of their surroundings."[59]

Hidde de Jong, the main technologist and programmer for The Smartphone Orchestra project, was able to share a few details about how their technology works. Essentially, using javascript environments, they turn each person's phone into a MIDI player, and they send very small and low-quality samples to the phones that are downloaded prior to the performance.[60] With the samples in place on each phone, MIDI information is streamed to each device and synchronized to a master clock, thus, the phone is not playing streamed audio, but instead being

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[56] Ibid.
[57] "The Smartphone Orchestra Has World Premiere At Lowlands Festival," The Ransom Note, accessed June 2018, https://www.theransomnote.com/music/technology/the-smartphone-orchestra-has-world-premiere-at-lowlands-festival/.
[58] Ibid.
[59] Eric Magnee and Hidde De Jong interview.
[60] Ibid.

streamed MIDI and playing sounds created right on the phone as instructed by the MIDI.[61] They do employ a variety of different musical threads, so that audience members may get to hear different music from their device versus their neighbors; however, they have not attempted to control how the audio is distributed for spatialized sound performances.[62] For their projects, what MIDI information is streamed to what devices is essentially random, meaning that a single MIDI stream may appear in different locations in the audience from one performance to the next.

In my survey of similar works and projects for synchronized sound diffusion across audience devices, it can be seen that many of them offered great promise, but fell short in at least one area if not more for my desired goals and purposes. In thinking about the use of the technology for my own projects, several of the most promising technologies were either not freely available for others outside the project to use, or proved to be too difficult to setup, even for more technologically savvy individuals like myself and the others on my team. Of the ones that were available, their approach to synchronization was not precise enough for use in my envisioned works. This is what ultimately pushed me to recruit Richard and Nick Saney to join me in creating SynkroTakt.

[61] Ibid.
[62] Ibid.

CHAPTER 2

SynkroTakt and Similar Technologies

Having become interested in performances with audiences using their cellphones for participation and sound diffusion, I began looking for technical resources, audio transmission environments, or pre-existing applications that would allow me to experiment with such musical performance ideas. Despite some of the public attention and success that a few of the aforementioned pieces have received, none of them were suitable for my purposes for one reason or another. For some, the technology did not allow for a sufficiently precise synchronization or it was custom-made and not sought to be shared or made available to paying consumers. For others, it was made freely accessible but with no promises or guarantees and working with it was so troublesome to set up and execute that my own attempts left me empty-handed and frustrated.

Between these several conditions, I desired and needed a technology that, beyond the fundamental requirement of sound diffusion throughout an audience via smartphones, could be set up, customized, and utilized very easily by anyone regardless of their computing skills. The technology also needed to be (1) flexible for various types of wireless devices and situations, (2) synchronize sound playback with very low latency, and (3) be made for public use once sufficient progress was made and stability in operation was achieved. Essentially, the SynkroTakt technology was born because, at the root of the issue, nothing was readily available or easy for me to use for my own compositional experimentation and desires. We have decided to continue development of it with the secondary purpose of making it readily available and easy to use for others.

My own initial research began in the summer of 2015 and stretched into the fall months. After finding that the technology that I wanted either did not exist or was not readily available and usable, and upon realizing that the level of programming skills required to create such an application was far beyond my own rudimentary knowledge base, I sought the help of several like-minded collaborators. Fellow musicians, technologists, and students at the University of Georgia, Richard Saney and Jake Reeves saw the project as interesting and worthy, and they joined in the research. Several months later, Nicholas Saney, brother of Richard Saney and University of Georgia alum, joined the project, mainly for his high-level expertise in programming, but his musical background was a welcomed bonus. The name for this project, SynkroTakt, was soon decided upon, being a portmanteau of the word “synchronize” and the word “takt,” which is German for “time” or “pulse” and clearly relates to the musical term “tactus” which means “tempo” in the study of conducting (as well as tactus being a general music theory term for the fastest tappable pulse).[63] Contemporaneously to our founding and initial research, we applied for and received funding from Ideas for Creative Exploration (ICE) at the University of Georgia for the 2015-2016 academic year. The funding served us well since we ended up needing several custom-set Wi-Fi routers for performances using our first incarnation of the software, as described later in this chapter.

In the fall of 2015, we began the project in earnest when I brought my ideas about musical performances involving audience phones to the rest of the group. We then discussed some basic aspects and desired functionality of such a technology and software in addition to assessing some fundamental obstacles inherent in such a pursuit. The basic aspects have already

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[63] "Takt," *Merriam-Webster.com*, accessed September, 2018, https://www.merriam-webster.com/dictionary/takt.

been mentioned: different audio tracks playing through different phones, the synchronization of those tracks to a universal timeline, and widespread accessibility to the software or system in regard to the connecting type of device the user or audience member may have. Other functionality discussed included the ability to start and stop audio playing from any point in a track or set of tracks, the spatialization of sound via many different tracks being sounded in a performance space, the option to have the audience choose which tracks they want to hear or to choose the tracks for them, and the ability to have the tracks distributed evenly throughout the audience.

The basic aspects of the technology were all solved early on in the development, while the additional features were developed at different points throughout the advancement of the project. During our initial discussions and planning, we set several goals with target timeframes in mind as a way of pushing ourselves on this project. Those goals were documented in the grant application to UGA's Ideas for Creative Exploration, submitted in October of 2015:

> Phase 1: In December 2015, we hope to implement an early and rudimentary version of the app at a concert to help assist the performers in the execution of a piece with critical timing. Phase 2: Sometime towards the end of the Spring 2016 semester, we would like to have a piece premiered in the Dancz Center for New Music with the audience members able to download the app, utilizing the speakers on each device to create an immersive piece of sound art, perhaps with a live instrumental element such as a soloist or small chamber ensemble. Phase 3: Perhaps by the beginning of the Fall 2016 semester or some time shortly thereafter, a substantial concert work on a grander scale than the previous two, for wind ensemble and electronics will be finished. The piece will be around 13 to 20 minutes and the electronic element will all come from the audience members' smartphones.[64]

We were able to achieve these goals roughly in the manner in which they are described, and close to the timeline we set. Achieving the three phases described above coincide with the

[64] Cody Brookshire, *Ideas for Creative Exploration Mini-Grant Application*, October 2015, Grant application, The University of Georgia, Athens, Georgia.

composition, testing, and performance of several original works, to be described and detailed in Chapter 3 of this document.

With the groundwork for the project laid and goals set, we started thinking about how the technology would actually work and went about designing it. Perhaps the most critical decision about the technology we made was the first one: whether to make it as a stand-alone app, or as a web app. The second-most critical decision, and one that is somewhat dependent on the former, was how the audio would be delivered to the devices: whether it was to be built into an app, be downloaded on a performance-by-performance basis just prior to a concert, or be streamed over a network connection.

We initially thought that creating a stand-alone app, one to be downloaded in digital app stores right on the devices themselves, would be the route that we would take. The main benefit of this approach is undoubtedly the greater flexibility in programming and operability, as one could program the appearance and functionality, without being limited to the fewer possibilities that are capable on a webpage. However, we ultimately turned away from the stand-alone app approach and focused on the web app approach due to matters of efficiency. Had we gone the stand-alone app route, we would have had to create two operationally identical apps for the separate phone markets: Apple devices which run on the iOS operating system, and numerous different devices (by Samsung, LG, HTC, and Motorola) that run on the Android operating system, not to mention a third, small, but not insignificant market of phones made by Microsoft running on a Windows Mobile operating system. There are, of course, many companies, both big and small, that make apps for multiple platforms that look, feel, and operate identically, so such a task would not be insurmountable. However, trying to create, test, and unify the project of separate but identical apps would take a significant amount of time and complicate our pursuits.

Conversely, going the route of a simple functioning web app environment allowed for much more widespread usage. The protocols and possible coding options for web pages are universally accepted across a wide variety of web browsing programs, both on mobile devices like phones and tablets, and also on laptops and desktop computers. Additionally, the web app approach offered widespread accessibility both now and in the future, as operating systems are much more likely to change (requiring stand-alone apps to update as well or risk malfunction or incompatibility) while web page and web app coding and protocol have traditionally remained relatively stable and are very slowly-changing. The web app approach is also usable for any new operating systems that might come along, since we would not have to create a new app for it, knowing that any manufacturer or programming team would need to have basic web functionality built into their device (lest they be laughed out of the marketplace by consumers and competitors alike).

With the approach to the system as a web app decided on, the second decision on how the audio was to be delivered was made slightly easier. Since there would be no linked app designed and made by our team on the phones themselves to download the audio to, that method was ruled out. However, our group was still split on whether the method of downloading the whole track and then using an app native to the phone to synchronize the playing of it would be ideal, or if streaming the audio and playing on the web would be better. After research and debate, it appeared that the former option presented several grave challenges. Firstly, there did not seem to be a clear way to control a device's native music player from an outside program in order to trigger and synchronize playback with a group of other devices, many of which would likely be of different types. While such a task is not impossible, mobile operating system developers like Apple and Android have their apps tightly secured and "tamper-proof," so that attempting to link into a native app and trigger it from an outside source would likely have taken far too long to "hack," and would have been fraught with workarounds and loopholes that would likely get "fixed" by the app's developers in later implementations and updates. Secondly, there was the issue of downloading the audio and storing it on the device. While questions loomed about how the track would be downloaded (via a music store like Apple's "iTunes" or by way of a traditional website), the largest variable in this option was the storage space on the receiving devices. If a user is close to capacity on their device, and a particularly long track or set of tracks needs to be downloaded for a performance, they might not be able to store the entire track, much less a large group of them. With both this uncertainty, and the difficult task of trying to link to, control, and synchronize a device's native sound playing app, this route was turned down in favor of the streaming audio option.

Just as making the SynkroTakt system a web app rather than a program app opened up a lot of accessibility in terms of how universal a web app can be, choosing to stream audio directly from a website reduced the demands on what we would be asking of users only two simplistic requirements: have a device that can (1) play sound and (2) connect to the internet via a web browser. It would be difficult to ask any less of potential users, given the pursuits of our project, and indeed, making it so easy for users was one of our initial objectives. However, the danger of using a streaming system is that it is possible that during a performance a user's internet connection may intermittently drop and sound may be lost for some (usually) brief period of time.

While we were able to keep a stream of audio synchronized (which was one of the most major objectives of the technology), we cannot guarantee that a user will maintain a steady and practically unbroken connection to the web for the duration of a piece. Such a guarantee is not in our capacity as the providers of the technology, but rather, it is in the hands of the internet service providers and any medium to which the user must connect, such as the Wi-Fi system of a venue. This danger would largely be mitigated if the technology had the user download the audio all at once and then play it, as they would only need to sustain an internet connection long enough to download the audio, synchronize the user's device clock with a master clock, and receive an initiation signal to begin playback. We proceeded developing the software with more pessimistic expectations about streaming the audio, but as we honed our technology and saw results, we found this concern to be largely unfounded. The ubiquity of good cell phone reception combined with the pervasive availability of Wi-Fi networks in concert halls and venues has resulted in few dropped connections even with mediocre data signals or Wi-Fi connections.

The debate and conclusion on how to approach those two aspects of the technology was most important to our research, design, and the implementation of everything thereafter. With these fundamental cornerstones laid, several changes were made and additional functionality was added to the software over the next year as we continued our work. Our initial version of the SynkroTakt software ran on an ordinary laptop connected to local network, one not connected to the internet, in which we set up our own Wi-Fi router for each audience member to connect to. Now, SynkroTakt software can be installed and hosted on servers in remote locations, and users connect to them via the internet. With this critical change, anyone in the world with a web-enabled device anywhere in the world that is connected to the internet can navigate to a conventional web address to connect to the system. Mainly, this change allows us to use much more powerful, efficient, and reliable computers than our own laptops to deliver the streaming audio. This change also saves a lot of cost too, as users implementing SynkroTakt for a performance no longer have to supply their own Wi-Fi routers for performances - they can either use a direct internet connection, or a venue's Wi-Fi connection. Concurrent with the move from the local network connection model to the internet connection model came a completely revamped and more user-friendly "Performance Manager," a user interface which allows the creation, editing, and saving of different "Performances" which are, in SynkroTakt terms, different banks of audio files which correspond to single specific performances of works or assistive needs. See the two images below for a comparison of the initial version of the software and the most recent version.

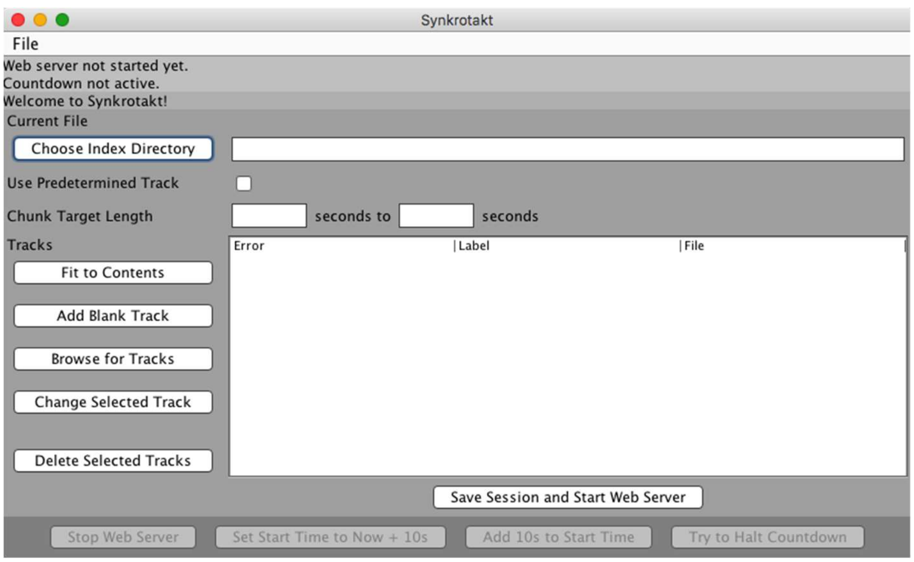

Figure 1. Screenshot of SynkroTakt software at startup state, version 1, running on an Apple computer.[65]

[65] Nicholas Saney, Richard Saney, and Cody Brookshire, SynkroTakt, computer software, version 1, SynkroTakt, accessed June 2018, www.SynkroTakt.com.

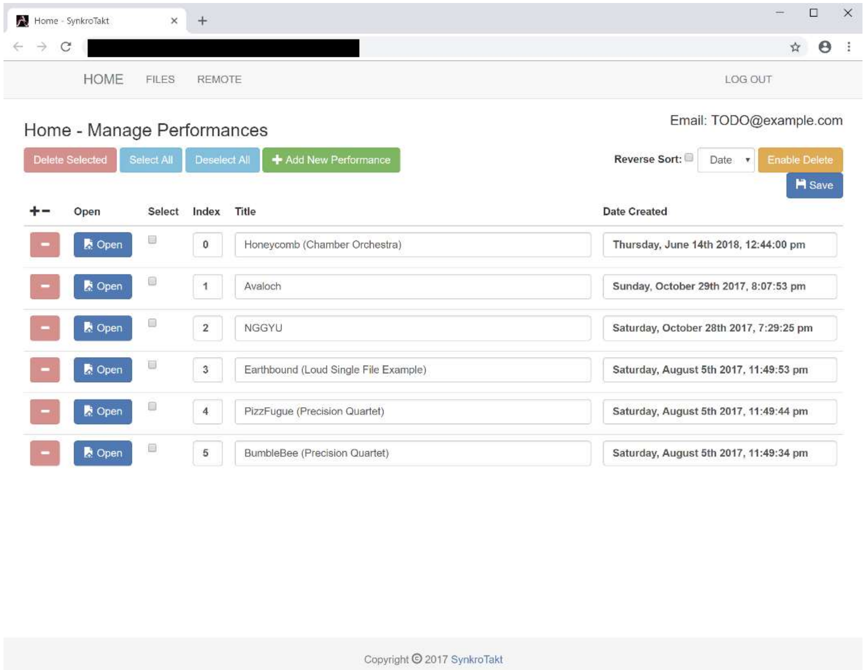

Figure 2. Screenshot of SynkroTakt software at login state, version 6 running on a website, accessed via Google Chrome web browser on a Windows PC.[66]

Other changes from the initial version include switching from the streaming of larger WAV files to smaller MP3 files. The move to streaming MP3 files and having each phone decode them increases network throughput and helps largely mitigate audio drop-outs due to inconsistent connection. Additionally, with the transmission of smaller pieces of data, the server can deliver more tracks to more clients in a more efficient fashion. Another feature that has been added is the ability for users coordinating a performance to program the assignment of specific tracks of audio to audience members' input of their location in the performance venue, which allows for the possibility of the spatialization of sound. Without this option previously, coordinators had two options: let the SynkroTakt server assign tracks to each client device (in a controlled and expected fashion, but with effectively random results), or let each audience

[66] Nicholas Saney, Richard Saney, and Cody Brookshire, SynkroTakt, computer software, version 6, SynkroTakt, accessed June 2018, www.SynkroTakt.com.

member freely choose which track they hear. With a performance setup for this third option, the audience member is still effectively choosing which track they hear, but the titles of the tracks are hidden and not available for the audience member to see; instead, they are presented with a pair of drop-down menu boxes to input their row and seat number, and a mapping of row and seat numbers to specific audio tracks determines which seats receive which audio tracks. The most recent feature added to the software has been the inclusion of user interface tools to change the start time of the playback of the audio. In rehearsal situations, the need to practice a section from a place other than the very beginning occurs frequently, so this addition solves a problem that we encountered during our rehearsals.

Technically speaking, the SynkroTakt software is a web application that calculates the latencies between client devices and a server application, and triggers playback on client devices on an individual basis based on each device's average latency.[67] Latency can be generally be described as the interval of time from the initiation of some action, and the observable consequence of that action within a system.[68] With SynkroTakt, the web application figures out the latency of communication back and forth from the client to the server to find the network latency for each connected device. It does this by the server polling the client 150 times to see how long it takes for the client to respond, then gathers that as a list of data, and excludes the highest and lowest intervals of times before finding the average interval of latency.[69] After finding all the network latencies for all connected devices, the application computes the differences in latencies and applies that difference in time when scheduling audio playback for

[67] Richard Saney, *SynkroTakt Application Technical Doc*, PDF, SynkroTakt, September 2017.
[68] "Latency," *Merriam-Webster.com*, accessed September, 2018, https://www.merriam-webster.com/dictionary/latency.
[69] *SynkroTakt Application Technical Doc.*

each client.[70] Essentially, the SynkroTakt application creates a "master timeline" in which it instructs different devices to start audio playback at specific points along the master timeline to offset their latency. The result of the application's calculations and staggered triggering of playback is an accurately synchronized set of audio tracks being played together, assuming the connected client devices maintain a relatively static and stable connection.

While SynkroTakt does calculate network latencies to adjust for time of delivery of audio from server to client, it does not calculate for audio hardware latencies. In all devices, there is some amount of latency from the action of instructing the device to perform a specific action and the device actually executing that action, and audio is not exempt.[71] For many devices, that interval of time is imperceptible from unassisted human observation, but for others that delay from the cause to the effect is easily perceptible. Our own initial testing seemed to indicate that most desktop or laptop computers as well as all devices made by Apple (which includes all iPhones, iPads, Mac laptops, Mac desktops, and all variants of each) have a very low audio hardware latency. It is so low, in fact, that it was below the psychoacoustic threshold for perceived simultaneities, which can vary from around 5 milliseconds for very short sounds, and up to 35 milliseconds for more intricate sounds.[72] However, other devices, such as Android mobile devices and some laptops exhibited audio hardware latency above this threshold.

To elaborate on this, in an experiment that was run early in the spring semester of 2016, many volunteers let us use their mobile devices so that we could gather data to confirm our suspicions about latencies in regard to various manufactures and products. By the end of the

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[70] Ibid.
[71] Evgueny Khartchenko, "Optimizing Computer Applications for Latency: Part 1: Configuring the Hardware," Intel Software, July 25, 2017, accessed September 2018, https://software.intel.com/en-us/articles/optimizing-computer-applications-for-latency-part-1-configuring-the-hardware.
[72] "Haas Effect," *Pro Audio Reference*, Audio Engineering Society, accessed August 2018, http://www.aes.org/par/h/#Haas_Effect.

experiment, we were able to confirm that all Apple devices synchronize to the server's master timeline and playback audio with such low audio hardware latency that differences in timing were impossible for us to detect with our own ears. Regarding non-Apple devices, we were able to confirm that they could synchronize to a master timeline with an offset that accounts for their network latency, but our experiment yielded a wide array of data on their audio hardware latencies. To our surprise and disappointment, we could not reproduce consistent audio hardware latencies of a specific device type from one distinct device to another, nor could we even get consistent latencies from the same exact device across different testing sessions. This inability for non-Apple devices to exhibit a consistent degree of latency from the triggering of audio to actually hearing that audio was prevalent across manufacturer, operating system, and model type. In some cases, the amount of playback delay between various non-Apple devices was well above the psychoacoustic threshold, sometimes as long as one or two seconds. Such durations of time may seem small at first thought, but in musical time, a sound being temporally-displaced by one or two seconds may completely obliterate the intended effect.

With timing being a critical element in music performance, the inability to truly synchronize the actual playback of all devices due to the audio hardware latency of only some devices obviously presented issues that could negatively impact music composed for a medium which involved sound being played back through phones. Unfortunately, the task of compensating or solving for a device's audio hardware latency was well beyond our resources, and perhaps even futile. We suspect that Apple devices have consistent audio hardware latencies due to the company's stringent control over their software being specifically made for their hardware, and also an ingrained company-wide philosophy for uniformity across all their devices. Meanwhile, for non-Apple devices, a wide variety of companies, models, and operating systems have different standards and approaches, and linking hardware to software is not always as straightforward as it might be if the same company made both the software and the hardware.

To compensate the audio hardware latency issue would have required testing and documentation of every non-Apple phone made by every manufacturer, and testing it on each operating system, then creating a database of audio hardware latencies that would need to be applied to a device's timing offset from the master timeline when it connected to the system. Such an undertaking would only be viable for an entity with the financial resources to acquire hundreds, if not thousands of devices. Of course, the undertaking might also be never-ending, as new non-Apple devices enter the market, and as operating systems are updated, in which case, the aforementioned latency database would need to be updated almost constantly. Even if a group was to take on such a challenge, it is possible that mobile device manufacturers and developers might aim to decrease such latencies, and maybe audio hardware latency in non-Apple devices would eventually be reduced to below the psychoacoustic threshold, thereby rendering the work on such a momentous task no longer of any value.

With no feasible way to make up for the audio hardware latency issue present in Android phones, Windows phones, and occasionally present in non-Apple laptops and desktops, the only way forward was to work with this discrepancy rather than try to fix it. The creatively-minded solution was to design music that was to be sent to devices exhibiting high audio hardware latency differently than music sent to low audio hardware latency devices, creating musical components for these devices that would function in a different way as compared to the rest of the musical components. Since non-Apple devices consistently display various amounts of audio hardware latency which produces playback of audio above the psychoacoustic threshold for simultaneities, then musical elements that do not require high precision in musical timing could be programmed for tracks to be sent to non-Apple devices, and it would not matter if those musical elements were heard on time, just a little late, or fairly late, relative to a specific location in a universal master timeline for a piece of music. On the other hand, musical elements that require high precision in timing could be rendered to tracks to be sent to Apple devices, since all Apple devices could be counted on to reliably play audio streamed to them in a synchronized fashion below that psychoacoustic threshold.

Creating a distinction between the types of music that could be sent to two different categories of devices that would still result in effective music, assuming a few conditions were met. Firstly, we needed to be able to recognize each device that connects for a performance and to deliver the appropriate audio to them. This condition is easy to meet, as we simply request that each user identify their device type via a user interface with buttons upon connecting to the server, and then the server will send the correct audio to them. It is assumed that the probability of a user not knowing what type of the device they have is likely to be extremely low. Additionally it only creates a musical issue if a non-Apple device user accidentally identifies their device as an Apple device, as it would cause them to play back audio without precise timing that is actually meant to be timed precisely; it would cause no musical issues if an Apple device user accidentally identifies their device as a non-Apple device, as it would cause them to play audio in a precisely timed fashion even though it is not necessary to do so. Given all this, the likelihood of any negative impact on a musical performance by incorrect device identification is quite low.

The second condition would be to have a balance of Apple and non-Apple devices in the audience, so that there would not be an imbalance between the music that has high precision timing elements and low precision timing elements. Prior to research and data gathering, our general assumption was that roughly half of the audience would have Apple devices, based on simple and general observation of how many people we know use what type of device. Research showed slightly different results that the split is roughly 60% Android and 40% Apple for United States markets.[73] However, we set our servers to collect data on device type at each performance when SynkroTakt is used, and almost all performances have actually showed a majority of Apple devices at events in which SynkroTakt has been employed. Regardless, as the size of any audience grows, the balance can be expected to be closer to even as the sample size grows, and thus is not of a concern. In smaller audiences however, it should be noted that there does exist a possibility that a significant imbalance between the two device types could happen due to a smaller sample size.

Another condition to be met would be a compositional one, as any piece composed for use with this technology would need to have a fair share of musical elements in it that would not require critical timing so that those musical elements could be played out of the non-Apple devices. If this condition were not met, one would either have to accept that some audio tracks that would otherwise be played in a highly precise manner now would be played out of time in an unpredictable way while other tracks (and even the same track coming out of another phone) would be happening at different times, or one would have to reject the involvement of any audience member without an Apple device, which would eliminate roughly half the audience from participating at any given performance. So, the compositional approach to work with this situation (having a device type that plays audio back at a slightly unpredictable offset from a master timeline) is to create musical content that can be performed in an aleatoric fashion with

[73] Mikey Campbell, "Apple Eats into Android, Samsung Marketshare in Q2, Study Says," *AppleInsider*, July 17, 2018, accessed August 2018, https://appleinsider.com/articles/18/07/17/apple-eats-into-android-samsung-marketshare-in-q2-study-says.

respect to timing. There are a number ways to create musical content that would work with this constraint, such as composing ambient and atmospheric pads, freely timed echoes that imitate music coming from another source, or dense granular textures. More possibilities for composition with this constraint will be discussed in the conclusion.

Even considering resources available in academic and experimental music circles, technologies that would allow for such immersive sound experiences as I was imagining were either not capable of synchronizing multiple different tracks, or were not readily available or functioning. The closest available technology that existed was called SpeakerBlast, which could stream and synchronize a single audio track among a crowd of wireless devices.[74] A few other similar applications exist, but despite our best efforts, we were unable to modify or hack these programs to synchronize different audio tracks. Regardless, the quality of the audio transmission and the synchronization itself with SpeakerBlast and similar technologies was fraught with glitches and inconsistencies. Otherwise, closely related software and technologies presented a variety of issues that made them unusable for the pursuits of our team and my compositional interests. In the following few paragraphs, I detail the pros and cons of a few different approaches to technologies similar to SynkroTakt, and their viability towards multi-track audio synchronization with audience devices for music performances.

First to note are the aforementioned approaches of Arthur Wagenaar with “Close Call” and “The Smartphone Orchestra” project. The approach for audience-phone involved performances with these projects has been to create proprietary software. While both projects deal with the synchronization of audio differently, neither have made their software available for use by other music creators in either a free or commercial manner, although the Smartphone

[74] "SpeakerBlast - Frequently Asked Questions," Speaker Blast, accessed August 2018, https://www.speakerblast.com/FAQ.html.

Orchestra project looks very promising in terms of other technologies that can synchronize multiple tracks wirelessly if they will ever release it for public use. Of other aforementioned projects, those of Booka Shade, Ng Chor Guan, David Baker, and Eric Whitacre all share a common thread in that they mainly rely on the audience to trigger or control the playback of sound in some manner. From my own experiences, I know that having a group of users try to coordinate the synchronization of audio without computer assistance is a futile task. While in the case of these composers, their music perhaps did not need to be precisely synchronized as they could have composed more ambient music like the approach Eric Whitacre took. For my pursuits, however, I would need precise synchronization and this approach was not viable.

In the case of SpeakerBlast, their website states that “SpeakerBlast turns multiple Internet devices into a huge stereo system via a web app; no download.”[75] On a Frequently Asked Questions page on the SpeakerBlast site, there is mention of the prospect of developing the ability to play multiple tracks, but this is not currently a possibility.[76] Airfoil, made by software company Rogue Amoeba, is a similar technology. Their website states that Airfoil can “send audio from your computer to outputs anywhere on your network,” continuing with, “hear your music through thousands of devices, like the Apple TV, AirPort Express, and other AirPlay devices, as well as Bluetooth speakers, iOS devices (iPhone, iPad, & iPod Touch) and even other Macs and PCs!”[77] However, no mention of multi-track playback is addressed. We tried to work with all these applications, but we were unable to alter their inner-workings to accommodate for multi-track synchronization. Additionally, even trying to get their normal mode of operation to

[75] Ibid.
[76] Ibid.
[77] "Airfoil - Any Audio, Everywhere," Rogue Amoeba | Airfoil: Wireless Audio around Your House, accessed August 2018, https://rogueamoeba.com/airfoil/.

work was rife with synchronization issues of the same track, and audio would frequently drop out of connection.

A promising software that was previously mentioned was Rhizome, built by Sébastien Piquemal. Of all the technologies other than SynkroTakt, Rhizome has the most potential. Rhizome allows users to connect at any point in a performance and, impressively, can offer interactive capabilities along with interoperability among audio software such as Max and Pure Data.[78] Also of note is that it can send different audio from one device to another depending on what location information the user inputs into the system, which would allow for spatialized audio effects.[79] While the upsides to Rhizome were that it appeared to check off all the parameters I was looking for in a technology, the downside was very discouraging: neither I nor anyone on my team could get the software to run. Despite reaching out to the small Rhizome community on the web for help, none of us could get a Rhizome server to launch successfully.

While it is clear that Piquemal and a few others were able to do something we could not in order to create networked musical performances, our inability to set up the server sowed seeds of discouragement. We became concerned that if I composed musical works that needed to use this, and others who are less-technically inclined would need to set up servers in order to execute the piece, they might not be able to do so. Even if we had been able to launch a Rhizome server successfully, three other problems loomed given our objectives. First, the Rhizome server application did not appear to be able to synchronize multiple different streams of audio (or at least they did not attempt to provide a way for delivery differentiation between the sort of music to send to various devices, as SynkroTakt does regarding Apple and non-Apple devices) which is one of the utmost requirements for the technology we were seeking. Secondly, the software does

[78] Rhizome, Interactive Performances and Network Topologies."
[79] Ibid.

not appear to be able to work over the internet, instead requiring a local server and wi-fi network. The third issue is of scalability, in that performances of over 250 connections were advised against by the creator of the technology.[80]

Blind Ear is another technology that caught my interest before we fully developed SynkroTakt. The 'About Us' page on the their website states that "Blind Ear is the brainchild of composers Jakub Ciupinski and Cristina Spinei.[81] Founded in 2009, Blind Ear presents concerts that combine new music with new technology. Our Blind Ear composers who are involved in every concert are Ryan Francis, Ray Lustig, Adam Schoenberg."[82] Also stating that "Blind Ear is about developing a new way of composing and performing music… We use a network of laptops to create compositions in real-time… For Blind Ear concerts we don't write new pieces, we write loops."[83] The basic operation of Blind Ear software is that a "real-time composer" sends notated music wirelessly that appears on the laptop screens of any number of musicians.[84] The Blind Ear technology is primarily focused on loops that alter or swap with other loops throughout a performance: "In Ableton Live you can place different electronic loops in slots on different tracks and trigger them whenever you want… A single loop will repeat until you switch to another loop on the same track... The problem with live musicians is that they are not machines (which is definitely not a bad thing!) and they need to see their music notated in order to play... We had to develop a new software."[85] The site indicates that performers can use click-tracks and the click-tracks can be made to be independent of each other, which also piqued my interest

[80] Ibid.
[81] Real-Time Composers Blindear, accessed August 2018, http://www.blindearmusic.com/Blind_Ear_Music/About.html.
[82] Ibid.
[83] Ibid.
[84] Ibid.
[85] Ibid.

given my desire for an easy tool that would allow for phase-centric compositions with a large number of players.[86]

While Blind Ear appeared to have the synchronization problem solved, it seems to be a tool primarily for performing musicians and ensembles to read semi-improvised sheet music rather than a tool to be used by audience members to stream synchronized sound. While I thought about the possibility of retrofitting their pre-existing software with the ability to broadly stream any audio rather than just stream click-tracks, I would never get the chance to try, as their software seems to be intended for use within their exclusive group, and not by outsiders. Regardless, if the Blind Ear technology could not be implemented on mobile devices, it would have been a moot point anyways for use with a typical audience. It might be unreasonable in some situations to ask each audience member to bring a laptop with them, whereas you can reliably predict a very high percentage of audience members will have a smartphone already on hand.

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[86] Ibid.

CHAPTER 3

SynkroTakt Development and Utilization in Original Works

The technologic concept behind SynkroTakt is a fairly simple and open-ended at its core; when put to use, this simplicity offers the potential for the technology to be employed in a variety of different circumstances. From performance situations where the electronic technology is at the forefront, to more balanced usages with other performing forces, to performance conditions in which the audience may not even know it is at play, SynkroTakt can be a versatile tool. This chapter highlights several different performance situations utilizing SynkroTakt through elaborating on a few compositions that I've written over the past several years. While writing these pieces that use SynkroTakt, the technology was continuously being developed, improved, and expanded, which is also recounted and illustrated here in this chapter.

SynkroTakt as an Assistive Tool in "Rainbow Gravity" and "Triple Helix"

A tangential interest of mine, and one that also helped drive the development of SynkroTakt, is polytemporal music. In the Summer of 2015, I tasked myself with a compositional experiment. I asked myself: "What is the easiest thing I can ask my performers to do that I can somehow shape into something with a high amount of entertainment for the audience?" I wanted to see if I could come up with a piece that amateurs could perform with a little coaching, but professional players could execute with high precision and shape into something more musical, and I was also interested in finding some sort of simple process that would spin out a wealth of material for the audience to experience. I quickly turned towards minimalism due to my first constraint, and then decided that some sort of phasing process would be at the heart of the composition.

After numerous experiments with polytemporal streams of MIDI notes of varying tempi via a Max 7 patch that I created, I settled on a group of 12 players with the instrumentation being semi-open: any pitched instrument but it must be 12 of the same instrument to achieve the uniform timbre throughout the ensemble. These 12 players would play very simple materials: a quarter-note and a rest in alternation of modulating octave and a half scales, with each performer playing at a slightly different tempo. Player 1 would play at 120 BPM, Player 2 would play at 119.85 BPM, Player 3 at 119.7 BPM, and so on until Player 12 at 118.35 BPM, with all players being separated by 0.15 BPM. From studying Steve Reich's early tape works, I had a very good idea of the sort of effect this would create, and I thought that I would add another aspect to the very slow gradual phase process by incorporating substantial tonal progression. Additionally, the thought of calling for the 12 players to encircle the audience (or alternatively, to spread out as wide as possible on stage if encircling the audience is not possible) to create swirling and rotating spatial effects as the different tempi pull apart from one another, would add a very compelling dimension. This piece came to be titled "Rainbow Gravity" after a theory about beams of white light being separated into their colorful constituents at the edges of black holes, which I found analogous to the aural effect of a stream of sound being pulled apart.[87]

With 12 players all playing in slightly different tempi, the use of click tracks was necessary, lest the performance of the work descend into chaos. From earlier experiments, I had

[87] Clara Moskowitz, "In a 'Rainbow' Universe, Time May Have No Beginning," *Scientific American*, December 9, 2013, accessed August 2018, https://www.scientificamerican.com/article/rainbow-gravity-universe-beginning/.

already found that attempting to have several people all simultaneously push play on a device with the click track stored was futile, especially on the scale of 12 players. The click tracks needed to be synchronized by a master source, and the first line of thinking to accomplish this was to load of the audio tracks into a DAW (Digital Audio Workstation) such as Pro Tools or Logic and route each click track to an individual output through an audio interface. The main issue with this approach is that most quality DAWs and audio interfaces that support that many outputs are somewhat cost prohibitive. Additionally, some of these are audio interfaces are not readily mobile and are intended to be rack-mounted. Finally, these technical requirements would greatly hinder repeat performances, as you would need the venue or someone participating in the performance to provide a computer with an appropriate DAW and audio interface, not to mention an abundance of cables, adapters, etc. With this in mind, I began dreaming of a way to utilize each performer's phone to play the audio, all synchronized to a master clock.

Very quickly, this coincided with my other motivations and interests, and the application of streaming click-tracks to performers became central to successful SynkroTakt performances. The primary benefits of using SynkroTakt as an assistive tool for performers in this manner are two-fold: cost and convenience. For my situations (and I imagine many others), the expenses should be minimal and the equipment readily available. SynkroTakt needs a web server to run, and ones that we use cost from around $1-2 a day. With a server set up and the click tracks uploaded, one would just need to ensure that the performers receiving the click tracks had Apple devices (to ensure that the audio playback will be synchronized) and headphones or earbuds. While the need to have an Apple device could be argued to be prohibitive in cost, especially if the performer is personally an Android user, I can imagine that fellow musicians or friends that had an Apple device would let the performer borrow a device for the duration of a performance and presumably also rehearsals. From a convenience standpoint, a SynkroTakt setup for click track usage is highly efficient and much less troublesome than setting up and using a DAW, audio interface, and yards of cables. As long as the performer's data signals or Wi-Fi connection are of at least medium-strength, getting the click track to the performer with their own equipment will not be a problem. Additionally, since cables from a central audio interface to performers are not used, space and distance are of no concern either.

Unfortunately, we were not able to accomplish Phase 1 of the SynkroTakt project (use a rudimentary version of the app at a concert to help assist the performers in the execution of a piece with critical timing) in the time we initially projected, which was December 2015. The software was not ready at that time, and a performance of "Rainbow Gravity" had to happen without SynkroTakt, but instead with the aforementioned complicated setup of a DAW and audio interface. At the beginning of the following April however, I was able to employ SynkroTakt for this purpose at Jacksonville State University in Alabama, where I was giving a composition lecture-recital. JSU's trumpet studio performed the work, and we only had about 40 minutes of rehearsal time in total. The trumpet performers were comfortable with getting their phones performance-ready, and using the webpage on their phones to select their appropriate track. They were spaced in a large and wide circle, encompassing the entire audience seating area. With all 12 players set up and connected correctly, the performance of the piece was without hiccups after only two very brief rehearsals with the music and technology.

Later on in 2016, the opportunity to use SynkroTakt as an assistive tool arose again. I was commissioned to compose a piece for Lineage Percussion Trio, and I settled on a marimba trio in which I explored other polytemporal techniques. The piece is titled "Triple Helix" and the concept for this piece has streams of ascending and descending music running at different and changing tempi steadily unfolding wider in tessitura and more gradual in phase, with the harmonic and melodic materials becoming less chromatic and more tonal as the work progresses. Eventually, an extremely tight phase is executed lasting a significant portion of the piece, and then the three percussionists finally play in the same tempo as the length of their motivic idea combined with the duration it took to make a complete phase at the measure, offsets the three streams of arpeggios perfectly, creating a triple helix.

I created the three click tracks for this work in Logic. In the music, marimba 2 stays consistent and quarter-note equals 144. Marimba 1 and 2 change tempi throughout the piece; marimba 1 begins at quarter-note equals 153 and works its way down to 144, while marimba 3 begins at 135 and works its way up to 144. Towards the end of the work, the click track fades out for the three players to have a less-restricted coda section. With the click tracks made, they were uploaded to the SynkroTakt server and were ready for streaming. The performers were able to intuitively navigate the user interface and initiate playback. The system was used both for rehearsal and performances, as well as for a recording session at the Dancz Center for New Music in Athens, GA.

Audience Device Setup and Connection with an Early Version of SynkroTakt, and the Initial Impressions via Performances of "We Could Live Forever Tonight" and "Rationalize"

Midway through the Spring 2016 semester, SynkroTakt was ready for some initial runs with an actual audience. At this time, the software was not yet capable of running and streaming on the internet, and instead, a local network had to be set up for performances using a strong Wi-Fi router purchased with funding through our grant. This also meant that the manner in which the audience connected their devices to the server was somewhat tedious, at least compared to later implementations of the technology. Firstly, it was required that they connect to this newly-created network, since SynkroTakt streaming was not yet possible over the internet. Secondly, they had to type in a cumbersome string of numbers into the web address bar of the browser in the format "xxx.xxx.xxx.xxx:yyyy", where x's represent the numbers of an IP address to the computer running the SynkroTakt software on the given network, and y's represent the port number for the SynkroTakt application on the given computer. Such an awkward setup process with an unmemorable address was not user-friendly enough for our liking, and the approach was improved in a later version of the software.

We also had another step which contributed to setup time – one that we still encourage for all SynkoTakt performances. We strongly recommend that each audience member turn off an "Auto-Lock" or "Sleep" type setting on their phone. Going by different names, depending on the developer of the phone's operating system, this setting controls the amount of time that it takes for the device to "fall asleep" after its last user input, or in other words, for the screen to go dark and touch-screen input to no longer register. While playing video from a smartphone is universally programed to keep the device "awake," playing audio is not. Of course, this is not a problem for on-board apps which can be programed to continue playing audio if the screen falls asleep, but the nature an audio file playing through webpage is not designed to keep the phone awake. When the phone falls asleep, the connection is broken and the audio playback soon halts. This is remedied by either the user periodically tapping the screen (which they often forget and it takes them out of experiencing the music), or by having them adjust this setting in their phone.

The first piece performed using SynkroTakt technology is titled "We Could Live Forever Tonight." This piece was inspired by and takes it title from a line of lyrics in one of my favorite songs: the Beach Boys tune “Don’t Talk (Put Your Head on My Shoulder)” from their album “Pet Sounds.”[88] From the program note:

> This piece draws from the gorgeous and bittersweet chord progression in the song, but durationally augments each voice of the original progression, recreated as if played by organs on derelict vinyl records. The mood goes in a very different direction with multitemporal manipulation, distortion, spectral blurring, and added field recordings. “We Could Live Forever Tonight” touches on themes of nostalgia, remembering and misremembering, connected webs of moments and memories, the desire to control the passing of time, and how music can make that desire not seem as futile as it truly is.[89]

While I had not started this electronic work with the thought of it being more than a two-channel, spatialized sound type of piece, it nevertheless presented itself as a good opportunity, both in construction and extra-musical concept, to be the first piece performed using SynkroTakt in a public setting. While composing the work, I saw a conceptual connection from the individuality (both in tempi and in timbre) of each voice in the chord progression, to the individuality of each audience member and their wholly unique experience that a spatialized performance of the piece would offer with individual and unique tracks coming from their phones. With all the tracks sounding together for all the audience to hear, I envisioned the shared experience would represent the “connected webs of moments and memories” that I had in mind as part of the program for the work. I planned this initial performance for a UGA Student Composers Association event midway through the semester.

The SynkroTakt version of “We Could Live Forever Tonight” is made up of eight-channels. Two channels are traditional “front-left” and “front-right” to be sounded from traditional loudspeakers provided by the venue. In order to make sure these tracks stayed synchronized to the audience tracks, they were also streamed through the SynkroTakt system.

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[88] Beach Boys, "Don't Talk (Put Your Head on My Shoulders)," recorded February 11, 1966, in *Pet Sounds*, Chuck Britz, 1966, CD.
[89] Cody Brookshire, *Program Note for "We Could Live Forever Tonight",* 2016, Program note.

We as concert personnel made sure that we would only have access to these tracks via a different type of connection to the server; thus, there was no possibility for them to accidentally end up coming out of an audience device. Of the other six channels, three are designated for low-latency devices (iOS) and three are designated for high-latency devices (Android). It is important to note that the channels or tracks that are intended for audience member's phones are duplicated across many devices for any given performance (unlike the tracks for the two front-left and front-right speakers), helping to bolster the volume and general presence of the music on these tracks – this is a strategy that all my works utilizing SynkroTakt for the audience have in common.

The two different audio files for the two loudspeakers carry music that consists primarily of the bassline for the chord progression, other low-frequency sounds, and full-spectrum field recording samples such as passing cars and church bells to put the music in a "space" in the programmatic sense. The loudspeakers were critical in order to reproduce the low frequencies and occasional loudness needed for a musical impact, as working with the speakers in the phones would afford no low-frequency reproduction whatsoever. The three tracks for iOS devices consist solely of the three upper voices of the chord progression, which undergoes extreme temporal manipulation and slowly changing timbral manipulation over the eight and half minutes of the piece. The three tracks for Android devices consist of, in the first half of each track: similar field recording samples as the loudspeaker, to further immerse the audience in the aforementioned "space" via the spatialization of those sounds; and in the second half: the hyper-speed versions of upper voice parts of the chord progression that is to sound concurrently in the iOS devices. Towards the end of the piece, the sound of all the tracks become more and more "smeared" by gradually saturating their repeating hyper-speed melodic lines in layer upon layer of reverb, until none of the attacks in any voice can be heard, essentially creating an undulating blanket of sound with gradually emerging and dissolving tones that, when combined altogether, form sonorous harmonies.

The performance of the work and the first live implementation of SynkroTakt went well, and from a technical standpoint, it was mostly successful – all the audio tracks were streamed from the server to the phones and they were generally synchronized (the iOS devices were very synchronized and less so with the Android devices, as expected and calculated for). From personal feedback given by friends and acquaintances in the audience, there were a few devices out of about 20 which did not play any sound, or the sound was distorted, but these bugs were sorted out as the development of the software continued. The performance was also successful in terms of considering it as a viable performance medium, with the general impression that the audience was engaged in contributing to the performance of the work and that the sense of being completely surrounded by many sources of sound was effective. However, while these two primary motivations for creating the technology and writing music for this new performance medium were showing promise for further exploration, "We Could Live Forever Tonight" as a piece in this new medium revealed two main problems compositionally.

Firstly were the issues of constant sound as a single instrument or voice. The nature of most of the audio tracks to be played out of audience members' phones, except for the first half of the Android tracks, are repeating cycles of sustaining notes that very slowly evolve in tempi and timbre. My line of thinking in the construction of the piece would be that each audience member's phone would act like one instrument or one voice for the duration of the piece, like a performer would in an ensemble setting. However, their continual and repetitive character, combined with the fact that each audience member had one of these sounds very close to them coming out of their own phone for the whole piece, proved to be too monotonous and not as interesting as it could have been for me and many of my colleagues as well, judging from discussion after the performance. It was not my intention to have each audience member hear what a single performer might hear in their role in an ensemble, but that was somewhat of a result in the way I approached this piece for this performance medium. I still wanted the audience to be entertained by a performance, and thus I did not want them to be too close to having a performer's experience, which could come across as boring, or "aurally imbalanced," depending on the nature of the music. As a result of this problem that manifested in the SynkroTakt performance of "We Could Live Forever Tonight," I quickly formed my own guideline for future works employing SynkroTakt that the individual audio tracks for audience member's phones should likely not remain too constant in their musical material in order to avoid fatigue on an individual track (and individual person).

Secondly, the performance had inherent volume and balance issues. Primarily related to the aforementioned constant and sustained musical material that makes up the piece, much of the audio coming from the venue's loudspeakers proved to be overwhelming to a group of only about 18-22 phones in the audience. At the climax of the piece, the problem became apparent and I manually turned down the volume to the loudspeakers in order to have a general balance between them and the crowd of phones. However, the remedy was unsatisfactory overall as the distorted organ-like sound that made up the lowest voice of the chord progression lost its musical and programmatic power without its volume. During the mixing of the composition, I had taken steps to boost the overall volume of each track, such as compression and EQ adjustments for middle and higher range frequencies, knowing that they were going to be coming out of tiny phone speakers. But these precautions I took were conservative by traditional mixing techniques, and after the performance, it was clear that more extreme volume boosting measures would need to be taken in order to get the most of out those tiny speakers as possible. Of course, the relatively low number of audience devices did not help the situation either.

While a larger crowd with more devices would have helped the performance of "We Could Live Forever Tonight," I ultimately came to the conclusion that, due to the nature of the constant individual lines, the lack of spatial movement of those lines, and not wanting to really alter the central character of the music, the piece would be better as a traditional stereophonic piece. After some small changes and remixing, I was happy with the new version of the work, but the experimental performance of the piece with SynkroTakt pushed me to hone and develop my own cornerstones for creating engaging and musically interesting immersive compositions using SynkroTakt.

I improved my compositional approach to this performance medium on "Rationalize" for bass clarinet, marimba, and electronics, which I finished in late March of 2016. I composed this piece for several Georgia performances by the Boston-based duo Transient Canvas. Musically, this piece is not as repetitive as "We Could Live Forever Tonight," with many different sections, more harmonic and melodic material, and faster development of ideas. Much of the musical material in both the live instrumental parts for "Rationalize" is rhythmically focused with a "start-and-stop" type character. The marimba part is almost entirely focused on pulsation and having different pulse lengths against each other, or contrasting short repeated rhythmic ideas of different lengths against each other, which are ultimately expressed more fluidly by the end of the piece (hence the title). Much of the bass clarinet part is heavily rhythmic as well, sometimes locking in with the marimba or playing against it. Brief melodic flourishes in the bass clarinet work with the start-and-stop nature of the rhythms in a cause-and-effect type manner, and expand in role over the course of the piece, setting up for the last quarter of the bass clarinet part to be quite melodic.

For the electronic portion of the work, I composed three tracks to work in tandem with the marimba, both rhythmically and timbrally, while three other tracks connected with the clarinet, both in melodic gesture and in the sustaining and control over volume. The former three needed to be delivered to iOS devices for precise synchronicity. Much of the music on these tracks was to be played together with the marimba thereby creating a hybrid timbre, or playing in a specific rhythmic offset against the marimba. The other three were delivered to Android devices and accounted for anticipated different offsets in playback. I composed music for the Android tracks that consisted of either swelling tones or harmonies fading in and out to mirror the clarinet's control of dynamic range, or melodic fragments that would foreshadow or echo the bass clarinet's melodic flourishes, both in direct repetition and variation. The swells and melodic fragments were composed in such a way that, when played at different latencies from the master timeline (as we expect will happen given the research), the effect is one of aleatory: from performance to performance the result will not technically be the same, but will have the same general effect. In addition to the six tracks the audience hears, I also composed a click track for use by Transient Canvas. The performers accessed the click-tracks via a secret webpage that only they had access to upon connecting to the SynkroTakt server, and thus, was not streamed into the audience. While accessing the click-track is different than the performance-tracks, the method of synchronization is still the same.

In stark contrast to "We Could Live Forever Tonight" there is a great deal of silence in the audio tracks of "Rationalize." In the former, the unyielding streams of sound allowed no time for an audience member to have a break from the sound right in front of them in order to hear a sound behind them or across the concert hall. In the latter, the construction of sound and distribution of that sound throughout the audio tracks offered plenty of gaps of time for an audience member to hear a rhythmic fragment coming from their phone by itself, hear it echoed in the marimba part from the stage, and then echoed again in variation a few seats in front of them, to cite one example. With more musical events sounding in isolation, the sense of antiphony and spatialization have a much greater role, and the music takes more advantage of this performance medium which is leveraged by audience devices. Additionally, that same sequence of events would be different for the person a few seats ahead, and furthermore, given the random but even distribution of audio tracks, the uncontrolled spatialization offers the high probability of each performance having a different spatialization as the sounds will be heard from different places in the audience.

Volume and balance issues in “Rationalize” were also addressed much better than in “We Could Live Forever Tonight.” Firstly, the nature of the marimba’s sound envelope and the bass clarinet’s ability to play a wide range of dynamics offered a much more manageable collection of sounds coming from the stage rather than a powerful, distorted electronic organ-like sound in the previous piece. The quick decay of the marimba (and bass clarinet when it mirrored it in staccato fashion) allowed the audience to hear more electronic sounds from different directions in the spaces in between the live instrument’s attacks. Oftentimes, the iOS tracks would play in unison or at a multiple of the octave with the marimba, creating a hybrid timbre, as mentioned previously. But conversely, antiphonal “call and response” type gestures in “Rationalize” provided a familiar musical framework for the audience to hear in an unfamiliar, more spatialized way. The audio tracks themselves were also improved by using more clear sound samples and synthesis, choosing more cutting sounds with much higher frequency content. Not only would that be more suitable to the small phone speakers, it would also help with spatialization and localization, as higher frequency sounds possess more directionality to listeners. Additionally, I compressed these audio tracks more heavily than in the prior piece, pumping the lower-volume-level content of the electronic sounds upwards so that the small speakers on the phones would be used more to their capacity.

"Rationalize" has received two performances thus far: one at the University of Georgia and one at Georgia State University, both by Transient Canvas in the middle of April of 2016. With the improved compositional approach and a more carefully worded program note for the audiences to follow in order to connect their devices to the SynkroTakt server, these performances were more musically and technically effective than the "We Could Live Forever Tonight" performance. With a less powerful sound source on stage, more cutting and upwardly compressed electronic tracks, and more breaks of silence amongst the electronic parts, the audience was able to hear more spatial interplay of rhythmic fragments bouncing from one place in the concert hall to another and more melodic echoes and volume swells. Judging from the audience's reaction both during and after the piece was performed, as well as feedback from trusted colleagues, the general sentiment was that they were entertained and the traditional concert spirit was enlivened, but also and most importantly, that this unique combination of spatial interaction, technology, and audience involvement works and was effective. With this, the SynkroTakt team and I felt that we had successfully achieved Phase 2 of the plan we originally laid out in the grant submission for Ideas for Creative Exploration, and we set our targets on Phase 3 of the plan: a substantial concert work for wind ensemble and electronics.

Improved Audience Device Setup and Connection, the SynkroTakt Performance Manager, and Uncontrolled and Controlled Spatialization in Three Versions of "Honeycomb"

Over the Summer of 2016 and continuing into the Fall, we begin making several significant upgrades to the SynkroTakt system that would be paramount in realizing Phase 3 of our plan – the utilization of SynkroTakt in performances with larger ensembles (and thus, larger audiences). First was the move from SynkroTakt being run as local network instances to being run on the internet as web server instances. With this change, it was no longer necessary for the people wanting to connect to login to the isolated Wi-Fi network we set up in the venue. Now, people could choose how they wished to connect, be it connection through a Wi-Fi network that has internet access, or by a direct data connection. Physical distance would also not be of a concern either since the streaming is over the internet, and it is certainly possible to stream music in synchronicity to two users, or two audiences of users, cities or states apart. This was tested and proved successful during a Skype Session with Yale University band director Thomas Duffy in which I was demonstrating the technology to him before his group began rehearsals of the wind ensemble version of "Honeycomb."

There are practical advantages to these improvements as well, as streaming synchronized tracks over the internet alleviates or prevents potential bottlenecks on local Wi-Fi networks if users elect (or are instructed) to connect via their direct data connection. This optionality would be key with performances for audience sizes of 75 and upwards, with the two versions of "Honeycomb" being for chamber orchestra and wind ensemble, both of which present much larger turn-out than the traditionally small "black box" performances of new music events that we had experienced prior. Additionally, having a traditional web address for audiences to type in, such as www.SynkroTakt.com/live, has a much more professional appearance and is more user-friendly to type in rather than an unmemorable IP address.

With the move to the internet, the SynkroTakt system also received a massive overhaul to the server-side interface. For all performances prior to Fall 2016, the user interface was basic in presentation and less straightforward in operation: saving performance presets was cumbersome, there was no control over playback other than start at the beginning of the timeline and stop, and the appearance of the program left something to be desired. Now, the interface is run directly in the web browser, with clean and simple visuals and intuitive operation.

For the newest iteration of the SynkroTakt software, the online server-side interface is called the “Performance Manager,” and features several major components. It is organized into several main sections, the Home page which lists all the created “performances” on the server, a Files page which lists all the audio files uploaded to the server and any pertinent categorization that they have, and a Remote page which controls playback once a performance has initiated and has an assortment of controls featuring start, pause/resume, stop, and a seekbar to locate precise points on a timeline.

At the beginning of the Fall 2016 semester, the performance of “Honeycomb” for chamber orchestra and electronics was planned, utilizing the newest iteration of the SynkroTakt system as described in the previous paragraphs (for a detailed overview of how a performance would be set up for the wind ensemble version of “Honeycomb,” see the appendix of this document). I composed this first large ensemble piece employing SynkroTakt around the theme of “the whole is greater than the sum of its parts,” wanting to tap directly into the ideals and notions that led me to create SynkroTakt in the first place. While the title could (not unfittingly) be in reference to the industrious and group-minded nature of bees and beehives, the program note from the piece explains the full concept for the work and aspects of the work's composition more clearly:

> As my time at the University of Georgia's Hugh Hodgson School of Music draws to a close, I have thought much about and appreciated the sense of industry in music schools, the dynamics of ensembles in general, and shared experiences among a large group of people. … In Honeycomb, pointillistic textures from live instruments align with audio from audience members' smartphones, tablets, or laptops, creating an immersive aural environment as the many devices throughout the crowd play different segments of staccato-laden music. At times, the sound of the hall is, quite literally, honeycombed with separate parts of a moto perpetuo 16th-note ostinato that are spread variably throughout the crowd. At some points, music hockets from the live instruments on stage to the audience devices and back for antiphonal call and response effects, while at other times webs of glissandi interact with glissandi from the stage. ... With this work, I wanted to make each musician's part, as well as the music coming out of each audience member's phone, just one unit of something bigger and greater when all the separate components come together.[90]

The work begins with a thunderous opening with tam-tam, bass drum, and crash cymbal while string instruments fade in from nothing. At the same time, all the audience's cell phones blast a blend of static and glitched tam-tam samples. The net effect of this combined gesture is quite stunning as it gives the impression of the loud action coming from the stage directly causing the related sizzling sound to come from the phones. As this gesture sounding in all the devices starts dying away, I employed the two device types differently with different types of music more suited to their latency types.

In the six Android tracks, the static and glitched tam-tam slowly morphed into string-like synth, matching pitch (but with fairly noticeable undulating detuning) with the harmonic roles played by the live viola, cello, and bass parts. These electronic parts were well suited for matching with the string parts, as they were simple constantly sustaining parts with a little glissandi from one harmony to the next – musically, it was not an issue if there was variable

[90] Cody Brookshire, *Program Note for "Honeycomb",* 2017, Program note.

arrival times for the end of the glissandi from one android phone to the next, further aided by the slight modulating detuning, creating a rich and wavering field.

While the six Android tracks began morphing into string-like sounds, the six iOS tracks faded to silence to prepare for their next and arguably more critical role. Seeking to make use of the precise timing ability of iOS devices, I composed a gradually filling-in ostinato that doubles the clarinets and other wind instruments. From measure 8 to measure 53, the 16-note-long 16th note ostinato adds in an additional note every three measures. See Figure 3 below for a reduction of the process.

Figure 3. Reduction of composite ostinato in the first section of the chamber orchestra version of *Honeycomb*. Asterisks have been placed above each new note in the sequence.[91]

While the clarinets play an interlocking composite part, providing a live acoustic backbone to the electronic sound, interest is added orchestrationally by doubling all the notes in various registers

[91] Cody Brookshire, *Honeycomb*, chamber orchestra version, 1303 Publishing, 2016.

amongst the other woodwinds. This pointillistic type of texture coming from the stage musicians is mirrored in the audience, as the six iOS tracks split up the 16 notes of the ostinato roughly evenly and the location of those sounds occurring within the audience is randomized.

Rehearsal G in the piece marks an arrival point with the ostinato sounding in full both acoustically and electronically in the iOS devices, while the Android devices play brass-esque calls both harmonically and gesturally supported by the ensemble. This moment of completeness and unity is short-lived however, as by measure 62, the ostinato begins to fall apart and dissipate, gradually losing its component notes. Meanwhile, the brass-esque calls expand in timbre and become more dissonant, both acoustically and electronically. Throughout the middle section of the piece, the expanded calls continue, but are switched from the Android to iOS devices. Whereas before their role was that of aleatoric echos of calls from the stage, their role for the middle section of the work was to be in tandem with the live ensemble. For the middle section, the Android devices still echoed some parts, but mostly were refined to provide further harmonic support via sustaining swells to contrast the staccato nature of the iOS parts, as well as the staccato nature of much of the live ensemble.

Throughout the middle section of the work, a metric process unfolds to drive towards a climax. Beginning with 4/4 time, a new composite ostinato plays in full and each subsection shortens the ostinato along with variating in the overall pitch content. The meters compress from 4/4, to 3/4, 5/8, 2/4, and finally 7/16 as the overall harmony of the ostinato becomes more chromatic. This dual process builds tension in the live ensemble, as the climax of the piece approaches at the end of the 7/16 section, the electronic parts converge in role and responsibility. Both types of devices begin fading in a reversed sample of the static and tam-tam that sounded forwards (in a normal direction) at the beginning of the work. This rising swell in the electronics is abruptly cut short at measure 111, the climax, as the piece moves back to 4/4 and the tension is released via a web of pizzicato in the string parts which is directly mimicked by the Android parts.

As these pizzicato-styled parts decrescendo and chromatically rise into nothingness, and as the overall ensemble thins out to a persistent hi-hat, the Android devices mimic the glissandi parts that they played in the beginning, but this time a stuttering tremolo effect dominates the sound. When they sound in performance, however, the Android devices will naturally not be synchronized and thus the stuttering tremolo effect will create a rich texture in the audience. As this progresses towards the end of the piece, the tremolo effect is faded out to bring more cohesion to the Android part's overall composite sound. Meanwhile, the iOS parts begin a new ostinato (actually a chromatic inversion in retrograde of the original ostinato). However, the construction and process of this developing ostinato is a bit different than the original. For each iOS part, a synthesized version of the entire ostinato is present from the start, albeit very quiet and without much high-frequency content, while one of the six pitches making up the ostinato plays as a piano sample at a normal volume, retaining its temporal/rhythmic position in the ostinato with all other pitches removed. As this major section of the piece develops from measure 128 to measure 159 (rehearsal letters P to U), the synthesized electronic part in each iOS track gradually increases in volume, over-taking the separated piano samples. Figure 4 below shows the ostinato in composite form as it is heard in the synthesized electronic part that gradually increases in volume, and also shows how each iOS part is an individual component of the composite ostinato.

Figure 4. Ostinato in composite and component forms, as heard in the last major section of *Honeycomb*, chamber orchestra version.[92]

Rehearsal letter U through the end, measures 159 through 169, are the closing section of the piece and feature only one new approach. Taking advantage of the precise timing afforded by the iOS devices, a call-and-response section is played between the live ensemble and the iOS devices in the audience. First, the ostinato is played twice in the electronic ensemble (and lightly doubled by flute and xylophone in the live ensemble) and this alternates by the live ensemble playing a more ominous response with the ostinato being played twice by the piano and violins while much of the winds provide an augmented sonority underneath. This call-and-response gesture happens again, but this time the response gesture by the live ensemble is more triumphant in nature with an unadorned major sonority supporting the ostinato. With the Android devices providing still ascending and even more high-frequency content throughout this closing section, the ostinato sounds through the iOS devices twice more, joined only by a persistent bass drum. Both elements are promptly cut-off by a simple B-flat pizzicato in the strings.

Conducted by Cynthia Johnston Turner, UGA's Director of Bands and performed by a pick-up ensemble of some of the school's best musicians, the premiere of "Honeycomb" on August 13th, 2016 was a success. Coordinated with help and support from the music school's

[92] Ibid.

Director, Dale Monson, the premiere at the music school's convocation, an event that kicks off the school year featuring speeches and performances by faculty and students alike. Since attendance at the event is required of all music students, securing a performance at this event afforded the SynkroTakt team a large audience (and large ensemble) to test that this concept would work on a bigger scale.

The SynkroTakt team and I had felt like we accomplished Phase 3 of our original goal, and over the next week as the semester began, I received a lot of great in-person feedback from professors and students alike regarding the piece. Much of this feedback was overwhelmingly positive, with the general sentiment being that the piece itself was well done, exciting, and effective. I specifically asked for opinions regarding the integration of the technology, mostly inquiring about whether user experience in connecting to the server was easy, if the electronic element in the piece generally "worked," and perhaps my biggest concern, if the electronics were balanced with the live ensemble or not, to which most of the answers I received were positive. However, we had also set up an anonymous survey that each device's browser would redirect to after the convocation performance (using the performance manager's Exit Link feature), and while a great majority of the 62 responses were positive, some of the responders elected to give us more critical information about their experience, as we thought the anonymity of the survey would offer. While there were a few useless evaluations such as "entertaining, but has little musical value," many offered constructive criticism including feedback about the website and connection process, details about errors on their phone, various temporary synchronization issues, or that they thought the balance between the phones and the ensemble was too loud in favor of the phones (and vice versa).

The team and I took the survey responses in to consideration moving forward as we began work on the next iteration of the software. This next iteration would involve a few tweaks to the code to improve connection, synchronization, and the user interface, but it would mainly consist of adding an additional feature. This new feature, if engaged by a SynkroTakt operator, would be the ability for the audience to choose their location in a performance space based on of a "mapping" created by a SynkroTakt operator, composer, director, conductor, or some other personnel. If the audience could input their location information into the software, and a mapping of locations in a performance space could be created to correspond different locations to different audio tracks, then it would be possible to control where specific sounds would happen in an audience. Thus, a tightly-controlled spatialization of the electronic portion of a piece would be possible, in contrast to the uncontrolled spatialization of the previous pieces involving SynkroTakt.

The idea of spatializing the sound that happens in the audience was one of my earliest ideas when I began thinking of this project, and I was eager to move beyond Phase 3 of the project and try to create a spatialized piece using audience cell phones. As the team and I discussed this and plotted how we would go about it, an opportunity to plan for a performance with controlled spatialization would arise. On the strength of the chamber orchestra performance of "Honeycomb," Dr. Turner asked for a wind ensemble arrangement of the piece for the Hodgson Wind Ensemble to perform at the Concert Band Directors National Association's National Conference in March of 2018. Rather than creating a whole different piece for large ensemble and audience cell phones to experiment with spatialized sound in the audience, I simply made adjustments from the chamber orchestra version of "Honeycomb" to create a wind ensemble version, and recast the electronics in a new spatially-controlled mixdown. I reasoned that the chamber orchestra version of the piece was musically effective in combining the sound from the live ensemble and the sound from audience devices, and that a wind ensemble version would be fairly straightforward to adapt; additionally, given the experimental nature of this relatively unexplored medium combined with the high visibility of the CBDNA National Conferences, I thought it better to modify a successful piece of music rather than attempt making another successful piece that is so unconventional in nature.

As I started thinking about the spatialization of the sound for a new version of "Honeycomb," the first question I needed to answer was in regards to how complex the spatialization would be. Firstly, I decided that, for most performances of the piece and to be most flexible, the audience (and thus the spatialization) would exist in a two-dimensional space. While many higher-end concert spaces will have second and even third levels of seating, many will just have one "plane" of seating. Conversely, if I were to compose a piece with a three-dimensional electronic sound-space, many venues that the piece might be performed in would lose the three-dimensional aspect. In consideration of the lowest common denominator, I settled on a traditional two-dimensional sound-space for the spatialization, as my conclusion to the second question about the spatialization (detailed below) could likely solve any mapping issues encountered in a two-dimensional mixdown being performed in a three-dimensional space.

Secondly, I needed to settle on how "detailed" the spatialization would be, meaning, how many channels I would use. This was an interesting question to ask, and actually generated a decent amount of internal debate amongst the other members of the SynkroTakt team when I asked for their input. Going to one extreme, it would be possible (and a very exciting challenge) to create a spatialization in which each seat in a concert hall had its own individual track (or pair of tracks to accommodate either iOS or Android devices), and assuming that every seat was filled, it would create a very rich and detailed sound environment. However, such a project would need to be re-mixed on a venue-by-venue basis, and would thus be tremendously inefficient for repeat performances, not to mention additional stress on the SynkroTakt servers for having to distribute an exorbitant number of tracks. With modularity in mind, I settled on a square grid that could be stretched so that each space in the grid would encompass several seats (in the case of a very small concert hall or blackbox-type performance space), or compressed so that each grid-space was a single seat and then the grid was duplicated across the concert hall as many times as necessary. In regards to the former concern of a two-dimensional versus three-dimensional mixdown, a single grid of a two-dimensional mixdown could be feasibly be duplicated in a balcony section, while the inverse situation, a three-dimensional mixdown being squashed into a two-dimensional space, would insufficiently portray the intended sound field.

Given that SynkroTakt functions as a delivery and timing system for audio playback and not as DAW of any kind, the mono audio tracks with the intended spatialization needed to be created and mixed beforehand in a DAW. Unfortunately, my prefered DAWs, Logic and Pro Tools, only handle up to 9 channels for rendering simultaneous output, and I was looking for more. Reaper, however, offered up to 64 channels of output.[93] This DAW, combined with the GRM Spaces plug-in which allowed for positioning and movement in an up to 32 channel space, became my primary tools in recreating the spatialized tracks.[94] Regarding grid size and keeping maximum modularity in mind, I reasoned that a grid of equally-numbered rows and columns would be best, which reduced my options to matrices in the sizes of 2x2, 3x3, 4x4, and 5x5. 6x6 and above would be limited by my available resources, as the aforementioned GRM Spaces plug-in could only output up to 32 channels. I immediately ruled out 2x2 and 3x3 spatialization

[93] REAPER | About, accessed September 2018, https://www.reaper.fm/about.php.
[94] *GRM Tools Spaces: User Manual*, PDF, Groupe De Recherches Musicales.

grids because quadraphonic and octophonic (close to nonaphonic) works are somewhat common in electronic music scenes organized in universities and colleges, and I sought to create a richer sonic environment while concurrently displaying the capabilities of SynkroTakt. In choosing between 4x4 and 5x5, I decided against 5x5 so as not to over-stress the SynkroTakt servers with a 50 track distribution (two track types, one for iOS and one for Android, for each grid-space) and additionally to mitigate imbalances that might occur if square grids with an odd number of total spaces were to be duplicated (to be explained later in a section detailing a performance with multiple small grids).

So it was determined that I would be using a 4x4 grid for controlled-spatialization within the audience: 16 grid-spaces with one of two possible track-types in each grid-space for a total of 32 tracks (33 when including the conductor’s click track), with the possibility of stretching the grid to cover the entire seating area, or duplicating the grid a number of times across the concert hall. Now able to start the arrangement process from chamber orchestra to wind ensemble, I would first make a number of adjustments in the acoustic parts before changing the electronic components. There were obviously quite a few modifications that would need to be made with the absence of string instruments and voices in a wind ensemble, however some were more prominent and most critical. Where I had used the string instruments for integral glissandi effects which were matched and further developed with the electronic tracks, the only real option was to move these acoustic parts to the trombone. Parts that were sung by voices in the chamber orchestra version were re-composed and made more effective for percussion in the first section of the piece, contrasting horns in the middle section, and a solo English horn in the third section of the piece. The entire piece was also transposed up a whole step to better accommodate the low-end capabilities by various instruments for a number of moments.

The change in the electronic components firstly involved transposition, but secondly involved a change in sound diffusion of the electronic tracks from uncontrolled spatialization to one that is controlled. Like the acoustic parts, there were a majority of electronic components that were MIDI-based and would need to be transposed up a whole step, which is accommodated by just a few clicks in Logic. Several audio-based components which had critical pitch content in them would also need to be transposed up, which is taken care of with a little more work and finesse to maintain integrity of the content via pitch-shifting plugins. Other small tweaks involved adjusting the EQ of various tracks to focus on more high-end frequency content, as well as dynamic balance amongst concurrent tracks, decisions which I made after recalling how the chamber ensemble performance went.

After those adjustments, I needed to move the project from Logic to Reaper in order to accomplish a more controlled movement of sound. While Logic can only output up to nine channels of audio output, Reaper supports up to 64. Taking the exported tracks from Logic and importing them into Reaper, I then set up an instance of the GRM Spaces plugin on each track. This plugin proved critical in attaining a controlled spatialization because it enables the positioning and movement of a multichannel source (from 1 to 32 channels) in a multichannel space (from 2 to 32 channels). For this particular project, each source was one channel and I positioned and moved those sources in a 16-channel space, as per the 16-space grid I envisioned. Because of having two sets of tracks, one for Apple devices and one for non-Apple devices, I needed to spatialize and then render the two sets of tracks as separate 16-channel output sessions, yielding the 32-track total with two possible track types for each space in the 16-space grid.

The GRM Spaces plugin has several presets to work with for virtual speaker configurations, however, the 16-space grid I had in mind was not one of them so I needed to create it via the built-in Layout Editor. See the screenshot below for a visual of the Layout Editor plugin as I need it set for my spatialization plan.

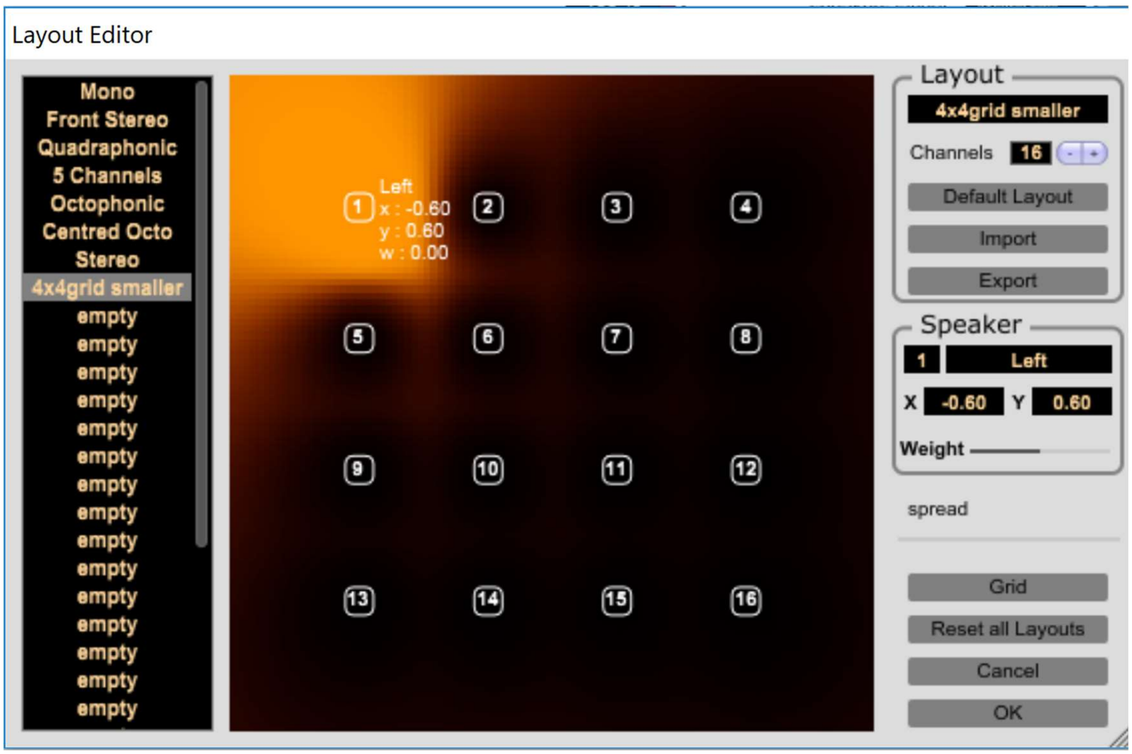

Figure 5. Layout Editor of the GRM Spaces plugin, with custom speaker layout in a 4x4 grid.[95]

With the speaker configuration set and then saved as a preset, I could then move a source sound (the track that each plugin is on) which is represented by a blue dot throughout the space in the plugin's main window, and document that movement, in several primary ways. One way would be to click and drag the blue dot throughout the grid while the audio plays and have the DAW record the path that it travelled, written to the track's automation in the form of changes in X/Y coordinates over time. Another way would be to manually write in the changes in X/Y coordinates over time into the automation, which, while more tedious, can result in much more

[95] GRM Spaces, computer software, version Version 3.6, Ina-GRM, accessed September 2018, https://inagrm.com/en/store/product/15/spaces.

precise results. Seeking that precision, the vast majority of the sounds which I sought to move through the performance space were automated in this manner.

A third way to create spatialization with this plugin would be to use the GRM Spaces plugins' own Trajectories Editor, as shown in Figure 6 below. This additional feature within the plugin allows the user to employ certain movement presets or create custom movement presets that require precision which would be too tedious to write in manually and too difficult to accomplish by the free-hand click-and-drag approach.[96] For instance, one of the presets offered is a circle which allows the user to move a source sound along a circular path, offering options to adjust the size of the circle, the direction of movement along that trajectory, the speed of movement, and other fine-tuning aspects.

[96] *GRM Tools Spaces: User Manual*.

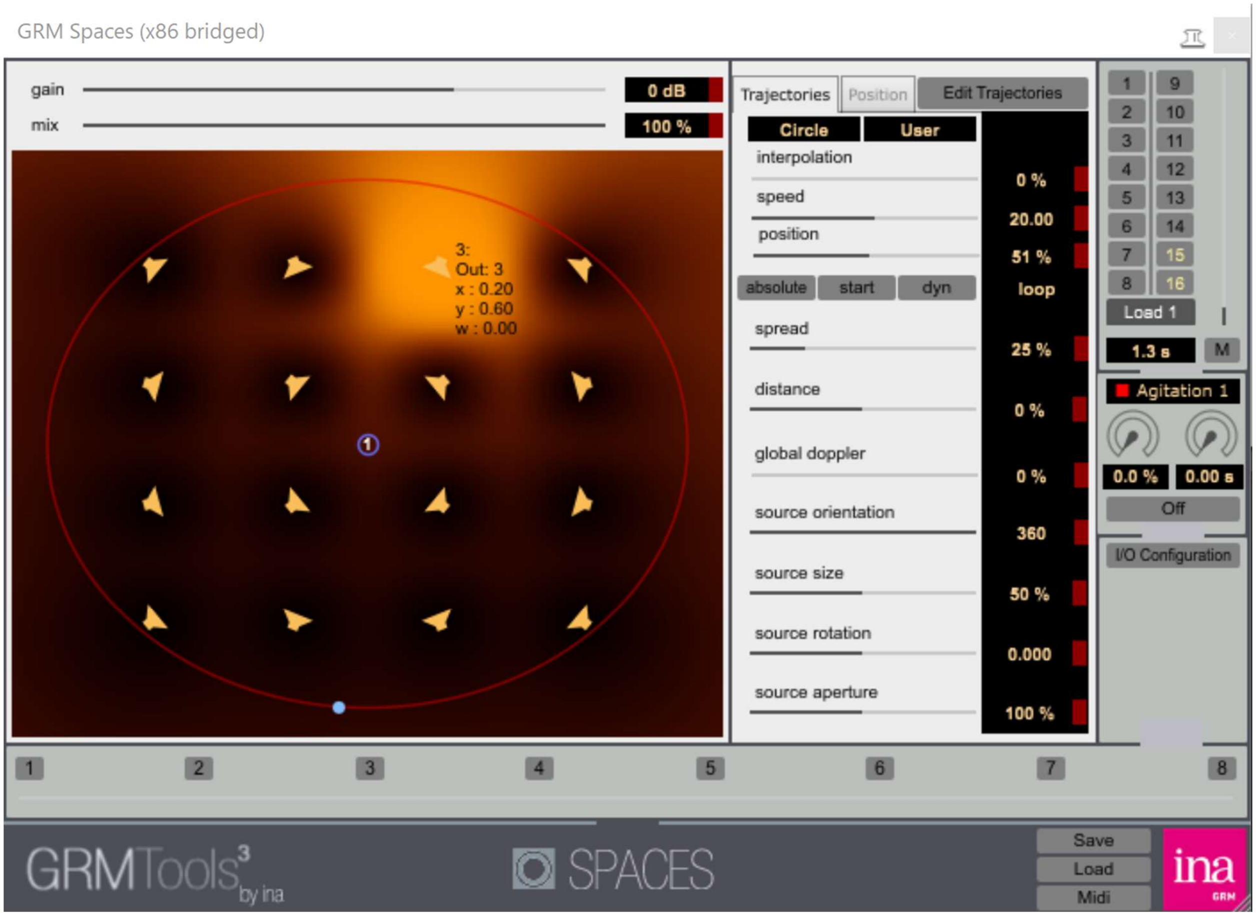

Figure 6. Trajectories Editor of the GRM Spaces plugin, showing a circular trajectory running along the edge of the 4x4 grid.[97]

With the appropriate tools to create a spatialization for a 16-grid space at the ready, I then thought about what sort of movement might be most effective. Given the relatively unexplored and undocumented nature of spatialization using smartphones as output, as well as the smartphone speaker's inherent weakness in power, I thought that it might be best to have the majority of movement be very clear and simple. I hypothesized that, in keeping most movement along a single axis, being front to back (or vice versa) for some electronic musical components and side to side for others, this would give the audience the best shot at actually perceiving the

[97] GRM Spaces, computer software.

movement of sound, given the unusual method of diffusion. Still though, I would also experiment with less-straightforward paths of movement in a few key moments during the piece.

One particular moment in the piece that uses clear and simple movement of sound is the very beginning, which is marked by an excessively loud tam-tam strike and a gradually diminishing aleatoric flurry of crotale notes coming from the stage. In the electronic parts, I have a complimentary track that initiates out of tam-tam strike which is a processed tam-tam hit with glitchy static that gradually morphs into a string and brass like synth sound. In the controlled-spatialization version of Honeycomb, I start this track out in the front row of the 16-space grid, playing through those four speakers, then it is quickly moved to the back and then to front again and repeated in a sweeping manner, as if the tam-tam hit is moving like a wave through the audience. The back and forth motion starts to slow and disperse at the same time as the tam-tam timbre begins morphing into the synth sound.

Another example of clear and simple movement of sound is throughout the middle section of the piece. An ostinato figure, which is doubled in the live ensemble as a composite ostinato in which its constituent parts are spread across many of the winds, starts on the right side of the audience and sweeps at a consistent rate from side to side. As the middle section of the piece comes to a climax, the moving parts gradually fade out to focus on non-moving percussive strikes and melodic content.

Not wanting to miss an opportunity to try something more complex with sound movement in this controlled-spatialization approach, I saw an opportunity with insect sounds that emerge out of the detritus that is left over from the middle section’s ending climax. As chromatic lines emit from the phones, reaching higher and higher while fading out, recorded samples of bee and beehive sounds begin fading up. Using the Trajectory settings in the GRM Spaces plugin, I was able to select both circle and spiral presets to set the sound in motion, swirling around and throughout the 16-space grid, directly imitating a buzzing insect or group of insects as if they were flying around in the audience. As the third section of the piece continues on and moves towards its climax, the insect sounds gradually gain more pitched content and begin glissing upwards, meanwhile the speed of movement for this sound also intensifies, ultimately halting before the final bars of the piece as a building ostinato in the live ensemble finally completes itself for its final presentation.

In the months leading up to the CBDNA performance, I acquired a seating chart of Kauffmann Center. In consultation with Dr. Turner, the Hodgson Wind Ensemble director, we decided to rope off some of the upper balconies and settled on one large grid for the controlled-spatialization type, with a single grid-space covering quite a few seats, from as little as 4, to as many as 9 or 12. From previous experience at the convocation performance and in an effort to avoid any unfilled seats where specific sounds should occur but might not be heard otherwise, the decision to rope-off some of the upper seats was made in order to pack the audience more tightly into sections closer to the ensemble so that every track that was made for a certain section would have a high probability of being heard without trying to coordinate or mandate various seating configurations based on Apple or Android ownership (such as, making all Apple-users sit in one section and Android-users sit in another), which would be futile and tedious venture. See the images below for a blank seating chart of the hall, and that same seating chart made into a spatialization mapping with my hand-drawn grid-space numbers on top.

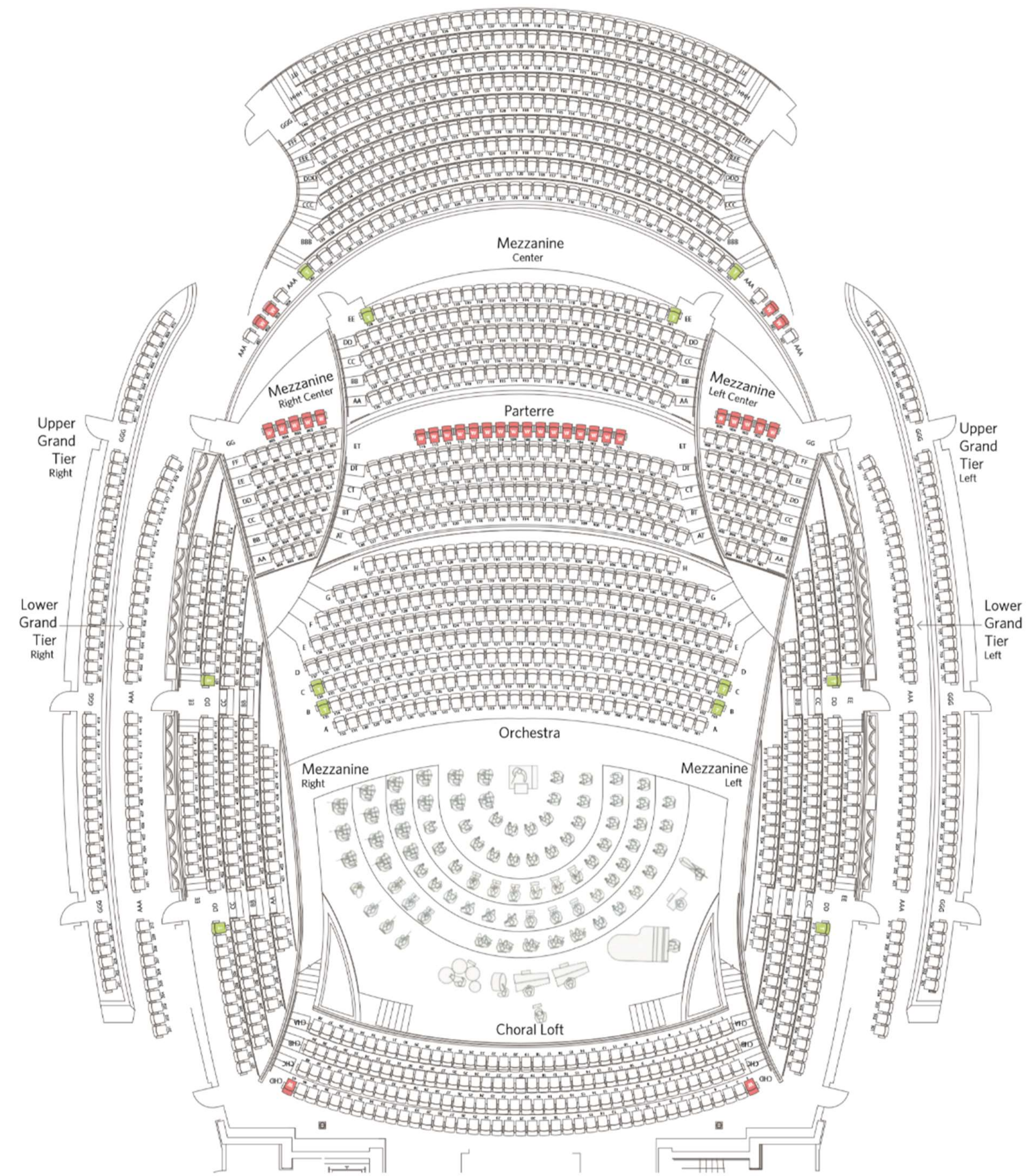

Figure 7. Seating chart of Helzberg Hall at the Kauffman Center for the Performing Arts in Kansas City, Missouri.[98]

[98] *Helzberg Hall – Detail Seat Map.* PDF. Accessed September 2018. https://www.kauffmancenter.org/wp-content/uploads/HH-Detail-Seat-Map-BEST.pdf.

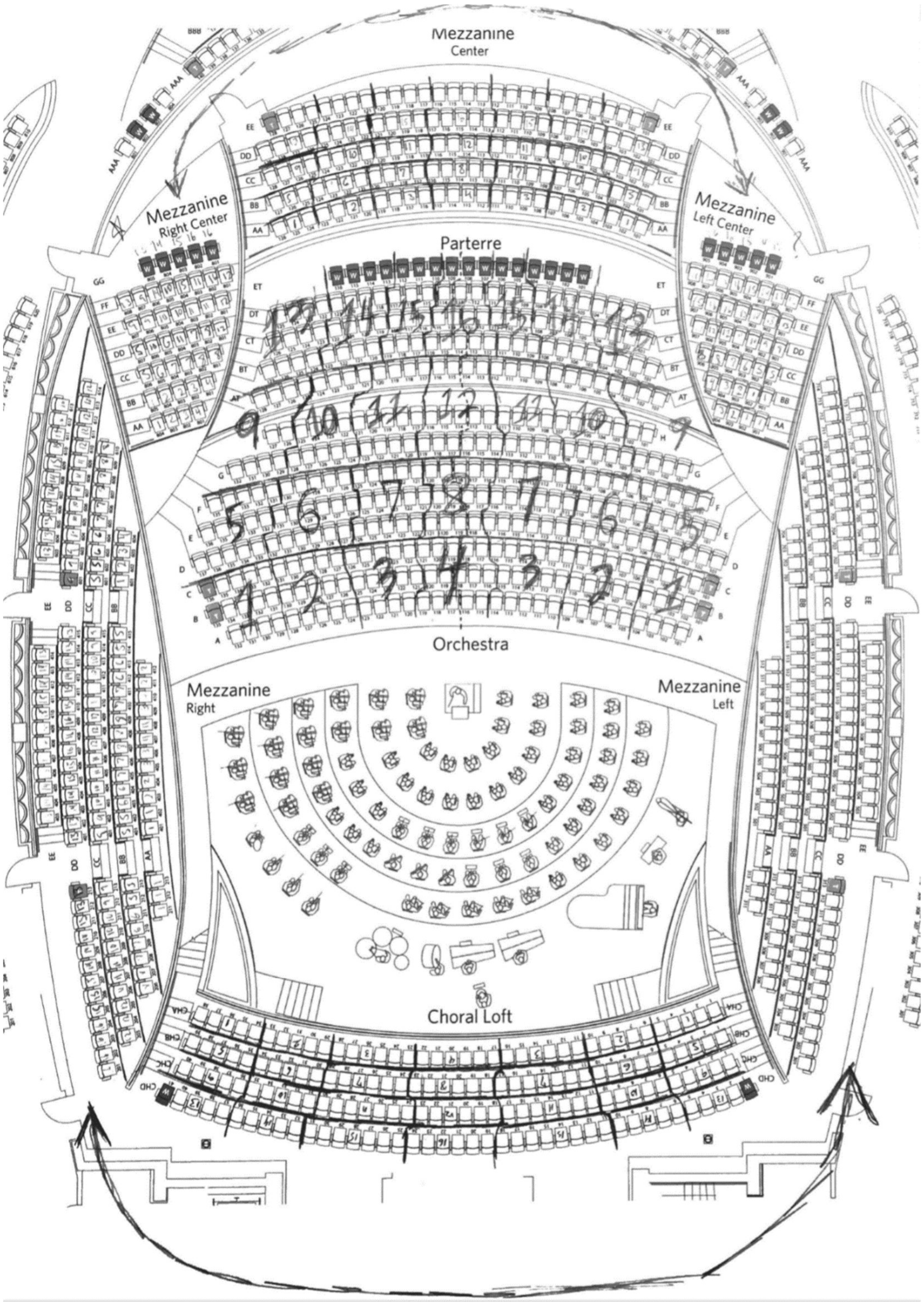

Figure 8. A scan of the seating chart for Helzberg Hall with hand-drawn mapping on top.[99]

[99] *Helzberg Hall Mapping,* edited version of *Helzberg Hall – Detail Seat Map,* edited and scanned by author, January 2017.

Notice in this mapping that the grid-spaces are not always of the same size, and skewing of the grid needed to be done, mainly at the edges and corners of hall.

On March 16th, 2017, “Honeycomb” for wind ensemble and electronics was premiered by the Hodgson Wind Ensemble, conducted by Jaclyn Hartenberger at Helzberg Hall in the Kauffmann Center for the Performing Arts in Kansas City, Missouri, as part of the 2017 CBDNA’s National Conference. The performance of the music was great overall: the live ensemble was spot on, and the SynkroTakt system worked nearly flawlessly, as there was one or perhaps two phones that had somehow gotten out of synchronization and were continuing past the actual ending of the piece, making for what many described as musically interesting (yet unintentional) closing to the performance. The reception of the piece was positive, as many were excited about the integration of this technology with live music to make a sort of shared, communal experience. From my perspective and that of others who I had talked to, it seemed that a horde of cellphones was able to balance the wind ensemble in key moments, and that I was successful at orchestrating quieter moments for the cell phones to take the spotlight while other moments put the live ensemble at the forefront.

But regarding the controlled-spatialization approach, it was a bit unclear as to whether or not it was successful. I was in the back of the first section closest to the ensemble, just right-of-center relative to the conductor, and there were perhaps about 10-12 rows in front of me. However, many of the seats in this first section were unoccupied, which hampered the effect of some of the spatial effects I was expecting to experience. Fortunately, the second section of the concert hall, just behind and slightly above me, was nearly packed to capacity, and I was able to clearly perceive one of the slow sweeping effects moving behind me that I programmed into the middle section of the work. While I personally did not experience all of the spatial effects I knew I had created in the mix, several people whose opinion I trust were sitting in very different locations in the concert hall, and they reported they had sensed clear movement of sound within the audience - whether or not it was truly the aural movement as I had designed in Reaper is unascertainable. While I would regard this performance as successful overall, I became skeptical about the large-grid approach to spatialization.

After this performance and with a home turf performance of "Honeycomb" lined-up for less than a month a later on campus at the University of Georgia, I contemplated the pitfalls of using a single large grid and tried to hypothesize the benefits of multiple smaller grids. Up to this point in time, I had only experienced the uncontrolled-spatialization and singular large grid controlled-spatialization types, and while I originally envisioned the audience being engulfed in immense spatial gestures such as side-to-side sweeps or spiraling motives, I now thought that this approach might not be best, for "Honeycomb" at least. I do believe, however, that a piece could be composed for audience devices alone or audience devices in conjunction with live musicians that could be highly antiphonal in nature, sounding various grid-spaces in alternation or using tremendous sweeping spatial gestures that would be quite effective when cast in a single large grid encompassing the audience. Such as piece could have a very clear focus on antiphony between different parts of the crowd and sound from the stage, provided that very little or no sound at all would be coming from devices if those devices are not part of a primary spatial gesture.

The potential for grandness and a sense of connection between all the audience members in the outcome of the previously mentioned hypothetical piece is something that I was attracted to, especially in regards to some of the notions that originally compelled me to begin SynkroTakt in the first place, and I thought that I might be able to create that feeling with a single large grid in the "Honeycomb" CBDNA performance. However, "Honeycomb" ended up being not even close to that type of hypothetical piece. While the overt harmony and melody are actually quite simple and uncomplicated, the texture is highly complex and nuanced, developing and churning like an evolving machine in near-perpetual motion for the entire piece. It is this continual type of texture, in combination with the general dynamic force of a wind ensemble, that greatly hinder the single large grid spatialization type in being the most appropriate type of approach, and in my opinion, also hinders it from achieving those musical and extra-musical notions of grandness and connection that I originally sought.

With this now in mind, and re-considering the spirit of the piece's program and impetus, (one of many moving parts coming together to create something bigger than their sum), the single large grid did not allow listeners to fully hear all the musical parts working together (either in balance or at all), with many of the companion sounds and second-halves of gestures possibly sounding physically too far away, and being drowned out due to the ever-present complexity and busy overall texture with the live ensemble and audience combined. Simply put, the intricate electronic component that I created was spread too wide to be played by even a sizable number of small speakers, and in my opinion, the listener was experiencing the musical equivalent of "losing sight of the forest because of the trees."

Conversely, shrinking the size of the intricate electronic component, as represented by a 4x4 grid in the case of "Honeycomb," would give a much greater chance for each listener to more fully experience entire spatial gestures that might sweep from side to side or front to back, and to more appropriately hear antiphonal and hocketing effects as composite ostinati and gestures are broken down and dispersed amongst the 16 grid-spaces. I hypothesized that creating many smaller 4x4 grids in a performance space would, in essence, create many micro sound spaces for clusters of audience members to better hear the subtlety and fine gradation that a complete 16-space grid of sound naturally creates. While this would undoubtedly sacrifice even a shot at the “grandness” as I originally envisioned it by connecting swaths of the audience with other swaths across the concert hall, I actually believed that it would even better achieve the musical and extra-musical notion of “connection” that I sought between the audience members, and between the audience clusters and the live ensemble.

In planning for the multiple small grid approach, I acquired a seating chart of Hodgson Hall in the University of Georgia’s Performing Arts Center, where “Honeycomb” was planned to be performed on April 4th, 2017, again conducted by Jaclyn Hartenberger. See the examples below for the unedited seating chart, and a seating chart with my mapping imposed on it.

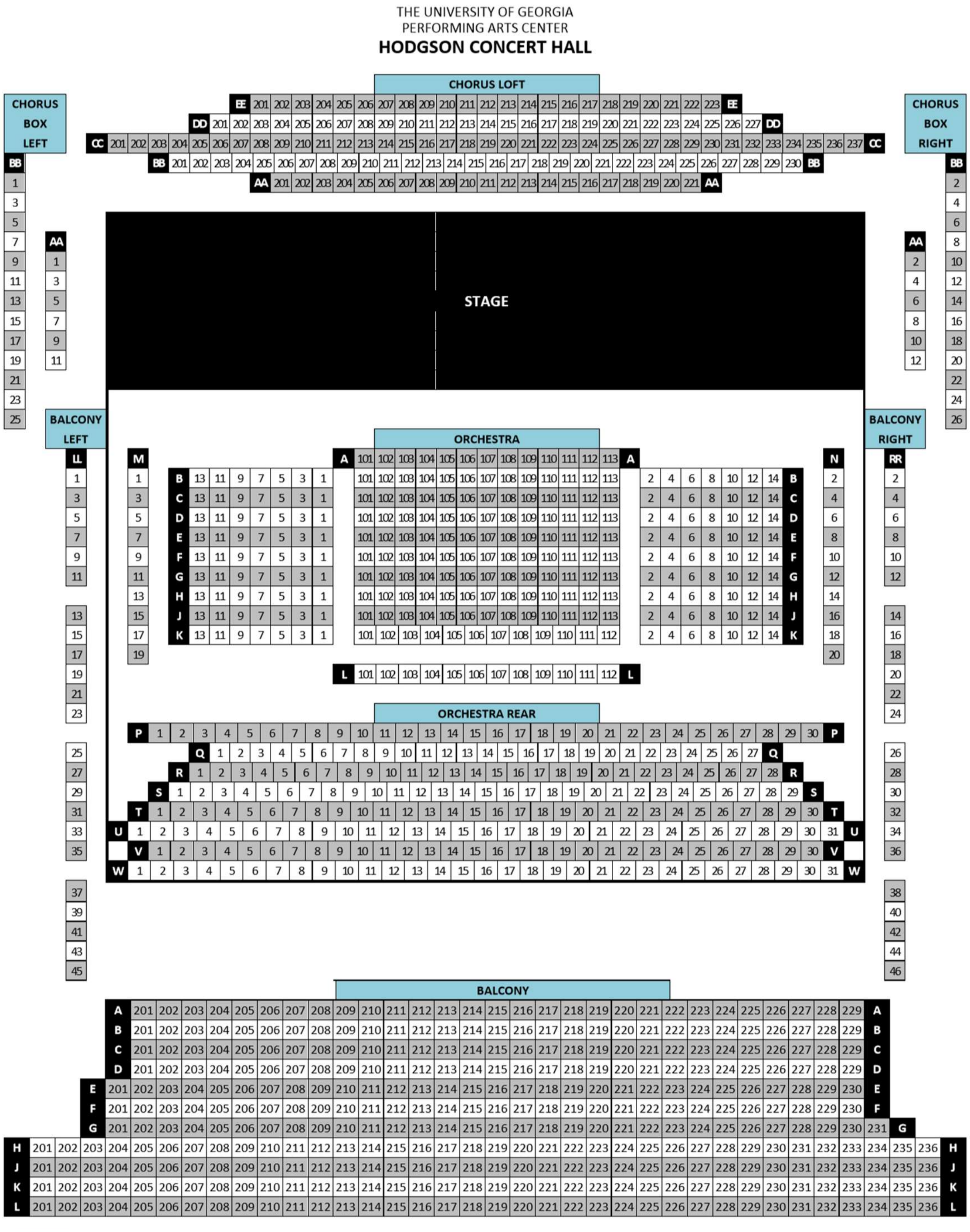

Figure 9. Seating map of Hodgson Hall, Performing Arts Center, at the University of Georgia.[100]

[100] *Hodgson Hall Seating Map.* PDF, accessed March 2017, https://pac.uga.edu/wp-content/uploads/2018/04/seat_map_hch_2010.pdf

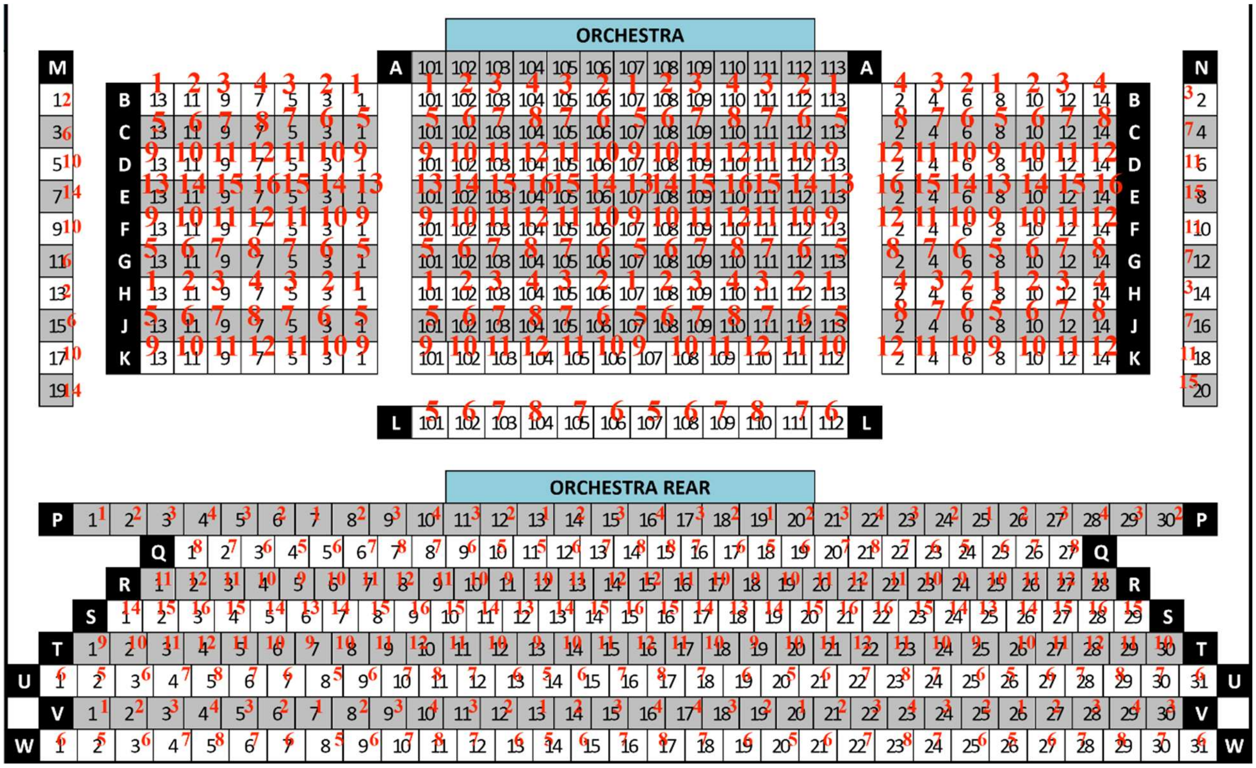

Figure 10. Spatialization mapping of Hodgson Hall.[101]

Notice that, in this mapping as compared to the Kauffmann Hall mapping, the size of the grid-spaces is exactly 1 seat. Because of this, a complete 16-space grid will not have all 16 iOS tracks or all 16 Android tracks (assuming one device per seat), however, given the very compact size of the grid, the likelihood of hearing the “missing sounds” from other adjacent grids is good. Other small peculiarities in this mapping include a visually-adjacent but physically-separated duplication of tracks 1, 5, 9, and 13 from the left orchestra seating to the center orchestra seating, orchestra right seating having the inverse mapping of orchestra left, and the staggered, angled mapping of orchestra rear seating due to rows of various sizes.

[101] *Hodgson Hall Mapping*, edited version of *Hodgson Hall Seating Map,* edited by author, March 2017.

Fortunately, feedback received from audience members in these sections indicated that these little issues were not problematic. From my personal perspective, and those in the audience that had also experienced the single large-grid version of the piece, the multiple small-grid capitalization approach applied in the “Honeycomb” performance at the University of Georgia appeared to be better for the reasons I postulated previously. Chief in the reasoning was us being able to hear a more complete electronic sound world rather than an electronic sound world dominated by perhaps just 2 to 4 tracks, and along those same lines of thinking, being able to hear more complete spatial gestures. While the execution of the electronic aspect of the piece was not perfect, as a couple of devices appeared to be a handful of seconds late as evident by their “overhang” beyond what was supposed to be the end of the piece, the net result of the performance was very successful. (For a solution to mitigate the “overhanging” audio tracks, please see the last paragraph of the appendix.)

In retrospect having listened to both types of controlled-spatialization concerts, I feel strongly that the multiple small grid spatialization type is the most effective, at least for “Honeycomb” and perhaps even as the “default option” for compositions or works of sound art involving SynkroTakt. Of course, there are situations and pieces in which a single large grid could be the best choice, with one possible type of piece that I mentioned previously.

CHAPTER 4

Reviewing Progress and Looking Forward

From my initial conception of seeking to leverage smartphone-addiction towards creating an encompassing aural environment, I saw a possibility in a new type of entertainment and more immersion into the sonic arts for an audience, and in the past several years creating and working on SynkroTakt while composing pieces utilizing this technology, much progress has been made. Through the early development of the software and the compositional findings about effective and ineffective sound and music for pieces using SynkroTakt, I realized this possibility was in fact truly viable as a new (or at least, more prominent) performance medium so long as careful attention is given to the arrangement of a piece's elements and the mixing of electronic parts. In continuing on through refinement of the software with added functionality and in composing a piece of music for a large ensemble and spatialized electronics with special attention to the arrangement and mixing for the electronic parts, the SynkroTakt team has shown that the technology is versatile and powerful while I have shown that the technology can be used to great effect in creating a compelling and immersive piece of music.

With the early precedent of the Flaming Lips' "Parking Lot Experiments" in audience involvement of sound production, and the more recent and similar precedents by Sebastien Piquemal, Booka Shade, Eric Whitacre, David Baker, Ng Chor Guan, Arthur Wagenaar, the Smartphone Orchestra, and perhaps other individuals and groups who are yet to be discovered, presented, or published, it is clear that there is a small community of artists who realize that having the audience be involved in the sound production of a piece has the capability to result in a very special experience. Combine this niche underground scene with the pervasiveness of the smartphone in 2018 and the years beyond as such devices will only become more commonplace, and we have a formula for a new class of performance which can substantially reshape the landscape of performances of music involving electronic sound reproduction. Additionally, there is potential for it to affect any sort of entertainment involving electronic sound reproduction and broadcasting.

In this underground community, the variety of technological approaches one can find covers any conceivable setup a composer, director, or sound engineer might be looking for. The technological approaches of Arthur Wagenaar with his "Close Call" project and "The Smartphone Orchestra" project involves proprietary software, and as mentioned previously, both projects deal with the synchronization of audio differently. While both are effective, neither have made their software available for use by other music creators in either a free or commercial manner; of course, it is possible that these could develop into freeware or commercially available products in the future. Then there is the approach of "audience activation" of the sound which we find in the projects of Booka Shade, Ng Chor Guan, David Baker, and Eric Whitacre. These approaches are perhaps the easiest to implement for both concert organizers, sound engineers, and audience members alike, but lack in precision and synchronization due to natural and unavoidable human error.

Projects with a clear commercial intent like SpeakerBlast and Speakerfy appear to have the capability to synchronize multiple audio tracks, but have not yet sought this functionality, and besides, lack in consistent performance. Sebastien Piquemal's Rhizome project looks very powerful and versatile, and while not commercial at this moment, is made available for free use, however, it too suffers for ease of use at this point in time. Meanwhile, the BlindEar technology looks excellent insofar as it solves synchronization, but it is primarily geared as a performance assistive tool and would need to be reworked and refitted if use was desired with an audience being the users.

To this community, our team adds SynkroTakt as an option. With it, composers and sound designers can achieve synchronization sound of audience devices, both amongst the devices themselves, or all devices in conjunction with a live ensemble, with a straightforward setup. While the synchronization is true with Apple devices, made possible in part by Apple's stringent software and hardware integration practices resulting in a near-zero hardware latency which aids in our timing offset approach, the synchronization amongst non-Apple devices can be made believable and effective if careful consideration regarding aleatoric techniques is given to the musical content of the tracks sent to non-Apple devices, and careful consideration given to the arrangement of the work as a whole. SynkroTakt's user-friendly interface makes it easy for even non-technical users to quickly pick up while still providing versatility and power in the setup of various performances and audio delivery. All of these features, plus the additional capability of concert-hall track-mapping allowing for spatialization of sound, gives SynkroTakt the potential to be a central figure in this growing community. When we make SynkroTakt public, we hope that it will be compelling choice amongst the other options, given the effective approach to synchronization and the ease of use.

While I have been using SynkroTakt in a music performance situation, this is by no means the only application of the technology. There are a number of other implementations where SynkroTakt could be used, by myself or others when the technology is made available to the public. For instance, we have imagined a possibility of using SynkroTakt in a cinema setting, where the audience would connect their phones to a server before a movie begins, inputting their row and seat number, then throughout movie, sound could emanate from the audience's phones, providing atmospheric or environmental sounds while primary sounds of the film such as dialogue could still come from the hall's main speakers. Of course, the application could be taken further with primary sound such as dialogue, music, and effects coming from the audience's phones for a more avant-garde approach. Other applications could include sound-based or sound-involved art exhibits, where groups of audience members could connect to a SynkroTakt server before entering and then be guided along through the exhibit based upon the sound they hear. Use of the technology as an assistive tool in marching band performances or dance productions could offer resolutions to synchronicity and timing issues.

While much progress has been made with SynkroTakt, there are still a number of improvements we aim to work towards and additional functionality we could expand to, especially if we wish to see it gain prominence in concert music performances as well as the other applications mentioned. One small improvement would be the ability to keep the phone awake without user input, or continue audio output even while the phone is asleep. In watching a video on one's phone from YouTube, for instance, phones have protocols built into their software that prevents the phone from "sleeping" and the screen shutting off if a video is playing. Audio can be made to continuously play, even while the phone goes to asleep, but these are usually from audio-based applications such as a MP3 apps. Otherwise, a phone will normally fall asleep after no user input on the touchscreen or other physical buttons after period of time (usual defaults are anywhere from 1 minute to 5 minutes). Currently, and due to the way phones handle background audio on websites, audio streaming alone from a website (contrary to video) will not prevent it from falling asleep, thus, we have made it standard protocol for any SynkroTakt performances for the audience to be instructed to either turn off their phone's sleep setting, or tap the screen periodically to keep it awake. While there are a handful of "hacks" programmers have come up with over the years which, when placed in a website's code, can trick phones into staying awake indirectly, they are often patched by operating system developers periodically and many usually behave inconsistently from one phone to the next. Currently, we are still assessing ways in which a phone could be made to stay awake while streaming background audio on a webpage, despite the system's sleep settings. We are hopeful to find something as this would shorten and simplify the audience's setup time before a piece.

Another small improvement could be a more direct and automatic way of detecting a phone's manufacturer (for the purposes of our system, figuring out if it is Apple versus non-Apple). While such code currently exists, we have found it to be inconsistent in our personal testing, misidentifying devices frequently enough for it to be a concern. This would also shorten audience setup time, alongside another simple and more feasible improvement of using a hyper-short URL, rather than www.SynkroTakt.com/live. Another improvement which we hope to implement in the next major update, would be the ability to play a synchronized audio track from the remote page. In many cases, an ensemble member or a conductor may be the best person to trigger the start of the audio, so if they could do that from their device while also streaming a specific track from the audio page, that would be most ideal. Yet another improvement, perhaps most important of all, could be more precise synchronization amongst non-Apple devices, but as stated previously, this has been found to be caused by hardware latency, which is completely out of our hands. However, new and emerging WebAudio protocols look to put more of an emphasis on low latency, and such protocols could greatly assist in synchronization of non-Apple tracks within our system, if the protocol becomes widely adopted.

In terms of additions to the technology, we have conceived of two primary features which would be great for ease of use and involvement in new areas. Firstly, a user-friendly and intuitive interface for audio track mapping in a performance space would be an excellent addition. Currently, in order to map tracks to a concert hall, it is a very manual process in which I look at a seating chart of the hall, decide on the mapping, and then I edit the code of a file to give certain track associations to certain rows or seats, naming them all individually. We have envisioned a user interface in which one could upload an image file to a SynkroTakt server, and then by clicking on specific locations (seats, rows, columns, etc) in the image, that would create an entry in an index the server would reference in a performance, in which the user would simply see a pop-up for them to give the location a name and then associate it to a specific track. This is a key feature in our development roadmap as it would be the last thing to be updated from a non-user-friendly state to a more intuitive one.

The other addition to the system would be adding the synchronization of visuals in the form of simple colors. We have envisioned utilizing the phones' displays to project a solid color on the entire screen, and to gradually or abruptly change the displayed colors over time. We are thinking of it as if the phone were following a timeline of information regarding color changes and that timeline would start when the audio starts. For instance, one phone in the audience could start a performance like this: solid white at 0:00, from 0:09 to 0:14 fade to black, at 0:20 change to purple, at 0:22 cycle through purple, yellow, green, blue in that order changing every 100 milliseconds, etc. Of course, much like having different audio tracks synchronized together, the intent would be to provide the same for visuals. This visual information, which could exist as a file of timestamps with corresponding hexadecimal color codes, could be given to the phones all at once and only triggered to start when audio begins due to its low data size, or it could be streamed alongside the audio. While this idea of bringing in a synchronized visual element is exciting, it would involve not only a whole new branch of coding within SynkroTakt, but also a way for creators to create or dictate what visuals should be displayed at what time. We are not currently pursuing this idea, but we have considered (and will reassess in the future) bringing in additional personnel to add this capability.

The future for this performance medium and the use of this technology in music performance as well as other implementations is promising. In addition to myself and the SynkroTakt team, various other composers, artists, technologists, and forward-thinkers realize the impact of what a shared (yet still individualized) experience can leave on an audience. Harnessing the power, connectedness, and ubiquity of the smartphone can not only create stimulating sonic experiences, but potentially stands to pull the audience more deeply into performances by taking control over the very thing that has been distracting us at artistic showcases and dominating our social lives. Asking the audience to silence their phones during a performance is usually a guideline most are happy to follow; only rarely now in 2018 does one experience a stray call or text message due to someone forgetting to adjust their phone. However, asking them to completely put their phones away is not enough and usually not heeded by a great many of audience members – anyone who has been to a concert in the last decade realizes this – and I'm just as guilty as the average concert goer.

The way I see this technological addiction is not as a problem, but rather as an opportunity. If we are going to be engaged with our phones during a music performance, or even if we are even so much as tempted to check for a text message or email, take video or pictures, or anything that could draw us out of immersion and appreciation in a performance, I could use this temptation and the desire to have a phone in hand to my advantage by putting our phones to good use. Indeed, by requesting the audience to contribute directly to the performance by using their phone's connection to the web and its speakers, each person can take on a small sense of responsibility and ownership in the performance while being more engaged and connected to the performance, the performers, and their fellow concert attendees through this communal experience.

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APPENDIX

This appendix provides a technical look at the operation of the SynkroTakt software. It is essentially an overview of the functionality and operation of each component of the Performance Manager, cast as a set of instructions as it would need to be set up for a performance of the chamber orchestra version of “Honeycomb.”

The first thing to do would be to upload the “Honeycomb” MP3s to the server via the “Files” page of the Performance Manager. See Figure 11 below for a screenshot of the Files page. On the Files page, clicking the “+ New MP3s” button and then selecting all the desired tracks, including any click-tracks that the performers may need, will begin the upload process. After the upload is finished and the webpage is refreshed, all the audio files currently on the server will be displayed. From here, several options are given to the user, including deleting any files (the red minus button), altering the filenames of the MP3s, re-uploading any MP3s, test playing each file, and sorting the list for display.

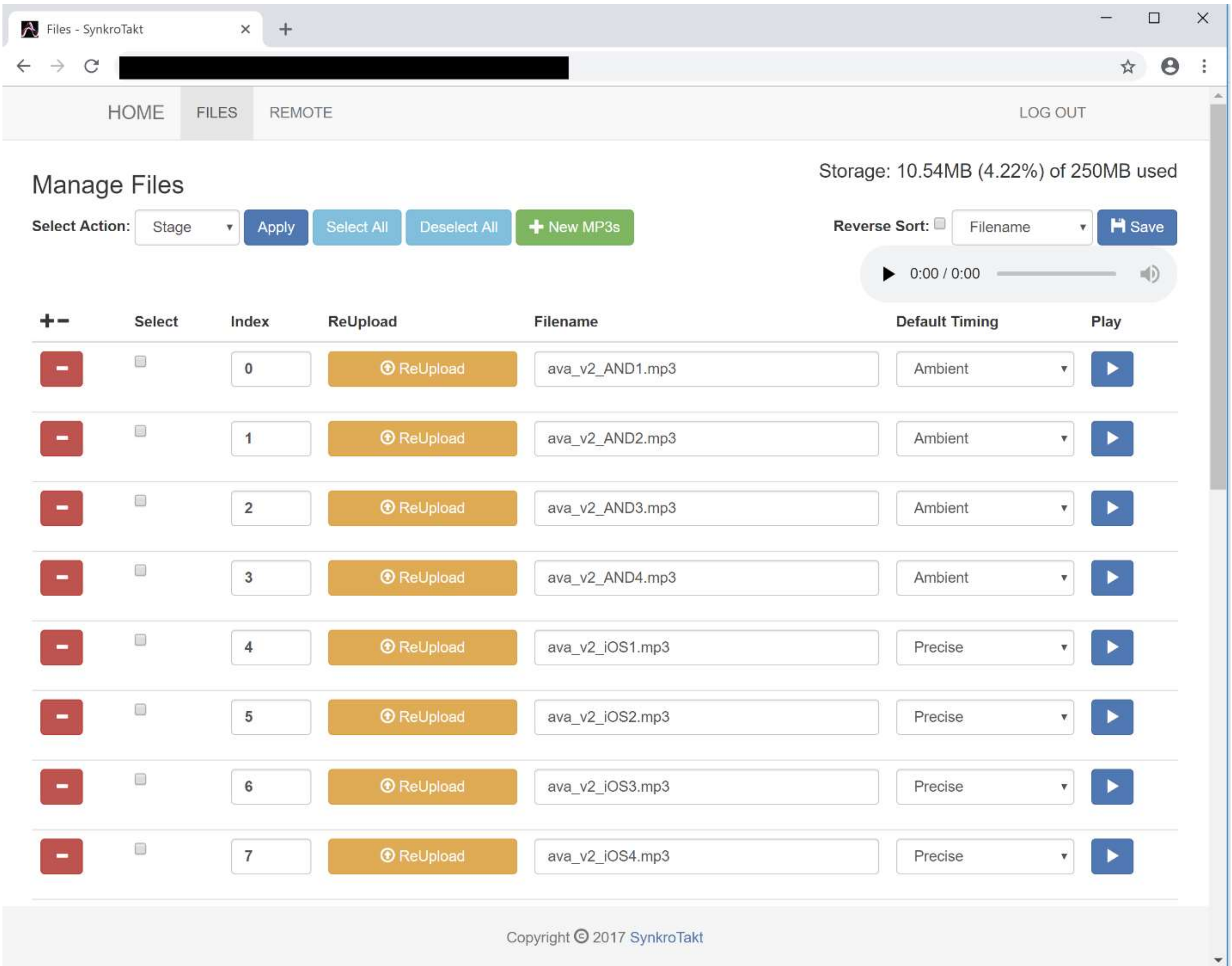

Figure 11. Screenshot of SynkroTakt software at the Files page.[102]

Most importantly in the setup of Honeycomb, however, is the "Default Timing" setting for each track, with the options consisting of "Precise," "Ambient," and "Stage." These three options for Default Timing refers to the audience accessibility and device-type assignment for specific audio files. Tracks assigned with the Precise setting will be only be sent to devices in which the user has indicated the device is an Apple device (with "precise" referring to the extremely low-latency in audio-hardware playback found in Apple devices). Tracks assigned

[102] Nicholas Saney, Richard Saney, and Cody Brookshire, SynkroTakt, computer software, version 6, SynkroTakt, accessed June 2018, www.SynkroTakt.com.

with the Ambient setting will be only be sent to devices in which the user has indicated the device is anything other than an Apple device (with "ambient" referring to the unpredictable latency in audio-hardware playback found in non-Apple devices). Tracks assigned with the Stage setting will be only be available to devices that have connected to the server via an alternate and secret web address, with the intention of this design being primarily for click-track access to conductors and/or performers. Tracks assigned with Stage as their Default Timing will not be delivered to the audience like all the Precise and Ambient marked tracks. For the chamber performance of "Honeycomb," the six iOS tracks should be set to Precise, the six Android tracks should be set to Ambient, and the click-track should be set to Stage. With all the tracks set to their appropriate Default Timing, clicking the blue "Save" button in the top right will solidify the changes and settings.

Navigating back to the Home page and clicking on the "+ Add New Performance" button will create a blank slot for the user to type in the title of the performance as they wish. For example, in Figure 4 on page 60, I titled the performance as "Honeycomb (Chamber Orchestra)," and then clicked the Save button to solidify the changes. Note that a new Performance need not be created every time the piece is played live. In this case, a "performance" simply refers to a collection of audio files and various settings associated with a specific work or project. Overall, the Home page is quite simple and offers a little other functionality as well, including sorting all Performances by date or title, and deleting performances. Depending on the capacity of the server, it is certainly possible to upload many MP3s for many different pieces of substantial length and have quite a number of Performances listed on the Home page.

Clicking on the blue "Open" button next to the performance labelled "Honeycomb (Chamber Orchestra)" will bring up a freshly-created and blank Performance page. Clicking the green "+ New Track" button 13 times (the number of tracks we need for this particular piece) will create 13 blank tracks that will be associated with this Performance. For each of these track slots, select one of the audio files that was previously uploaded from the list in the Filename column for each. Make sure that all the appropriate audio files are represented once and only once; it is best not to select the same file more than once in order to have the best chance at a balanced group of audio tracks playing in the audience. Now, the user may individually create a unique label, a title for the server to work with, for each track. Alternatively and more efficiently, the user may select all files' checkmark boxes, then select "FileToLabel" in the "Select Action" drop-down menu, then click "Apply." This action will automatically take the filename of each audio file and then make it the file's label. With all the file's checkboxes still checked, select "DefaultTiming" from the "Select Action" menu and click "Apply." This will update the Timing of each audio file to the Default Timing that it was set at right after it was uploaded on the Files page. This last step is critical in ensuring that the audio tracks are sent to their intended types of devices. See Figure 12 below for a screenshot of the Performance page, as it is set up for the chamber orchestra version of "Honeycomb."

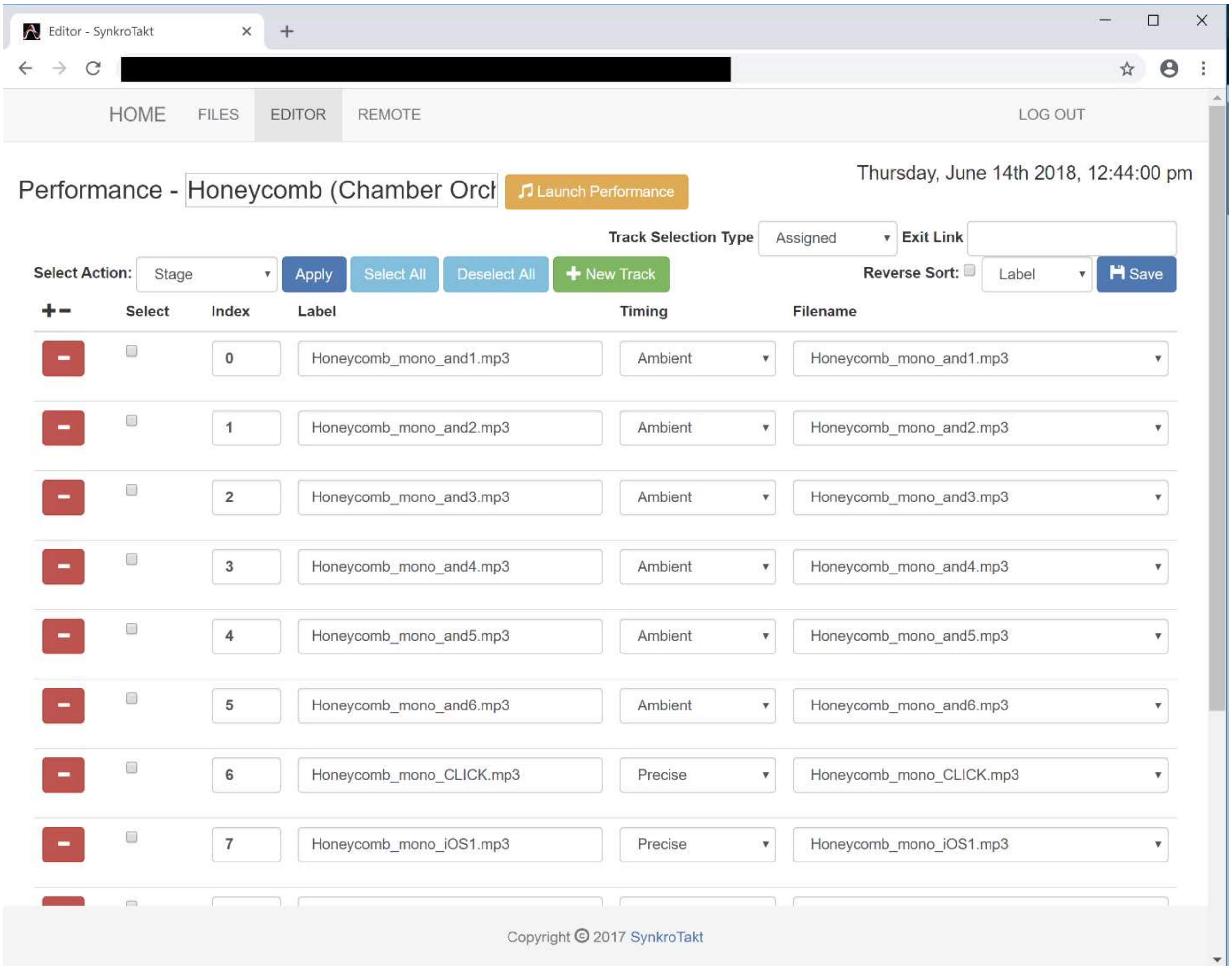

Figure 12. Screenshot of SynkroTakt software displaying a set Performance page.[103]

The Performance page offers other functionality as well, including the ability to delete tracks; change the performance title; sort the tracks by label, timing, or filename; as well as the ability to redirect an audience member's web browser on their device to a web page of the user's choice (useful for sending them to surveys after a concert, or the homepage of a composer, performer, or venue). Most important, however, is the "Track Selection Type," which when modified, changes the way the audience receives their tracks. The three options in this drop-down menu are "Assigned," "Direct Choice," and "Venue Map."

[103] Ibid.

If “Assigned” is chosen, the audience will have no choice in which audio track is streamed to their phone. The server will distribute all tracks to their designated device-types in a maximally-even fashion. For instance, say that a group of 7 audience members, who all happen to have Android devices, is the first to enter the hall and sit down for a chamber orchestra version of “Honeycomb.” The first Android device to connect and indicate to the server that their device is an Android-type (or any non-Apple device, essentially) will receive the first track intended for Android devices (tracks with the “Ambient” Timing); the second Android to connect will receive the second Android track; and so on until the seventh Android device connects, in which the distribution count would reset and this device would receive the first Android track. The process would be the same for Apple devices and the six tracks intended for Apple devices (tracks with “Precise” timing). As the size of an audience grows and the likelihood of a 1:1 ratio between Apple and non-Apple devices increases, the “Assigned” method of track distribution will lend itself to a balanced field of sound.

One of the other options for Track Selection Type, “Direct Choice,” will allow the audience to choose among all the tracks for their intended device-type. After a user indicated their device type (let’s assume for a moment they indicated Apple), the user will be presented with a list of all the tracks that have the Timing set as “Precise” in the Performance, and they can choose which track they wish to hear. In the case of “Honeycomb” this particular Track Selection Type is not appropriate for the more balanced sound field I desire. With “Direct Choice” set, it is more probable that an imbalance in track selection could occur with users simply picking the first track or last track. However, this option could be very useful for more interactive performances, in which audiences could choose from tracks with more descriptive and enticing labels, where an imbalance in track choice could prove to be a more interesting musical experience, or a personal choice based on the label could be interesting to hear against other audience members' personal choices.

The last option to choose from for Track Selection Type is "Venue Map." With this option, a member of the SynkroTakt team must create a customized mapping of the hall, with each specific row and/or seat number, or entire sections or quadrants, corresponding to specific tracks. The audience members would input their location information during a slightly modified connection process and be given a specific track based on that input, which when taken advantage of by appropriate mixing, can create an immersive and controlled spatialized musical performance. This was Phase 3 of the original SynkroTakt development plan, and it was finally realized when "Honeycomb" was performed by the Hodgson Wind Ensemble at the 2017 CBDNA National Conference in Kansas City, Missouri and again with a slightly different approach to the spatialization and mapping a month later at the University of Georgia. (The approach to controlled spatialization and wind ensemble version will be covered below.)

After the user is satisfied with parameters of the performance, they will click the "Launch Performance" button and after a brief synchronization process, the "Remote" page will appear. Aside from the primary function of initiating playback of the piece via the large green play button, this page offers some additional functionality. Particularly useful for rehearsals is the seekbar, which allows the user to start the audio playback at a location in the audio timeline other than 0:00, by an intuitive scrub-type operation. Alternatively, the user can take advantage of the minute and second drop-down boxes to achieve the same ends in a more precise fashion. See Figure 13 below for a screenshot of the Remote page.

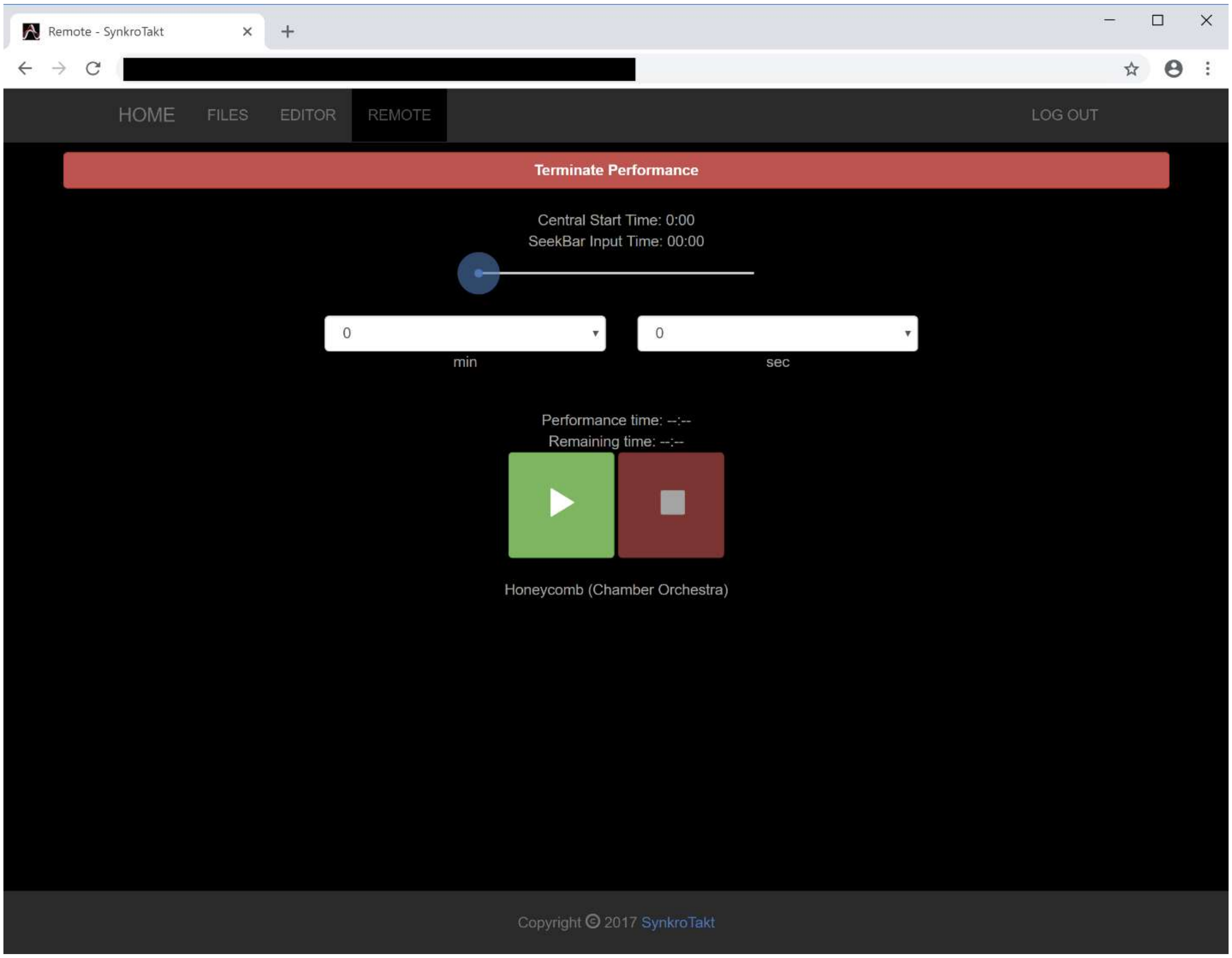

Figure 13. Screenshot of SynkroTakt software at the Remote page, ready to initiate a performance.[104]

Right next to the large green play button is a red stop button, which immediately halts all audio playback. After pressing the stop button, re-hitting the play button will restart audio playback at 0:00, or the location in the timeline as specified by user input via the seekbar or the drop down boxes. For instance, say that a conductor was needing to rehearse a particularly difficult section beginning at 3:15 for about 20 seconds in a 5:00 piece. After setting the seekbar or using the drop-down boxes to set it to 3:15 and then initiating playback, they would hit stop

[104] Ibid.

when they were finished rehearsing that section, and SynkroTakt would automatically have the 3:15 start time already set and ready to be utilized again. If desired, the user can always reset to 0:00 by sliding the seekbar all the way to the left, or by using the drop-down boxes.

Lastly, but important to note is the large red "Terminate Performance" button. Primarily, this is to be used when the performance (or rehearsal session) is over, where clicking it will bring the user back to the Performance page for that work. This clears the server of any set Performance and can be thought of as reverting back to a safe "standby" state. However, there is a secondary use for the "Terminate Performance" button, in the event of errant and "overhanging" sounds and audio tracks. As mentioned previously, there have been a few instances of audio tracks continuing to play beyond the end of the piece, meaning that they were de-synchronized likely due to a user letting their phone fall asleep during performance. If a performance coordinator that is running the SynkroTakt remote for a performance happens to observe such errant sounds at the end of a performance, tapping the "Terminate Performance" button overrides all previous directions every phone received in regard to streaming and playing any current or remaining audio buffers, halting all playback upon reception of the signal from the SynkroTakt server. While not perfect, this secondary functionality does serve to mitigate the errant sounds issue should it arise at the end of a performance.