Hyperaudience

Designing Performance Systems for Audience Inclusion

AKITO VAN TROYER

Bachelor of the Arts in Interdisciplinary Studies for Multimedia
University of Hawaii, 2007

Master of Science in Music Technology
Georgia Institute of Technology, 2011

Submitted to the Program in Media Arts and Sciences,
School of Architecture and Planning,
in partial fulfillment of the requirements for the degree of
Master of Science in Media Arts and Sciences at the
Massachusetts Institute of Technology
August 2012
[September 2012]

Author: AKITO VAN TROYER
Program in Media Arts and Sciences
August 1, 2012

Certified by: TOD MACHOVER
Muriel R. Cooper Professor of Music and Media
Program in Media Arts and Sciences
Thesis Supervisor

Accepted by: PATRICIA MAES
Associate Academic Head
Program in Media Arts and Sciences

Hyperaudience

Designing Performance Systems for Audience Inclusion

AKITO VAN TROYER

Submitted to the Program in Media Arts and Sciences,
School of Architecture and Planning,
on 26 August 2012, in partial fulfillment of the requirements for the degree of
Master of Science in Media Arts and Sciences at the
Massachusetts Institute of Technology

ABSTRACT

We define the concept of the Hyperaudience and a unique approach towards designing real-time interactive performance systems: the design of these systems encourages audience participation and augments the experience of audience members through interconnected networks. In doing so, it embraces concepts found in ubiquitous computing, affective computing, interactive arts, music, theatrical tradition, and pervasive gaming. In addition, five new systems are demonstrated to develop a framework for thinking about audience participation and orchestrating social co-presence in and beyond the performance space. Finally, the principles and challenges that shaped the design of these five systems are defined by measuring, comparing, and evaluating their expressiveness and communicability.

Thesis Supervisor: Tod Machover
Muriel R. Cooper Professor of Music and Media
Program in Media Arts and Science

Hyperaudience

Designing Performance Systems for Audience Inclusion

AKITO VAN TROYER

The following person served as a reader for this thesis:

Thesis Reader ______________________ JOSEPH A. PARADISO

Associate Professor of Media Arts and Sciences
Program in Media Arts and Sciences
Massachusetts Institute of Technology

Hyperaudience

Designing Performance Systems for Audience Inclusion

AKITO VAN TROYER

The following person served as a reader for this thesis:

Thesis Reader ROSALIND W. PICARD

Professor of Media Arts and Sciences
Program in Media Arts and Sciences
Massachusetts Institute of Technology

ACKNOWLEDGMENTS

I'm deeply indebted to the following individuals for their support and inspiration:

My Advisor Tod Machover.

Friends, colleagues, and peers of Opera of the future group: Ben Bloomberg, Bob Hsiung, Elena Jessop, Taya Leary, Simone Ovsey, Eyal Shahar, Peter Torpey, and Janice Wang.

Chroma District: Dimitris Papanikolaou, David Costanza, Seung Jin Ham, and Meg Rotzel.

DrumTop: Joseph Paradiso, Mark Feldmeier, Nan-Wei Gong, and Laurel Pardue.

SIILPE: Rosalind Picard, Javier Hernandes, Rob Morris, and Akane Sano. Also anonymous participants who participated in the study.

A Toronto Symphony: Tae Kim and June Kinoshita for project.

Members of *Punchdrunk*: Felix Barrett, Pete Heggin, Colin Nightingale, and Livi Vaughan. MIT Media Lab Team members for *Sleep No More* including Gershon Dublin, Jason Haas, Nick Juliot, Brian Mayton, and Jie Qi.

Tom Lutz and John Difrancesco for fabrication support.

Families from the Georgia Tech Center for Music Technology (GTCMT): Parag Chordia, Frank Clark, Jason Freeman, Gil Weinberg, Aaron Thomas Albin, Meghashyam Adoni, Andrew Beck, Brian Blosser, Xiang Cao, Ruofeng Chen, Andrew Colella, Gilberto Gaxiola, Mark Godfrey, Oliver Jan, Jagadeeswaran Jayaprakash, Sang Won Lee, Trishul Mallikarjuna, Vamsi Bharadwaj Mynampati, Ryan Nikolaidis, Alex Rae, Avinash Sastry, Sertan Senturk, Sidharth Subramanian, Sriram Viswanathan, and Andrew Willingham.

My roomies David Lakatos, Adam Setapen, and a cat Lilu for being awesome.

People from Hawaii: Chris Formaneck, Joseph Formaneck, Christian Miller, Mayco Santaella, Nicholas B Tillinghast-Lewman, James Hearon, Byron Moon, Pak Hardja Susilo, Pattie Dunn, and Paul Rausch.

My family: Tomoko Oshiro, Gene van Troyer, Miika Asama, and Makoto Oshiro.

CONTENTS

LIST OF FIGURES

DESIGN STUDIES

TOWARDS A FULL HYPERAUDIENCE SYSTEM

1. INTRODUCTION

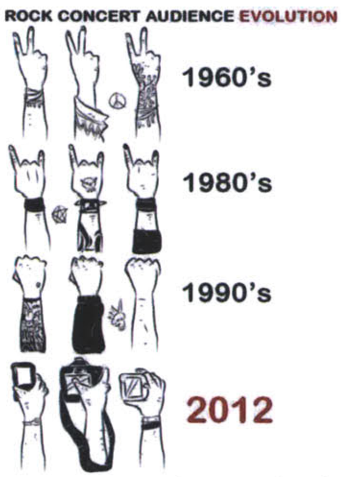

Figure 1.1. Evolution of rock concert audience.

Visual.ly, a community platform for data visualization and infographics, posted the image shown in Figure 1.1. on July 8, 2012 on Facebook [Visual.ly, 2012]. This image demonstrates the evolution of the rock concert audience: it shows how the audience hand gestures changed over the last fifty years as the rock concert culture changed. If we focus our attention on the gestures in the year 2012, we see that the rock concert audience members are now carrying bulky objects in their hands. These are digital cameras and mobile phones. Audience members in present-day rock concerts take pictures and videos with these devices during a concert to keep as a memory for themselves or to share with their friends and families. To share their experience, these audience members may choose to upload their pictures and videos to social media platforms such as YouTube and Twitter. The modern technology empowers audience members to extend their experience of a performance beyond the performance space.

This is a small and simple example, but it well illustrates the topic of this thesis: audience members with modern technologies are actively collecting their experiences in order to connect with and to tell their own version of a story to the others. In other words, modern technology is mediating and augmenting the performance experience of audience members. In this thesis, we call the audience members who use such participatory technologies to augment their experience the *Hyperaudience*. The Hyperaudience augments their experience by becoming communicative and participative in the performance using technologies. They are the emerging new audience in the modern performance space, and such an audience is capable of contributing to a performance and connecting with other people through a technologically mediated performance space. We define the concept of the Hyperaudience and a unique approach towards designing interactive performance systems that brings a special performance experience to the audience in and beyond the performance space.

1.1. Hyperaudience System

The Hyperaudience exists in a technologically mediated performance space. The audience members actively participate in a performance and may be connected to computer networks to experience a performance in and beyond the performance space. A performance system for the Hyperaudience needs a conceptual framework; namely, the framework for designing interactive performance systems for audience participation and communication. Such systems are capable of empowering audience members to shape and create complex and unique personalized experiences. This is achieved using digital interfaces to capture the activities of the audience to influence a real-time interactive performance environment. The focus of a Hyperaudience system is to measure and interpret audience expressions and feelings. The system uses such information as the fundamental design principles of a digital performance system to engage and connect audience members.

1.2. Objectives and Scope

This thesis seeks to fulfill the audience's desire to experience something spectacular in a performance by creating new interaction models and by advancing the state of the art in performance technology. Specifically, the mission is to take advantage of technology-based performance spaces to empower audience to be communicative, co-creative, and performative. We envision the future audiences in the performance space to enhance their experience by being communicative and participative: the audience members use the space as a communication platform to contribute to a performance and to have a multimodal dialogue among them and also between performers and the audience. We foresee that such an enriching audience experience flourishes from the conceptual and aesthetic parameters associated with the technology in a performance space. Based on these parameters, we synthesize the conceptual framework of the Hyperaudience system to explore how and in what way can the technology be used in the performance space to connect and enhance the experience of audience.

This thesis is significant because it illustrates a unique vision for interactive public performances: it explores ways to enhance social experience and enables an interconnected performance experience for audience members and performers. The goal of this thesis is the design and implementation of the Hyperaudience system. The ideal form of this system inspires audience members in ways such that they feel connected to performers and to each other. In addition, the system motivates the audience to realize new ways to be creative and to become aware that the performance was unique, partly because of their contributions to the performance. This thesis presents several examples of works that approach this goal.

The conceptual framework of a Hyperaudience system includes the following:

- The system empowers the audience to be expressive.

- The system supports active audience participation, by which we mean audience members readily shape and contribute to a performance in real-time through an interface. The system is also capable of giving feedback to the audience to inform them of their contributions.

- The system encourages audience members to be communicative, co-creative, and co-explorative. By doing so, it promotes audience members to co-experience a performance.

- The interface that audience members use to participate in the performance is transparent and user-friendly. The audience does not need to learn about or be skilled at operating the interface, as most audience members are likely to be first-time users and have no time for a learning curve.

- The system is robust and modular, in order to accommodate the spontaneous changes to the development of a performance production and the improvisational nature of an actively participating audience.

These conditions originated in theories found in ubiquitous computing, pervasive gaming, affective computing, interactive arts, and audience participation works from music and theatre. Using these fields of study as a background, this thesis captures an extensive view of the audience in order to inform our discussions with the issues that surround the Hyperaudience system. In addition, the systems demonstrated in this thesis make use of digital fabrication technologies for producing objects, custom electronics to give intelligence to produced objects, and computer software to facilitate real-time audience interactions.

1.3. Contributions

This thesis develops a new framework for thinking about engaging an audience and orchestrating their social co-presence in and beyond the performance space. The significant contributions from this thesis include:

- A history of systems that carry the characteristics of the Hyperaudience system. This includes both digital and non-digital aspects of prior audience participation systems.

- Five new systems that embrace the characteristics of the Hyperaudience system, including the design concept, interaction model, implementation, and execution of each system.

- A language for evaluating the overall success of the five new systems. This is achieved through an analysis of the five new systems, including a classification of their interaction design patterns and a comparison of the relative success of each system evaluated according to this language.

- A Framework that, when put together, defines the properties of an ideal Hyperaudience system.

- A brief outline of future directions, unexplored areas, and example applications for continued research in the domain of Hyperaudience.

1.4. Terminology

The *Hyperaudience* extends the idea of *Hyperinstruments* [Machover, 1992]. Hyperinstruments is a concept: the goal is to design expanded musical instruments that use technology to give extra musical power to performers and to the general public. In this thesis, we call the audience who have the similar extra power as the Hyperinstruments concept and can communicate and participate in the performance as the Hyperaudience. Such an audience exists in various technologically mediated performance spaces including theaters, museums, art galleries, and music venues. The Hyperaudience augments their experiences by contributing to a performance and connecting with other people in and beyond the performance space.

The goal of this thesis is the design and implementation of participatory technologies for the Hyperaudience. In doing so, we synthesize the conceptual framework of the *Hyperaudience system*. The conceptual framework is built upon studies of the past audience participation-based performance systems and the design studies conducted and reported in this thesis.

1.5. Roadmap

The rest of this document is organized into four chapters. In Chapter Two, *Background*, we study the preceding performance systems for audience participation as they are the forerunners in forming the conceptual framework of the Hyperaudience system. The framework adheres to both digital and non-digital aspects of the prior audience participation works. The non-digital works are included because they enlighten us with unique audience participation practices that have a significant impact on the audience perception.

The chapter also reveals the underlining design characteristics of audience participation systems. By studying the strengths and weaknesses of the prior systems and borrowing the conceptual ideas from these systems, a set of hypotheses are introduced that any Hyperaudience systems should satisfy. This framework forms the basis of the new work that is presented in this thesis.

Chapter Three, *Design Studies*, presents new studies that support this hypothesis. These new studies are performance systems, each designed for a different purpose, and they were developed during the author's enrollment in the MIT Media Lab with the Opera of the Future group over the last two years. They all explore ways for audience members to participate, to blur the boundaries between performers and audience, and to empower audience to intuitively play with the system. These systems all contain some aspects of the Hyperaudience framework. As each system is discussed, the chapter considers the concept of the project, design methodology, implementation of the system, and execution of the performance.

Chapter Four, *Towards a Full Hyperaudience System*, analyzes the systems that are presented in Chapter Three. In doing so, we illustrate the ways in which each system differs, succeeds, and fails and the design space of the Hyperaudience system. The chapter is divided into four parts: a section on the interaction design patterns derived from the systems in Chapter Three; a comparative study of the systems using a set of qualitative measurements; a section on the challenges encountered in the development and execution of each performance; and a section that discusses the contexts within which the systems can be evaluated.

Chapter Five, *Conclusions*, presents the summary of the thesis and discusses directions for the future research. This section discusses improvements to the current framework of the Hyperaudience system and demonstrates example applications that would conform to the conceptual framework of the Hyperaudience systems.

2. BACKGROUND

In this chapter, we explore a survey of related works. Along the way, the chapter introduces the underlining characteristics of audience participation and the design of systems that underpin participation in real-time and non real-time settings. Furthermore, these existing practices are then used to assess the objectives of the framework of Hyperaudience System in the latter chapter. Together with the strengths and weaknesses of the prior works, a set of hypotheses is introduced that forms the conceptual context, within which these works are situated, that any Hyperaudience Systems would satisfy.

This chapter separates the relevant background into three sections. The first section, *Music*, introduces several unique practices in music that describe the transforming relationships of the audience and performers as well as the audience inclusion methods. The core part of this section focuses on technology-based audience participation works found in music. The second section, *Theatre*, also examines the transforming role of the technologically mediated audience members and the technology-based audience participation works found in theatrical settings. The final section, *Public Spaces*, examines the general audience participation practice in public places such as art galleries and urban environments.

2.1. Music

Audience participation in music performance is certainly an old concept, but it is valuable for us to look at how the practice of audience participation works in music has evolved with the development of new technologies. In this section, we first briefly cover the context in which the audience is situated in music and seek the reason why encouraging participation is crucial from sociological perspectives. We then examine *Hyperinstruments*, the conceptual project that the idea of the Hyperaudience stems from. Finally, we look into audience participation in music, including concert hall music, collaborative music making, network music, and social music listening.

2.1.1. Music Theories and Culture

In the past, many great music theorists dreamed of a world where audience members becomes the focal point of music performance. A twentieth century composer, John Cage, once wrote that he aspires to change the relationship of performer and audience, especially in the classical music scene [Cage, 1984]. He argued that music cannot be separated and detached from its listeners and form its context. For him, creating music was a process that was initiated by the composer or performer, but could only be completed by the audience. The listeners' experience of the work was essential to the music itself.

Jaques Attali writes that the future production of music will take place under the concept of *Composition* [Attali, 1985]. He meant that listeners, who were then only consumers and listeners of music, will become its producers and performers as well. In Attali's vision, the future audiences will not only listen to music but create their own music for their own pleasure, and no distinction between musicians and audiences is made: a world in which people define music for themselves to compose, perform, and serve as the audience for that music.

The concept of the Hyperaudience follows the ideas of these music theorists in that the audience becomes the focal point of the music and the role of audience transforms from just merely being the observers of the music to participants, or to even performers of music. The Hyperaudience achieve this by empowering the audience with modern technologies to blur the boundaries between performers and the audience. The new possibilities and innovations are envisaged when distinctions between musicians and audience are destabilized.

Music Audience Across Cultures

This section is prepared to remind us that some music performances in cultures place the audience in a unique position. Unlike the traditional Western concert hall where the boundary between the audience and the performer is distinguished clearly, the boundary between the audience and the performer in these performances is less well-defined in some cases and the role of the performer and the audience in the performance often may switch. For instance, in epic performances by the Kpelle of Liberia, the audience becomes the singing chorus [Stone, 1988]. The singing underlines the epic as it is narrated and dramatized. Stone notes that the Kpelle people have a hard time imagining people who might only watch a performance. For the people of Kpelle, 'the music is not successful with those who are content to stand still' [Stone, 1988].

The prominent elements of Algerian folk traditions, *sha'bi*, include the repetitive melody, percussive beat, audience participation through dancing, hand clapping, and joyous singing [Al-Deen, 2005]. Al-Deen notes that Rai musicians targets the young audiences and music is purposely made to be danceable so that they can participate and carry on the music tradition. Looking through these examples, some cultures in Africa experience audience participation based ritualistic performances that are tightly integrated with a social community.

Dwight W. Thomas writes that the gamelan audience at Lou Harrison's Javanese gamelan performance have different expectations at gamelan concerts. Talking is common, children are expected to attend and often walk the aisles, and people even come up on stage to see the performance closer [Thomas, 1983]. These activities contribute to the new form of audience expectation and audience/performer relationships, destabilizing the performance situation.

The concept of the Hyperaudience follows in a similar footstep to these music practices in different cultures where the audience is not just an observer of the performance, but a partner who co-create the performance with the performers.

2.1.2. Hyperinstruments

The Hyperinstruments project was originally started in 1986 by Tod Machover at the MIT Media Lab. The basic concept of a Hyperinstrument is to take musical performance data in some form, to process them through a series of computer programs, and to generate a musical result [Machover, 1992]. The goal of the Hyperinstruments project is to design expanded musical instruments, using technology to give extra power to virtuosic performers. The Hyperinstrument systems have been used by many exceptional performers including Yo-Yo Ma (Figure 2.1.), Peter Gabriel, and Penn & Teller.

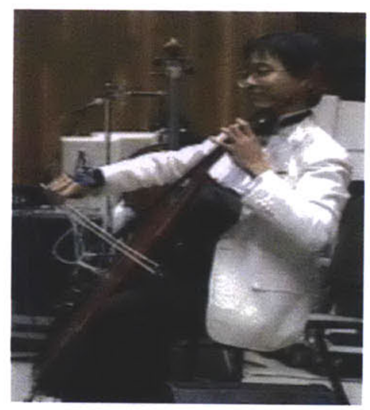

Figure 2.1. Yo-Yo Ma performing with the Hypercello.

Hyperinstrument systems have also expanded in an attempt to build interactive musical instruments for non-professional musicians, music lovers, and the general public. They allow non-musicians to shape and create complex and interesting musical pieces by using gestures or word descriptions to influence the real-time interactive environment.

The framework for the Hyperaudience system extends Hyperinstruments, specifically, from those of *Brain Opera* and *Toy Symphony* projects [Paradiso, 1999][[Jennings, 2003]. The focus of the

Hyperaudience framework expands upon the Hyperinstruments agenda part three: 'giving unprecedented creative power to the musical amateur.' [Machover, 1992]. The framework for the Hyperaudience system inherits this idea but with various performance spaces in mind where audience exists, such as a concert hall, an art exhibit, and a theatre.

We examine *Brain Opera* and *Toy Symphony* in detail to explore the elements of music performance that contribute to active participation and co-experience.

Figure 2.2. Kids playing with the Rhythm Tree.

Brain Opera

Brain Opera is a large multimedia production and performance where audience members first explore musical instruments at a variety of novel and interactive settings before experiencing them in the actual performance by the performers [Paradiso, 1999]. The project connects audience with a series of Hyperinstruments designed for the general public and a series of real-time music activities on the Internet. Audience members explored the tangible musical instruments and created personal music that makes each performance unique. For example, the *Rhythm Tree* included a large number of drum pads connected to a tree-like structure that was actuated by the audience to produce percussive sounds (Figure 2.2.) [Weinberg, 2005]. The project brings self-expressions and creativity to everyone, in the public space or at home, by combining an exceptionally large number of interactive modes into a single, coherent experience. *Brain Opera* redefined the nature of collective interaction in public spaces and explored the possibilities of expressive objects and environments in and beyond the performance space.

Figure 2.3. *Mind Forest*. The *Brain Opera* performance space.

Interactive Experience

Brain Opera encouraged audience participation [Orth, 1997]. The audience who participated in the first session of *Brain Opera* were diverse, with many older people and kids. They interacted with many Hyperinstruments to create music and graphics. The Hyperinstruments were arranged like furniture on the stage (Figure 2.3.) and facilitated interactions for the audience by a sense of privacy for an individual player and a sense of communal experience as a group. The sculptural qualities of the Hyperinstruments motivated curiosity in the audience, encouraging them to try more than one instrument and move around the space to try other instruments. The interaction with these instruments was designed to be unexpected yet clear to the audience. The clues to direct and assist the audience were both given from the physical design of instruments as well as the software design. Some instruments displayed directions on the computer screens while others used visual metaphors of familiar shapes, such as punching bags and bicycle handles, to guide the audience.


Figure 2.4. The Singing Tree in *Brain Opera*.

The online audience was also able to participate in the performance of the *Brain Opera* by contributing sound samples that were to be used in the performance and manipulating the online instruments in real-time [Machover, 1996]. It was a new genre of collaborative systems, engaging the online players to communicate over a network from remote locations. *Brain Opera* demonstrates aspects of participation and co-experience in a technologically mediated music performance. People participated in the performance by actually playing the instruments on the stage, and some others contributed sound samples to the performance through the internet. People also were co-experiencing the Hyperinstruments on the stage, providing a pivot point for the audience to be communicative, co-explorative, and co-creative.

Toy Symphony

The *Toy Symphony* is a large project that involves children, orchestras, and technologies. The aim of the project was to connect professional musicians and children as well as audience and performers through musical activities such as composition and performance. The project also aims to change how children are introduced to music and to redefine the relationship between professional musicians and young people [Toy Symphony, 2012]. The performance of the *Toy Symphony* project also was designed to provide an inclusive experience for the audience to change the relationship of the orchestra with youthful collaborators, the new instruments, sounds, and ideas. During the course of the project, children in Europe and the US participated in composing music pieces. Some of the composition were then performed by the local professional orchestra. Children also collaborated with the professional musicians in the performance by performing music in front of the audience. We cover some of musical instruments and software used in this project that enhanced the musical experience of the general public.

Figure 2.5. The Toy Symphony logo.

Composition

The participants in the *Toy Symphony* project used Hyperscore, a graphical music composition software environment, to intuitively compose music without necessarily having expert knowledge in music theory. The software provides opportunities for people to compose a piece of music and have the orchestra play that piece for them

[Farbood, 2004]. Hyperscore facilitates composition through mapping musical features with graphical abstractions of a drawing canvas. Notating music scores is accomplished through drawing a line 'as opposed to displaying musical events in a procedural notation or as a set of parameters' (Figure 2.6.) [Farbood, 2004]. Hyperscore is intuitive enough for children that, in almost all cases, they were able to successfully complete the task of composing a short piece of music within the workshops of the *Toy Symphony* project.

Figure 2.6. The example computer interface of Hyperscore. Hyperscore lets you compose orchestral music intuitively through drawing gestures.

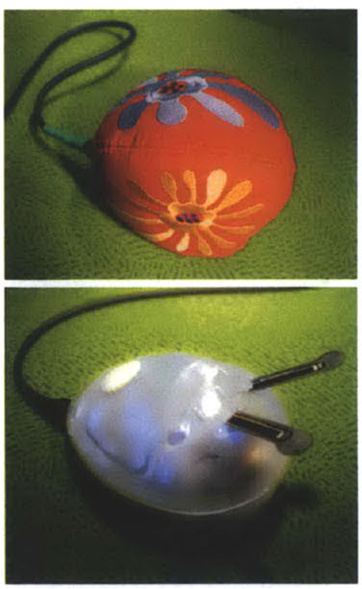

Figure2.7. The Music Shaper (Top) and the Beatbug (Bottom) used in *Toy Symphony*.

Performance

The children used physical music toys to perform music with the orchestra. Two main instruments used in the project were the Music Shapers and the Beatbugs (Figure 2.7.). The Music Shaper is a fabric musical instrument designed to be played in a group configuration, and it contains pressure sensors that measure squeezing pressure. The sensor data is processed by a computer and the data is used in number of different ways. For example, the Music Shapers were used to trigger and manipulate synthesized or pre-recorded sample sounds.

The Beatbugs are handheld electronic percussion instruments. The instruments are made for a collaborative performance for novices. The instrument was struck or tapped by hands to produce a percussion sound from a computer and LED flashes provided extra visual feedback to the performers and audience. The programmed rhythm patterns were then modified using the antennas on the instruments to affect the tempo and pitch of the percussion sounds. The Beatbugs are also capable of sharing rhythm patterns among players, making collaboration among players fun. The children performed music with the professional musicians using the Beatbugs and made collaboration and improvisation unique and enthusiastic.

Kevin Jennings notes that the interactions in music happen through people performing, composing, or listening to music [Jennings, 2003]. The children involved in the *Toy Symphony* interacted with each other through these attributes of music. The children involved in the project commented that participating in the project, workshop, and performance were the most enjoyable experience for them, and the ability of the project to facilitate participation and co-experience among children was the core element that made this project a successful one. The concept of the Hyperaudience for music performance also harnesses such attributes to engage the audience in the performance.

2.1.3. Computer Music Performance

Computer music performances that portray the ideas of the Hyperaudience are mostly found in musical works for audience participation. The tradition of musical works for audience participation is to transform the role of audience into performers or composers: the audience creates or shapes some or all of the music during the performance. One of the first attempts at creating a real-time audience participation-based performance for a large scale audience can be seen in the works of Jean Hasse's Moths [Hasse, 1986]. During the performance, the conductor directed the audience when to whistle and a graphical score was also projected for the audience. The piece did not require a complex technological configuration, but it successfully transformed the role of the audience to be the performers of the music.

Real-Time Music Notation Systems

More recently, a real-time music notation system became one of the common ways to have the audience participate in a computer music performance. *No Clergy* is an interactive music performance situated in a gallery setting [Baird, 2005]. The piece explores the boundaries between audience and composer by providing a web browser-based interface for the audience to participate in shaping the outcome of the musical performance. The audience was able to participate in the performance by modifying the ongoing music through the web browser interface set up in the gallery. They altered music notations, and the notations were then displayed on computer screens prepared for the performers. The alteration of notation was accomplished using stochastic transformations of music and the audience was able to influence both the general directions of musical changes and the range of variations in music. Baird notes that thinking about the outline and environment of a performance in which audience members can comfortably participate are critical for the success of the audience participation-based computer music performance.

Figure 2.8. An example visualization of an audience gesture that a performer saw [McAllister et al, 2004].

An interactive performance work done by McAllister, et al provided the audience with the ability to interact with a live musical performance using Personal Digital Assistants (PDAs) [McAllister et al, 2004]. The wireless PDAs captured and transmitted gestures on the touch screen from the audience members. The gestures were then translated into a visualization that mimics the Western musical notation system (Figure 2.8.). The musicians interpreted the visualization as a music score and performed according to the score. In the performance, only limited amounts of PDAs were available for the audience and participants were randomly chosen to use them. A gesture activated on one PDA corresponded to controlling one of the music score visualization computers on the stage. The participants of the performance suggested that the communication with their corresponding musician enhanced their performance experience encouraging them to be actively involved in a jamming session. They also found that the system gave them an instantaneous musical response from their associated performer.

The LiveScore project, by Barrett, et al, experimented with a real-time generative music system and the ability of human musicians on acoustic instruments to play that music [Barrett et al, 2007]. In doing so, gallery visitors were invited to change the knob positions on a MIDI controller to change the parameters of a stochastically generated music notation. Musicians performed the resulting notations appearing on a computer screen while audience members walked around the space and viewed the music notation. The performance offered the gallery visitors the ability to experiment with the human musicians and it effectively blurred the boundary between the audience and the performers. The performers noted that the participants' ability to manipulate a style of music was a critical point of interest in playing the piece.

Glimmer, by Jason Freeman, is a composition for audience participation with the chamber orchestra [Freeman, 2008]. In this performance, audience members are given a battery-operated multicolored light stick. The audience used this to flicker their light sticks during the performance (Figure 2.9.). The flickering lights were captured using a computer vision system and a computer algorithm translated the activities into music notations for the orchestra. The performance accommodated a large number of audience members and they were divided into groups. Each group then had influence over a corresponding group of musicians in the orchestra. *Glimmer* relied on the activities of the entire audience groups rather than of individual members. Because of this, facilitating groups to collaborate the light flickering was important in *Glimmer* to control the course of the evolving piece.

Figure 2.9. Audience waving light sticks in *Glimmer*.

In *Flock*, Jason Freeman builds upon *Glimmer* and pays special attentions to how the course of musical interactions takes place (Figure 2.10.) [Freeman, 2010]. The level of interactivity allowed by the participants was carefully chosen. The performance for *Flock* requires videos, sounds, dancers, a saxophone quartet, and audience. The audience for *Flock* wears an illuminated hat and moves around an open performance space with help from the dancers. The location of the participants is determined using a camera and computer software. The software takes advantage of this location data and generates music notation, electronic sound, and video animation on the fly.

Figure 2.10. The performance of *Flock*.

Freeman evaluates *Flock* by collecting surveys from the audience and the result shows that the audience had a mixed response to whether they had been creative and the performance could have been different without them. Freeman notes that facilitating the audience's understanding of the work is important so that they know their role in the performance and know how to appropriately contribute to the performance. An interesting observation of the performance is that the audience members were most creative when only a handful of participants were on stage. We suspect that, in *Flock*, fewer participants in the performance space helps the participants better understand their relationships to the musicians, dancers, and visuals because as the number of participants on the performance space decreases, the individual participants come to have more control over the musical and visual outputs of the performance system.

Mobile devices

Researchers and artists are actively exploring the ways to use mobile devices in a musical performance for the purpose of audience participation. These projects are valuable resources for the design of the Hyperaudience system when incorporating mobile devices in the performance. *Moori* is a music performance that incorporates dynamic interfaces and Short Message Service (SMS) on a smart phone in order to have an audience actively participate in the performance [Moori, 2012]. Through the mobile interface, the audience tells stories in response to guided questions sent by the performer. The story data then is processed and generates algorithmic music and visuals. The performance is a collaboration between performers and the audience, and the project aims to provide a captivating and remarkable experience for individuals.

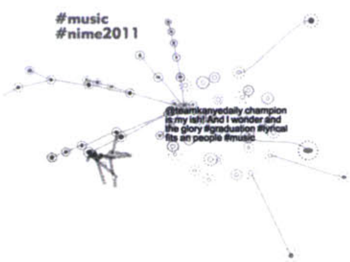

Figure 2.11. An example of the Twitter message visualization in TweetDreams.

Stanford Mobile Phone Orchestra (MoPho) from the Center for Computer Research in Music and Acoustics (CCRMA) explored the use of mobile devices in audience participation-based computer music performance [Oh and Wang, 2011]. *TweetDreams* is a performance based on Twitter messages from the audience members in and beyond the performance space to influence sound and visuals in the performance [Dahl et al, 2011]. The performance system for *TweetDreams* creates real-time sonification and visualization of Twitter messages and their relationships (Figure 2.11.). The human performers shape the piece on the fly by filtering and organizing the messages from the audience. The survey conducted after the performance reveals that about a half of the audience were unable to interact with the piece because they either did not have an Internet connection or a Twitter account. As of today, Twitter is a popular Social Networking Service (SNS) that many people use, but the issue of effortless participation from the audience members remains a problem in this performance.

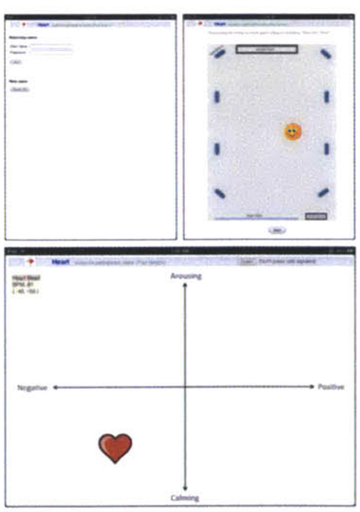

Figure 2.12. An example interface of *Heart*.

MoPho also experiments with interactive mobile web applications and computer music performances. *Heart*, a musical piece with web browser-based interactions, enables real-time audience participation using a two dimensional self-reporting scale interface on iPad (Figure 2.12.). Nonetheless, only a subset of the audience members reported their self-monitored emotional states while listening to a recorded song in a concert setting. The rest of the audience listened to the song and observed the visualization projected on the stage. *Heart* achieves a bidirectional communication among the audience members through iPad and a large public display. These two technologies helped connect the audience members and resulted in synchronized group behaviors

[Oh and Wang, 2011]. Oh and Wang write that *Heart* realizes a socially engaging experience using a unique audience participation model. This reminds us that having socially engaging elements in the audience participation-based performance is critical.

massMobile is a software based client-server framework for a large-scale audience participation in live performances using mobile devices [Weitzner et al, 2012]. massMobile can adapt to a variety of audience participation-based performance, and it satisfies the needs of various performance venues where mass audience participation in live performances is wanted (Figure 2.13.). The framework is not only limited to music performances, but can also apply to other types of performances such as dance.

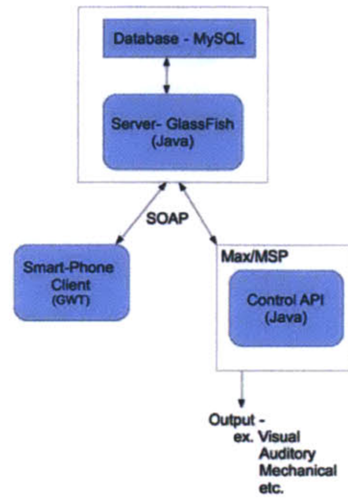

Figure 2.13. A diagram of the massMobile framework.

massMobile was first used in *FILTER*, an audience participation-based dance performance, to carry out an initial testing of the framework. Audience members participated in the performance by voting on their lighting preferences. The votes from the audience were displayed on a screen and signaled the dancer to change his choreography. The framework for audience participation is a compelling idea in that anyone who wants to quickly and easily configure a specific implementation of audience participation-based performance can use massMobile to produce a collaborative, expressive, and creative performance experience. However, even though using such a framework may help us in quickly prototyping a performance system, we still need to consider how to facilitate the development of a cohesive group interaction in audience participation-based performance as Weitzner, et al explain.

All computer music performances using mobile devices for audience participation presented in this section require computer network connections. The ability to network audience members during the performance is an important component in mobile device-based audience participation. When a computer network is required in a real-time music performance, the issue of the network latency must be addressed, as long delays can interfere with the course of performance [Chafe, 2004] and hinder the understanding of contributions made by the audience members. A solution to the latency problem can be approached in many ways, such as installing a faster networking system and running an absolute timing clock [Burk, 2000].

Passive Participation

Works shown in this section are not strictly works of a performance for audience participation, but they show us one of the Hyperaudience characteristics: how and in what way communication in a music performance can take place. As with the previous section, the communication systems in these works are primarily done through mobile devices. Nonetheless, the communication systems in these works are unidirectional: the performance content originates from the performance system to the audience members, and the audience passively consumes that content.

Figure 2.14. An example interface of the Concert Companion System.

The Concert Companion (CoCo), developed under the support of the Kansas City Symphony, is a handheld device intended to enhance concert experiences by presenting information that complements the music while the music is being performed [CoCo, 2003]. Using wireless technology and PDAs, CoCo delivers program notes and video images in real-time in conjunction with the music (Figure 2.14.). Participants who used Coco completed a short survey and had mixed feeling about using Coco in the concert hall: about half of the participants said that they 'definitely would' use Coco in the future when they attend a classical music performance. In one way or an other, the participants felt strongly about the CoCo because their concert experience was fundamentally changed with the device. Most participants who are in favor of CoCo were casual listeners of classical music who wanted extra context about the music to which they were listening. Interestingly, a prior experience with a mobile device did not seem to have a major impact on satisfaction of the participants. The user study concludes that CoCo can be best used in a concert hall as audience development and an educational tool.

Figure 2.15. *DialTone* performance at Ars Electronica.

DialTones by Golan Levin demonstrates a special case in audience participation [Levin, 2001]. This project also utilizes mobile devices in the music performance (Figure 2.15.): the audience's mobile phones are used to playback sounds in the performance. During the performance, the performance system calls phones at specific times and relies on ringtones to create the music. The visualization of audience seats and ringing phones was displayed to the audience to let them know whose phone is currently ringing. Even though some may have felt that they were involved in the performance, the audience in *DialTones* did not make any meaningful musical contribution to the performance. This work demonstrates a case in which creating a consistent musical result while encouraging a large number of participants to meaningfully contribute in the musical activity is extremely difficult [Weinberg, 2005].

2.1.4 Collaborative Musical Experience

In this section, we explore the collaborative musical experience for novices in a physical environment. We include this section in the background because it aids in formulating the conceptual framework of the Hyperaudience: the collaborative musical interfaces that enhance the social interactions among players and are design to be simple and intuitive for musical novices. Tina Blain and Sidney Fels argue that an interface design for musical collaboration facilitates communication between the players [Blain and Sidney, 2003]: it enables them to explore music and sound without having expert skills in music. In such collaborative music performance systems, the musical exploration of players comes out in the form of expression which then becomes the social interplay and communication among the players. Social interactions among the players are what a successful Hyperaudience system often seeks to achieve as well.

Composition on the Table by Toshio Iwai (1998) is a collaborative tabletop musical interface for novices [Weinberg, 2005]. In one of the applications for this project, a light grid is projected on a large horizontal projection surface (Figure 2.16.). Players give directions to animated objects by changing the orientation of arrows at each cross section on the grid. This particular application of the project shows many characteristics that contribute to a rich collaborative interface and experience. The simplicity of the interface affords players to anticipate the sounds they create. This leads to fun and game-like challenges for the players to keep experimenting with the movement of lights to make interesting sound combinations. This project is a good example of a simple interface with restricted musical output that create a successful collaborative interface for the participants. However, the ability of the system to facilitate collaboration among the players is achieved by sacrificing the number of participants the system can have at once. Only three to ten players in close distance can have this enriching interpersonal interaction.

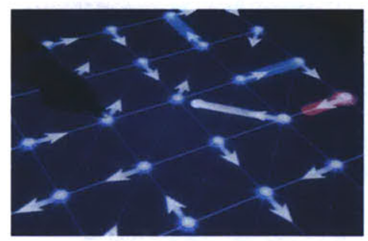

Figure 2.16. The interface of *Composition on the Table*.

MidiBall, by D'CuCKOO, was a massive scale audience interaction experiment that took place in a live concert venue (Figure 2.17.) [MidiBall, 2012]. A helium-filled large plastic ball was equipped with a wireless device and the audience triggered sampled sounds and images in real time when they hit the ball. The resulting music was created

Figure 2.17. Audience interacting with *MidiBall*.

from everyone else in the audience through the *MidiBall* and a jam session by the live performers on the stage. The design of *MidiBall* was accessible to everyone without having any expert skills in music to play it. The community awareness in the performance was accomplished through the spontaneous participation of the audience in a collective audiovisual experience.


Figure 2.18. People playing *Jam-O-Drum*.

Jam-O-Drum, by Tina Blaine and Tim Perkis, is a multi-user interactive music system with a circular projection surface that embeds drum triggers (Figure 2.18.) [Blaine, 2000]. In this system, images generated by a computer are projected onto the tabletop surface to facilitate a digital drum circle. Blaine and Perkis write that the system could become too chaotic to coordinate drumming when more players are present. The system incorporates a call and response mechanism and the process of interaction becomes harder with the increasing number of players, resulting in players ignoring the intended interaction of the system. From this finding, they suggest a number of guidelines for designing interfaces to facilitate a successful group interaction in a public setting such as incorporating more game-like musical interaction in the system, creating goal-oriented activities for encouraging more social interaction between players, and designing interactions that directly map to player's action.

2.1.5. Shared Sonic Environments

Computer network systems have led to new approaches for composition and improvisation for musical novices. In this section, we explore music projects that involve the use of remote networking systems. These network music systems enable geographically separated participants to collaboratively create shared soundscapes. Barbosa calls these types of works *shared sonic environments* [Barbosa, 2003]. He explains them as 'a new class of emerging applications that explore the Internet's distributed and shared nature and are addressed to broad audience.' We will not only cover works in the age of the Internet but also precursor works that use radio and telephone signal networks that could also be considered a part of shared sonic environments. In addition, the works covered in this section are focused on the systems that do not demand the users to have expert music skills to participate in the performance. The framework of the Hyperaudience system have much to learn from these examples with regard to how a remote musical collaboration system can be designed and provide engaging experiences for the Hyperaudience.


Figure 2.19. The telephone network in *Radio Net*.

Early shared sonic environments used radio and telephone networks to invite audience members to participate and to become musical material itself for the networked performance. For example, *Radio Net* (1997) by Max Neuhaus is an autonomous musical network system that let phone callers mix and group themselves during live radio broadcasts and used caller's audio input to dictate the course of sound synthesis [Neuhaus, 1994]. The participation method for the audience was extremely easy as all they had to do was to call the radio station and whistle into a telephone. Furthermore, the resulting music was completely dictated by the audio input from the audience, making participants feel that they have contributed in the performance even from a remote location. Similarly, in a more recent work by Neuhaus, *Auracle*, the computer system analyzed vocal expressions from the online players in real-time and rearranged vocal sounds to synthesize new sounds that can be heard by the other online participants (Figure 2.20) [Freeman, et al. 2004]. *Auracle* was an extension of *Radio Net*, but was entirely implemented using the Internet with a computer interface enabling the online participants to synchronously multitrack vocal sounds.

Figure 2.20. An interface example of *Auracle*.

Examples of *shared sonic environments* are numerous: WebDrum is an online shared drum machine that can simultaneously be played by multiple people over the Internet and its architecture is based on the Audio Synthesis API for Java, JSyn, and the TransJam system (Figure 2.21.) [Burk, 2000]; Daisyphone is an interface for a remote group music improvisation and composition where multiple participants edit short semi-synchronously updated shared loops of music (Figure 2.22.) [Bryan-Kinns, 2004]; and Patchwerk is a networked synthesizer module with a tightly coupled web browser and tangible interfaces that concurrently allow multiple users to remotely interact with a modular analog synthesizer in near real-time (Figure 2.23.) [Mayton, 2012].

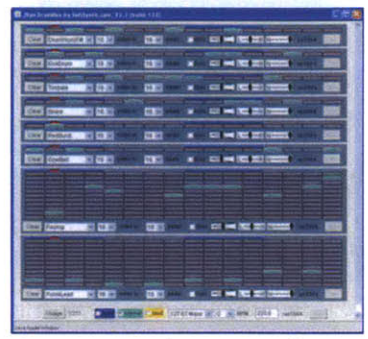
Figure 2.21. An example interface of WebDrum.

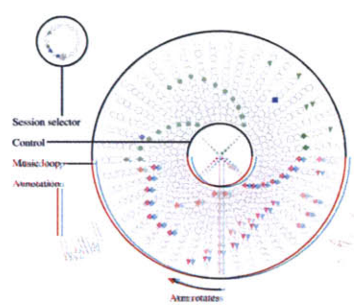

Figure 2.22. An interface description of Daisyphone.

All these examples in the above paragraph provide a simple web-based interface to participants with graphical buttons and sliders that can easily be adjusted and tweaked to quickly experiment with the resulting musical effect. Nevertheless, the social presence of other online participants appears to be stronger for WebDrum and Daisyphone because the visualization of other participants' activities is clear and intuitive for the participants. The interfaces for these projects use a basic music sequence editor view and the view helps facilitate a competition and collaboration among the participants. The interfaces give a good indication to the players what other people are doing while interacting with the systems. This demonstrates a case in which

Figure 2.23. A Patchwerk web client interface.

the design of the interface for the Hyperaudience system needs to be simple and intuitive: a clear feedback system enhances the experience of the Hyperaudience in a performance environment.

The examples above are projects based on user-generated musical collaboration and performance, but more recently the availability of mobile devices and the cloud-based computing are evolving the applications of the shared sonic environments. The *Leaf Trombone* from Smule is a commercial iPhone application and a music instrument that incorporates and experiments with the *World Stage* [Wang et al, 2011] [Smule, 2012]. The *World Stage* is a platform for connecting many users in a social and musical game environment (Figure 2.24.). The platform aims to expand the expressive musical performance and collaborative musical feedback of the *Leaf Trombone* players. The players can share their composition made with the *Leaf Trombone* and participate in the judging of other player's performance world wide through the application. The powerful aspect of the *World Stage* is the ability to incorporate human intelligence into a social-musical system and have participants pseudo-anonymously judge other participants' performance. In addition, the game elements in the *World Stage* motivate more musical participation and engagement. The World Stage is a great example of a new crowdsourcing shared sonic environment that creates new musical experiences for the participants.

Figure 2.24. Smule's *World Stage* interface example in the *Leaf Trombone*.

2.1.6. Social Music Listening

While most work presented above is primarily aimed at musical composition and performance using digital technologies, In this section, we focus on the social music listening systems that stimulate musical creativity and social interactions for the participants. These projects enlighten the conceptual framework of the Hyperaudience system by showing that a simple act of participative listening can lead to create a socially enriching and engaging experience for the audience.

Posting and sharing music among listeners is becoming an increasingly common social interaction in a public space, such as bars, as well as on the Internet. The systems that support such social interactions mostly take a form of jukeboxes or automatic or semi-automatic disk jockey (DJ) systems. In the next two sub sections, we present approaches by artists and researchers that use new technologies in an effort to allow the audience to publicly and virtually participate in a collaborative music listening and sharing experience. For those readers interested in further exploring social music listening practices, we recommend reading the book *Consuming Music Together* by Kenton O'Hara and Barry Brown [O'Hara and Brown, 2006].

Public Spaces

Music in public spaces can appropriate the social interactions of people in the same physical space and it can facilitate people to be in the right mood within a given social situation. The characteristics of the place and the particular occasion can be informed through the music ambience in the public space [De Nora, 1986]. Given the fact that music influences people's behavior in the public spaces, what we look for in this section are unique systems that encourage people to collectively affect the type of music that is being played in public spaces. These systems also conform to the conceptual framework of the Hyperaudience system in that they allow audience members to be co-explorative and communicative by providing different ways for people to interact around music and their choice. In such systems, playful competitions, discussions, negotiations, and learning can take place and they provide new forms in which social interactions in public space can be established.

The Jukola system, an interactive MP3 Jukebox device, democratically allows a crowd to vote on what music is to be played in a public space [O'Hara et al, 2004]. Music tracks are nominated and voted by the crowd for the next song using networked wireless handheld devices and public displays (Figure 2.25.). The system promotes competition, identity management, and the sense of community among the crowds. The use of the Jukola system by the participants varied: some participants voted for their favorite songs while others voted strategically to influence the next selection of the music. Some participants also used the system many times to clarify their preferences or to have a deeper understanding of how the system works. The ability of the Jukola system to allow participants to democratically vote for the next music enabled the participants to co-experience music listening. One way for a Hyperaudience system to facilitate a co-experience among participants is to democratize the performance system just like the Jukola system did.

Figure 2.25. Jukola in a public space: People are discussing what songs to vote.

The following examples also reveal the democratic principles of music listening systems. hpDJ utilizes an automatic DJ system that promotes a dynamic interaction between the crowd and the computer system [Cliff, 2005]. The participants collectively collaborate on composing music by specifying a selection of tracks. Music is sequenced and seamlessly mixed by computer, but the crowd qualitatively referenced what type of mix they wanted to hear.

PublicDJ encourages every interested visitor of a public event to bring their own music collection on a wireless network enabled mobile device and participate in choosing music that will be played in the space [Leitich and Toth, 2007]. The human DJ then takes the music selection made by the participants and mixes songs in a public space.

The list of the crowd music listening systems in a public space is quite large: there are many other systems that target a club or bar scenario where music selection is made by the audience, or even created and manipulated by the audience [Feldmeier et al, 2002][Hromin et al, 2003][Quay, 2010]. These systems typically make use of multi-sensory feedback systems to monitor the activity of participants.

The systems presented in this section used ubiquitous technologies to democratize music choice making in a public space. They provided some level of control to the participants and enhanced the experience of choice making music in a public space. These systems suggest ideas for the conceptual framework of the Hyperaudience system such as the democratization of choice-making by the audience in a public space.

The Internet

The systems presented in this section reveal many of the same features found in the previous section, such as the democratization of music choice-making, but the interaction of participants primarily takes place over the Internet. We include these system in this section because they show us different ways to encourage participants to be communicative, co-creative, and co-explorative.

Perhaps one of the earliest attempts at an online public listening system may be *HubRenga* (1989) by the Hub [Gresham-Lancaster, 1998]. In HubRenga, the members of the Hub involved the general public in remote interdependent interactions by allowing them to submit renga, a Japanese poetry form. HubRenga was a live radio performance using a computer messaging system and a bulletin board. The public dialed up the computer system from their home and typed in lines of text. The text was then read aloud on the radio and the music system of Hub responded to certain keywords in the renga with each Hub composer's unique musical actions. HubRenga not only supported active audience participation, but also empowered the audience to be expressive through creating poetry.

Masataka Goto argues that *Crowd Music Listening* (CML) is the new way people will listen to music in the future. CML is an Internet-based music listening system with shared semantic information and communication [Goto, 2011]. Goto notes that CML facilitates a deeper understanding of music through shared experience. In this environment, listeners post and share comments over the Internet and watch time-synchronous comments as a music video plays along. The listener's understanding of music is amplified in this environment because people know how others understand music. According to Goto, the understanding of music can be deepened through seeing and editing music, and also communicating with others.

Figure 2.26. An example interface of Dance ReProducer—An instance of a CML system presented by Goto [Nakano et al, 2011].

Goto presents *Dance ReProducer*, a mashup music video generator, as an example of the CML system (Figure 2.26.). The system segments and concatenates existing dance video clips on the NICO NICO DOUGA service, a Japanese-based crowd music listening service, to automatically generate a dance video clip suitable to a specified piece of music [Nakano et al., 2011][nicovideo, 2012]. The users of this system can also interactively change the video clip sequence by simply selecting different video clip candidates. Dance ReProducer focuses on machine learning and dealing with emerging trends in music listening: the users deepen their understanding of music through seeing, editing, and communicating by uploading the created video to the crowd music listening service site. Dance ReProducer is also a good example of a system that depicts the characteristics of the Hyperaudience system: the system supports communication among participants and keeps the interface simple and user-friendly to achieve socially engaging experience for the participants.

Figure 2.27. An example interface of turntable.fm.

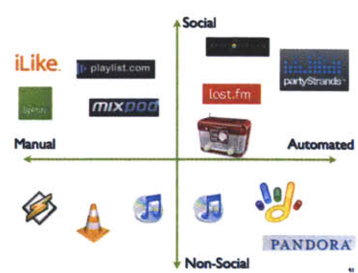

Figure 2.28. A survey of playlisting systems and tools by Ben Fields and Paul Lamere [Fields and Lamere, 2010].

More recently, social media websites have become popular among Internet users. These include, for example, turntable.fm, Listening Room, and MUMU player [turntable.fm,2012][Listening Room, 2012] [MUMU player, 2012]. These websites allow users to interactively share music and create *rooms* which other users can join, chat, and listen to music in real time. SoundCloud is another example of social media website that does not have a shared listening room but allows users to actively comment on music and watch other users comment while listening to music [SoundCloud, 2012]. These systems may incorporate a playlist: 'a set of songs meant to be listened to as a group, usually with an explicit order' [Fields and Lamere, 2010]. Some of such systems can be socially engaging to the music listeners online because they may allow the creation of collaborative playlists, playlist sharing, forum posting, or an interaction through Social Network Services (SNS's) such as Facebook. Fields and Lamere provide a survey of playlist systems on a chart with axes of social/non-social and manual/automated revealing which systems attempt to engage online music listeners through social networking tools (Figure 2.28.).

2.2. Theatre

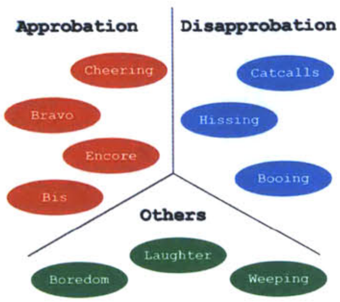

Figure 2.29. Audience gestures that potentially affect the performers. Taken from [Kennedy, 2009].

Audiences affect theatre performances through their reactions, such as applause, laughter, sighs, and restlessness as illustrated in Figure 2.29 [Kattwindel 2003]. These reactions can often shape the way actors perform. This is a simple example of audience affecting theatre performance, but the examples we examine in this chapter are rather focused on extreme cases of audience participation practice found in theatre performance. We harness these extreme examples to examine the elements of audience participation techniques from different perspectives. Examples in this section uncover the practical settings in which audience participation takes place, the transformational role of audience and actors when participation is involved in the performance, and the methods for encouraging audience members to be communicative in the theatre performances. The conceptual framework of the Hyperaudience system has innumerable amounts of ideas to learn from these examples.

2.2.1. Coney Island and the Blowhole Theater

Figure 2.30. *Barrel of Fun* at the Steeplechase park.

At the turn of twentieth century Coney Island was as big an attraction in its day as Las Vegas was about ten years ago: the island once had the largest amusement park in the United States [Zukin et al., 1998]. At Coney Island, part of the audience experience was the transformation of the roles of performer and audience. People came to the island to see and to be seen by the others: they became actors in a collective drama. Many of the rides had their own viewing stands, where the audience was thrilled to hear the screams of the roller-coaster riders and watch them go flying by. As suggested by Coney Island historian John F. Kasson, rides like Luna Park's "Tickler" and Steeplechase Park's "Barrel of Fun" brought strangers into sudden and intimate contact (Figure 2.30.) [Kasson, 1978].

Within the context of this thesis, what is especially intriguing for us in the old Coney Island amusement park is the audience experience in the Blowhole Theater at Steeplechase. In this theater, audience members were tricked into performing because of the blowholes that shot up jets of compressed air and an electronic shocking device: the air coming out from vents blew up the skirts of female audience members and midgets electronically shocked the male audience members (Figure 2.31.) [Blowhole Theater, 2012]. The audience members who participated in the act knew that such blowholes existed in the theater, and the female audience members reacted dramatically to give the viewers a good time. Other audience members actually paid to see the skirts fly up and listen to the embarrassed female voices. The Blowhole Theater was very popular and it is known as the longest running show ever existed in New York.

Figure 2.31. A typical scene found in the Blowhole Theater.

As far as we know, the Blowhole Theater is the first audience participation-based theater performance that also used technologies such as air jet vents and electronic shocking devices. The Blowhole Theater also reminds us that audience participation can be as simple as lifting the skirt of a female audience members, providing excitement for both the viewers and the participants. The performance system for the Blowhole Theater is transparent to, and simple for the participants: the audience members did not have to learn anything to participate in the performance and the system empowered participants to be expressive through screaming and shouting. The Blowhole Theater also teaches us that it is not only the technology that is important in enabling audience members to participate in the performance, but also the context in which we use that technology.

2.2.2. Fluxus, Happenings, and Flash Mobs

In this section, we cover the audience participation-based performance works of Fluxus, Happenings, and Flash mobs to explore the patterns of participation mostly from non-digital perspectives. These works comply with the conditions that we proposed for the conceptual frameworks of the Hyperaudience system.

Fluxus was an international network of artists, composers, and designers known for mixing different artistic media and disciplines in the 1960s. Some of the works done by Tomas Schmit, one of the core members of the Fluxus and Happenings movements in the 1960s, experimented with audience participation and art aiming 'to CHANGE the DISTANCE BETWEEN AUDIENCE AND ART' [Berghaus and Schmit, 1994]. For example, in the audience-participation Actions opus 26, *Sensatorium minimaxmum* (1964), the performance was executed with the audience in ways such as

Figure 2.32. Tomas Schmit performing Cycle for Water Buckets (or Bottles). 1959.

blindfolding the audience, a paper bag covering the audience's head, and putting crushed eggshells in the audience's pocket. In *Sanitas op. 3* (1978), The performers threw small, simple objects into the audience in the dark auditorium. The performers then light their torches and search for the objects. When all the objects have been found, the piece is finished. The audience was encouraged to create their own art with the elements or the impulses offered to them by the performers.

None of the audience participation work done by Schmit involved technology, but his experiments enlighten us with the idea that 'without the audience's collaboration no performance is possible' [Schechner, 1971]. This is especially the case with audience participation-based performance. Participation by the audience in a performance means breaking the boundary between the role of the performer and the audience. Including audience as a part of the performance means collaboration between the performer and the audience and the medium of collaboration is the trust between the performer and the audience.

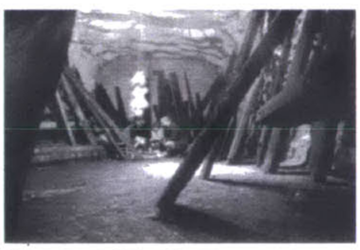

Figure 2.33. The performance space of *Eat* by Allan Kaprow.

Happenings is a performance or situation meant to be a work of performance art. Happenings seeks to re-think theatre practice such as the stage and the relationship to the audience [Schechner, 1965]. The Happenings performances often actively involve audiences as the central ingredient of the performance. In Allan Kaprow's *Eat*, the audience participates by becoming part of the non-verbal, plot-less performance (Figure 2.33.) [Edmond, 2004]. The audience was presented with apples hanging on strings from the ceiling in front of the building entrance. The audience could eat the apples or leave them as they are. Interacting with the object that the artist provided was a familiar experience to the audience, but the performance could not have been completed without the participation from the audience. Theatre companies that practice Happenings as the main element of the performance include, for example, the Living Theatre and the San Francisco Actor's Workshop [Schechner, 1965].

The performance of Happenings, just as Fluxus, typically did not involve modern technologies. Instead, the works of Happenings usually used everyday objects and people as performance materials. This conforms to one of the conditions of the conceptual framework of the Hyperaudience system: the interface that audience members use to participate in the performance is transparent and user-friendly to allow them to easily participate in the performance. Everyday objects are ordinary things that are familiar to most people, and using those objects as a part of the interface in the performance allows the audience members to easily participate in the performance.

Unlike Happenings, which took place in spaces hidden from public attention, flash mobs aim to capture the public attention [Muse, 2010]. Flash mobs happen when a group of people assemble quickly in a place, performing an unusual act for a short time. The flash mob has become one manifestation of audience participation and it often happens for the purposes of entertainment, political reasons, and artistic expression. In a typical flash mob, anyone may join in to the act even when there may be a clear boundary between performers and the audience. According to Gore, the first flash mob happened in June 2003, organized by Bill Wasik [Gore, 2010]. He invited people through text messages, email, and blogging and some hundred people gathered around *Macy's* to buy the rug sold in the furnishing department to use it as a 'love rug' (Figure 2.34.). They created a scene and drama disrupting the normal flow of activities.

Figure 2.34. The first flash mob event at Macy's department store in New York City on June 3rd, 2003.

The concept of the flash mob is entirely based on participation from the audience. Flash mobs, whether it involves technology or not, encourage audience members to be communicative, co-creative, and co-explorative in a public setting. Flash mobs promote audience members to unite and co-experience the event in an attempt to convey a political or commercial message, or artistic expression. When telecommunication systems, social media, and other forms of digital communication systems are involved in the act of a flash mob, the performance can become tremendously powerful, spreading word to the general public to participate in the act of performance art.

2.2.3. Site-Specific Experience

In this section, we focus on site-specific theatrical projects that explore unique forms of engagement between the performer and the audience. As the name suggests, site-specific theatrical performances often take place at a unique and specially adapted non-theater location rather than at a traditional theater [Wilkie, 2002]. The performances commonly allow audience members to walk or move around the performance space and are generally more interactive than a conventional theater performance. We include works of a site-specific theater performance in this thesis because they reflect broadly on the conceptual framework of the Hyperaudience system even though these performances may not involve the-state-of-the-art technology to realize participatory experiences for the audience members. We cover the details of how the framework adheres to site-specific performances as we describe some of the projects found in this domain.

We primarily focus on works from Punchdrunk and Secret Cinema, but projects that focus on the site-specific performance experience are numerous. These projects include, for instance: the Donkey Show by Diane Paulus; The Asylum by Kneehigh Theatre; and mis-GUIDE by Wrights & Sites [Fish, 2010][Kneehigh Theatre, 2012][Wrights & Sites, 2012]. For those curious readers who would like to explore more about site-specific performances, we recommend reading [Wilkie, 2002][Turner, 2004][Carlson, 1989].

Punchdrunk

Punchdrunk, a British theater production company formed in 2000, specializes in site-specific immersive theaters [Punchdrunk, 2012]. In a typical Punchdrunk production, audience members freely walk around without direction or instruction in the performance space. The audience members can either follow the performers, the themes of performance, or simply explore the world of the performance, treating the production as a large design installation of unexpected sites. One of Punchdrunk's beliefs is to reject the passive nature of the audience in many traditional theatrical performance and have them experience the 'epic storytelling inside sensory theatrical worlds' through journeys and discoveries.

Sleep No More, one of the most recent Punchdrunk productions taking place in Chelsea, New York, is an event inspired by Shakespeare's *Macbeth* and narrated through the lens of a Hitchcock style found in films such as *Rebecca* [Worthen, 2012]. The performance is staged in the McKittrick Hotel, a five story high building with over one hundred rooms, that is designed with the theme of *Macbeth* and *Rebecca.* Inside the building, audience members, who must wear a mask to participate, find themselves immersed in the environment with dark lighting and a captivating soundscape. Approximately twenty performers, each with a distinctive role and without a mask, simultaneously act around the building in costumes noticeably different from the audience members. For the most part during the show, the audience members are treated as ghosts, they are ignored by the performers but can keep a very close distance to the performer in observing their act. Moreover, the audience members also have the chance to interact with the performers on a one-on-one basis: the very special moment comes when a performer grabs an audience member and unmasks him/her to have a personal interactions typically in a private room. To capture this

Figure 2.35. Masks worn by the audience members in *Sleep No More.* © Alick Crossley.

personalized experience more clearly, we borrow reports made by Worthen about the one-on-one experience of Alex Shaw with Macduff:

> Macduff was holding an egg. He stopped and looked at me like I was a freak. Then, he grabbed my hand and pulled the door shut, locking it behind us. He pulled out a cigar box and opened it up . . . and made me look at these eggs (that were inside) really closely. . . . He took an egg out of the box and started squeezing and the egg broke and it was full of dust. He freaks out and shoved me against a wall, asking "Who are you?" and takes my mask off my face. . . . Then there was a crash, and the lights went out. When I looked back at him, he started shivering and grabbing me really close and he bear-hugged me and said "Me thought I heard a voice say sleep no more." Then, he was butterfly kissing my face and he kept saying "sleep no more," and then he really shoved away hard, pushing me against the wall, and he ran away. I ran after him, thinking I would follow him. He had my mask, and then he just threw my mask. People were waiting to see when we would come out of the bedroom and they all saw me without my mask on." [Worthen, 2012].

Figure 2.36. The "rave" scene in *Sleep No More*. © Alick Crossley.

Figure 2.37. Macbeth and Lady Macbeth in *Sleep No More*.

The key to the participatory experience in *Sleep No More* is the theatrical immersion. The audience members in *Sleep No More* are given the freedom of choice to follow any of the performers they desire or touch and investigate objects, such as books, pay phones, and drawers, placed around the performance space. However, if audience members are not curious and deeply involved in the performance, they will not have an interconnected experience with the performers. *Sleep No More* enacts immersive theatrical experience effectively, means of audience participation are transparent and require no special skills: the performance uses everyday objects, texts, characters, spaces, and atmospheric music to constantly keep the audience members immersed and participative.

Secret Cinema

> *Tell no-one.*
>
> \- Secret Cinema, 2012.

Secret Cinema, a branch of Future Cinema, is an underground site-specific film event mostly taking place in secret places around London since 2007 [Secret Cinema, 2012]. The event specializes in sudden and unexpected film festivals, transforming movie watching into a theatrical experience. Although they appear in various social media campaigns, the company does not advertise the showing using common methods such as television commercials or online advertising. Instead, they depend on word-of-mouth to spread the film event. Even though the audience is not informed exactly what film will be played at the event, Secret Cinema immerses audience members in the film in an unusual way: the audience are given instructions about what to wear and what to bring to the event, and they are given additional tasks when they arrive at the event. The fictional characters from the film interact with the audience at the location where the environment is completely transformed into the theme of the film. Until the moment the film begins, Secret Cinema aims to immerse viewers in the simulated world of the film, breaking and extending the boundary between fictional work and audience.

Figure 2.38. Audience members waiting at the entrance at one of the Secret Cinema events.

Figure 2.39. One of the sets in the Secret Cinema event for Prometheus [Gibson, 2012].

In one of the Secret Cinema events, audience members were taken to the fictional off-planet environment of *Prometheus* by Ridley Scott [Prometheus, 2012][Van Spall, 2012]. The audience members were told to choose their career path from a list that included ore surveyor, matter analyst, and control operator, and they dressed up according to their career and entered the warehouse, turned into space ship, launching for a secret expedition (Figure 2.38 and 2.39.). They were given missions to complete and explored the vast space ship using pieces of star maps. As audience members explored the space ship, they lost track of the distinction between performer and audience, because the performers dress just like audience members, and the dark interior immerses them in the space. The time and location of the film screening was not announced. Instead, the audience members were told to evacuate to an escape pod after the space ship had launched on the hypothetical alien planet. The pod was actually an auditorium where the film was screened and the audience members finally discovered that the film was Prometheus. One of the audience members commented that "the experience was quite good, even if the film wasn't great. But it was still a good night out" [Gibson, 2012].

The audience at the Secret Cinema actively participates in the film event and they also co-experience the event by taking on their given role. This enhances social experience and enables an interconnection between experience of the audience members and performers by navigating a site-specific performance environment. The Secret Cinema events also demonstrate common principles, proposed by Benford et al, for orchestrating participatory experiences for the audience [Benford et al, 2003]. For example, the admission to an experience is obfuscated for the audience. This creates a mysterious feeling and a sense of excitement,as they are unsure what to expect at the film event. In a way, they are already engaged in the event even before they actually enter the space. Another example is establishment of engagement during the event: the audience members were given missions at the introductory briefing and these missions supported the audience members to engage and immerse themselves in the performance space.

2.2.4. Stelarc and Fractal Flesh

Stelarc is a cyborg performance artist who uses machinery to control his body or body parts to control machinery during his performance [Dixon, 2007]. His performance work raises questions of evolution and adaptation in our modern technological environment often by transforming his body into a cyborg and a metaphoric post-human form. While most of his work does not involve audience participation, we include his work in this chapter because one of his performances, *Fractal Flesh* (1995), involves audience participation in quite an unusual way (Figure 2.40. and 2.41.). This performance has a significant impact on audience perception that we can learn from to develop the conceptual framework of the Hyperaudience system.

A number of his performances, such as Fractal Flesh, *Ping Body* (1996), and *ParaSite* (1997), utilized the Internet to stimulate his muscles in different parts of his body through electrical sensors [Caygill, 1997] [Dixon, 2007]. Signals were sent to Stelarc's body in various ways through the Internet but always resulted in astonishing physical performance. In *Fractal Flesh,* audience members used touch-screen computers to activate different areas of his body. The display screen had Stelarc's simulated body as the interface and the performance enabled audience members to remotely touch his body. Incorporating the performer into the interface itself provided a magnified experience for the audience in manipulating the computer interface.

Figure 2.40. *Fractal Flesh* by Stelarc. ©Stelarc.

Reeves et al writes that Stelarc explores the idea of the performer and the interface as one unified object [Reeves et al, 2005]. The performance completely transformed the role of the audience and the performer: through the touch-screen interface that triggered muscle simulators located on his body, the audience became the performer of Stelarc's body, and, in return, Stelarc was the interface of the audience. The resulting gestures, movements, and emotional reactions around the interface/performer provided power and participative experience to the audience.

Fractal Flesh transformed Stelarc into the first tele-operated human performance in the history of the performing arts [Dery, 2012]. This performance is significant in synthesizing the conceptual framework of the Hyperaudience system: the performance system supports active audience participation by making the audience member into the performer of Stelarc's body. In addition, the simple computer interface in which the audience member effortlessly touch on the simulated body of Stelarc makes participation easy and effective in shaping and contributing to the performance. Even if the audience members were in a remote location, the performance system was able to give feedback to the audience to inform them of their contribution through live video streaming Stelarc's body condition, helping them to establish a intimate engagement in the performance.

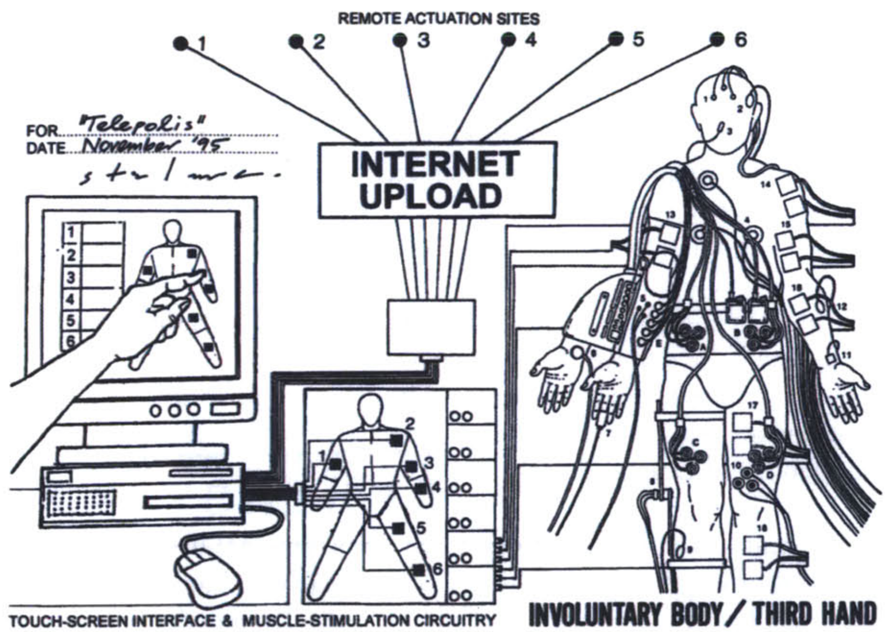

Figure 2.41. The *Fractal Flesh* Performance system. Taken from [Caygill, 1997].

2.2.5. Cyberspace Performance

Cyberspace performance exist in the mediated environment of the computer interface and the Internet. These performance often have distinguishing principles and implied interactivity's than what we normally see in the traditional theatre performance [Kattwinkel, 2003]. For example, the idea of mediation is a key element in understanding the cyberspace performance. All of the Internet performances are literally mediated by the computer hardware and software for participants to virtually take part in a performance. In addition, such performance environments can prepare prerecorded videos of performers in advance or broadcast live the act of performers from a remote location. In either way, the performance is mediated by software programs and computers in cyberspace, sometimes involving a simulated graphical three dimensional virtual reality world. Cyberspace performances are highly interactive environment that require audience members to input text and commands using a computer keyboard and a mouse. Because of this interactive nature of the performance environment, the conceptual framework of the Hyperaudience system can draw many practical ideas from the these works.

Perhaps one of the earliest examples of a cyberspace performance is Multi-User Domain (MUD). MUDs are usually text-based and are real-time multiplayer virtual worlds. They may involve games, play, or entertainment. Moreover, a communication and interaction happen among the participants through characters created in the online world [Muramatsu and Ackerman, 1998]. MUDs integrate the elements of online chats, interactive fiction, and role-playing games. Besides communication with each other, participants can also create an environment and objects within the environment. The audience in MUDs are always active as it involves creating characters, story lines, and dialogues as the game proceeds. The audience performers are typically one and the same. The example MUD applications include Dungeons and Dragons, Zork, and ATHEMOO.

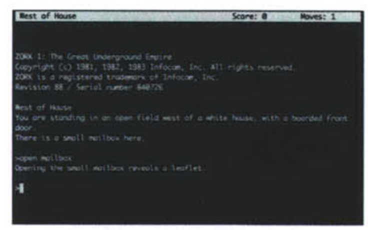

Figure 2.42. An interface example of *Zork*. The performance experience is based on a text interface.

Muramatsu and Ackerman suggest that, in playing MUDs, separating the issues of social and sociable, as well as sociable and intimate, are important because depending on the type of MUD, the players may not need to be socially engaged in playing the game. For example, some combat MUDs require the players to collaborate to vanquish dragons or monsters while other MUDs do not. In those combat MUDs that require collaborative social interactions, the players are communicative, co-creative, and co-explorative in their quest to defeat the monsters, making the players co-experience the play in MUDs. Intimate conversations and discussions among the players are realized through social environments and the fictional characters that the players created to collaboratively progress the plot of the story behind each MUD. MUDs show us an important element in designing the Hyperaudience system: How do performers and players coordinate to plan and execute what needs to be done to tell the story underlying the performance.

2.2.4. Mixed Reality Performances and Gaming

In *Computers as Theatre*, Brenda Laurel proposed that computers can be considered as a form of theater rather than tools [Laurel, 1991]. She meant that human computer interaction (HCI) can be designed from a perspective of the content rather than a perspective of technologies in the process of engaging users. She also suggested that, in order to maintain and orchestrate the user experience, various background activities are necessary, just as any theatrical performances require backstage activities. Laurel's ideas provide an important lesson in forming the conceptual framework of the Hyperaudience system in that not only is technology important in orchestrating a participatory experience for the audience but also the information and materials the performance system provides to the audience.

The ideas that Laurel suggested in her book are also widespread in present-day mixed reality performances and gaming. Technologies such as smartphones and handheld devices are being used to engage users in the experience of a theatrical performance and gaming and a number of projects focus on bridging the real and virtual worlds through theatrical and gaming experiences. In this section, we focus on those mixed reality theatrical performances and games that use dramaturgical information and materials to engage participants in the interactive experiences. These projects give us insight into establishing the conceptual framework of the Hyperaudience system relating to how a performance space can be used as a communication platform that promotes dialogues among participants and performers.

Figure 2.43. A street player in *Can You See Me Now?*.

Can You See Me Now?, by Blast Theory and the Mixed Reality Lab, is a mixed reality pervasive gaming project that took place on the streets of a city and in an online world [Benford et al, 2006]. The online players moved across the city on the virtual map that they accessed through the Internet, while the runners, equipped with wireless global positioning system-enabled (GPS) mobile devices, chased the online players by physically running through the streets in the city. The game focuses on the tactics of the runners and the online players,which yield valuable lessons on designing a Hyperaudience system. For example, enhancing the local knowledge for both the street and online players through active communication among them is crucial in creating engagement in the performance. The role of audio for the runners also proved to be significant in the gaming experience, and this suggests to us that the modalities of various communication methods in the performance space have a significant impact on the experience of the participants. Finally, designing an entry into and exit from the game experience for both the street and the online players is important, and these issues need to be also considered in the process of designing a Hyperaudience system.

Uncle Roy All Around You, also by Blast Theory and the Mixed Reality Lab, is a mixed reality game and theater performance that took place in urban areas and in a virtual reality world [Benford et al, 2001]. Just like *Can You See Me Now?*, the project involved the physical street players and the online players. The street players traveled through the city with a wireless mobile device in search of a character called Uncle Roy. The online players were immersed in a parallel 3D model of the same city as the street players. In the virtual world, the online players were able to see their progress and could also communicate with the street players to give help or to create difficulties for them. Just as Laurel suggested, one of the major methods used to create a captivating experience has been to combine preprogrammed content with the elements of live performance. The performance required a large number of human resources to facilitate a rich and engaging experience for twenty players at a time. This suggests to us that designing a Hyperaudience system that is geared towards mixed reality performance may require not only technology but a large number of people who orchestrate the performance behind the scene.


Figure 2.44. An example online interface of for *Uncle Roy All Around You.*

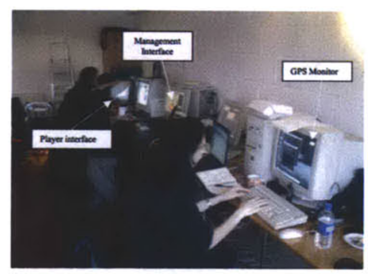

Figure 2.45. The operators in *Uncle Roy All Around You.*

ARQuake is an augmented reality gaming system and an extension of the desktop video game Quake [Thomas et al, 2000][idsoftware, 2012]. ARQuake experiments with how a desktop first-person shooter game can be converted into a mobile augmented reality game. The project also relies on real and virtual worlds to provide an experience for the participants. The gaming system requires a wearable computer system. The system uses technologies such as head-mounted displays (HMDs), a GPS, a digital compass, and a fiducial marker-based vision tracking system (Figure 2.46.). These technologies are used to implement a first-person perspective gaming experience in the physical world, and the participants of the game shoot monsters and collect


Figure 2.46. A participant in ARQuake with a wearable computing system.

weapons and other items. The researchers of ARQuake commented on the usability and playability of the system based on the participants' experience: the appropriate calibration of the field of view (FOV) on the HMD, the tilt of digital compass, and the lighting system in the physical world is important in providing an optimal experience for the participants [Thomas et al, 2002]. We learn from this that, in order to maximize the experience of the Hyperaudience in a performance, conducting a rigorous testing of the usability and playability can provide useful information in improving a Hyperaudience system.

2.3. Public Spaces

This section covers audience participation works that take place in public spaces. Most of the works presented in this section transform everyday environments, such as urban cities and public indoor spaces, into playful environments where participants become expressive through interaction with various digital technologies. We include these works in this chapter because they inform our discussions about issues that surround the Hyperaudience system and help us in synthesizing the conceptual framework of the Hyperaudience system. The section is divided into four parts: interactive art, urban playgrounds, night clubs, and crowd computing. Each subsection is devoted to defining the scope of the practice and gives example projects that apply such a practice.

2.3.1 Interactive Art

In this section, we examine interactive installation works that create opportunities for audience participation. We first look at the outline of interactive art—which interactive installation works derive ideas, beliefs, and methods from—to consider the positioning of the audience in the work of interactive art. We then look at some examples of an interactive installation.

Researchers and artists have been interested in active audience participation with artworks using computers since the 1960s. For example, as early as 1966, Roy Ascott has developed a theoretical view in which participation and interaction between audience and artwork are central [Ascott, 1967]. Interactive art is about the way the object performs and how it appears to the audience [Edmonds et al, 2004]. Interactive art works achieve audience participation using technologies that typically generate sound, image, or multimedia contents based on audience reaction. Cornock and Edmonds suggested that the digital computer can control 'the way an artwork performs in relation to its environment including' the audience [Edmonds et al, 2004]. Burnham takes this idea step further and suggests that all objects 'which process art data are components of the work of art' [Burnham, 1969]. Following this argument, we can say that the audience is a part of the artwork. Therefore, interactive installations are naturally audience inclusive, allowing them to influence the behavior of the installations and form a community around the installation.

Figure 2.47. Passengers interacting with the installation, *Light Around the Edges.*

The *Light Around the Edges*, by Todd Winkler, is an audiovisual installation in a large public space [Winkler, 2000]. The computer system for the installation tracks the location and movement of people using a video camera and interprets the data to trigger individual sound samples and create music. While participants heard the resulting sound from their actions, they also saw themselves in an abstract form through video projection. The installation is mostly invisible to the audience in the space, but it can accommodate an unknown quantity of participants. As the number of participants increases, the software changes its interaction mode to define how a sonic environment is created. The software is programmed to do so because it becomes difficult for the participants to perceive their direct impact on the system as the number of participants increases. The installation facilitates conversation, eye contact, and movement among participants.

While joining the experience of the installation was intuitive and engaging, Winkler's work demonstrates a problem with accommodating large number of participants simultaneously. Even though the software was programmed to accommodate many participants simultaneously, the participants' perception of influencing the outcome of the installation fractures as more people take part in the installation at the same time.

RE:MARK, by Golan Levin and Zachary Lieberman, is a small speech visualization installation that only accommodates two people at a time [Levin and Lieberman, 2004]. In the installation, participants' spoken voices were captured through microphones and computer software analyzed and recognized the voice to extract phonemes. Phonemes were then projected and animated on the large screen display as texts, often appearing from the shadow of participants' head. This was made possible by tracking the shadow of participants with a computer vision system. When the software did not recognize phonemes in the participants' speech, the installation responded by generating an

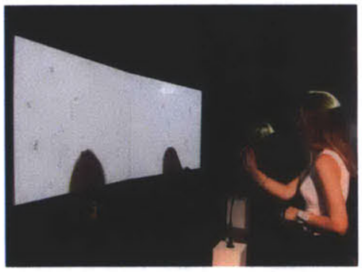

Figure 2.48. Participants enjoys interacting with RE:MARK.

abstract shape. The installation explored a visualization of speech in which sound and image originated together from the participants' body. The aim was to create an interactive fictional world where the participant's speech is aesthetically visible. The authors use the term *in-situ speech visualization* to describe such work that visualizes speech using augmented-reality techniques.

RE:MARK requires no special training or familiarization for the visitors to participate in the interactive environment. The installation intuitively teaches the visitors as they watch and interact with the system: the only requirements for the visitors are to be at the site and make a spoken sound. Speaking or uttering sounds from the mouth comes naturally to most people and the installation requires no learning curves for the visitors to participate. The system satisfies one of the conditions of the conceptual framework of the Hyperaudience system: the interface that audience members use to participate in the performance must be transparent and user-friendly.

2.3.2. Urban Playgrounds

We refer to projects that are collaborative, locative, and playful for the participants as *urban playgrounds*. These projects typically take place in the public urban area, often incorporating mobile devices, virtual reality worlds, and game elements. Players usually freely move around the outdoor public spaces while having networked social communication with other players in real or virtual worlds. These projects are relevant in synthesizing the conceptual framework of the Hyperaudience system because they empower participants to be expressive, collaborative, and playful in an urban environment. This section is divided into two sections: pervasive gaming and soundscaping.

Pervasive Gaming

Pervasive gaming, also called location-based gaming, uses players' physical location as the essential element of the gameplay to bring gaming experiences out in the real world. Therefore, pervasive gaming projects normally support the use of localization technologies such as GPS, Near Field Communication (NFC), and Bluetooth. Other types of technologies such as mobile devices, sensors, and wearable computing systems may also be used in creating a gaming experience for players. Players with mobile devices move around the physical space while game systems capture information about their current context to analyze what they are feeling, where they are, and what they are doing to provide a gaming experience. We include pervasive gaming projects because these projects demonstrate similar challenges to that of the Hyperaudience system.

Two approaches in creating pervasive gaming experience are to reinterpret existing board, video, and computer games onto physical world settings and to emphasize social interaction among the players [Benford et al, 2005]. We examine Human Pacman, a mobile gaming system based on ubiquitous, physical, and social computing to demonstrate how these two approaches are implemented in a particular gaming system.

Figure 2.49. The description of Human Pacman.

Human Pacman melds the physical world with a virtual reality playground using mobile devices, HMDs, and motion-capture technologies [Cheok et al, 2004]. The project focuses on collaboration and competition among players in an outdoor space: some players physically become the characters of Pacman and the Ghosts, and freely move around the real world while communicating with other physical and virtual players. In the gameplay, real world objects are embedded and linked virtual world objects. For instance, a player obtained a virtual magic cookie by physically collecting a physical treasure box which had an embedded Bluetooth device. In this way, the players were able to experience seamless activities between the virtual and real worlds.

The researchers of Human Pacman conducted a user study by collecting survey results from the participants. One of their major findings is that Human Pacman was much more well received than the normal arcade version of Pacman. They think the reason for this is because of the element of physicality that the participants experienced. They also write that the immersive experience of the Pacman role playing could be another factor that contributed to this result. Laurel notes that establishing a first-person, rather than a third-person, relationship with the mediated environment is the key to engage participants in a play [Laurel, 1986]. We think that the participants enjoyed Human Pacman because they were actually Pacman in the first person view, actively shaping and influencing the game play. This is one of the conditions proposed in the framework of the Hyperaudience system: to support active audience participation and to give appropriate feedback to the participants to let them know of their contribution to the performance.

Soundscaping

The word *soundscape* originates from the World Soundscape Project (WSP) from Simon Fraser University in 1970 [Schafer, 1977]. Murray Schafer defines soundscape as the sonic environment considered as a piece of music or the sounds heard in a particular location that we 'hear or ignore, that we all live with.' Soundscaping projects develop systems that enable participants to create soundscapes or electronic music compositions in real time through exploring urban environments. We include soundscaping systems because such systems consider the urban city as an interface that the participants interact with and allow participants to actively create soundscapes or electronic music compositions just by moving through the urban area.

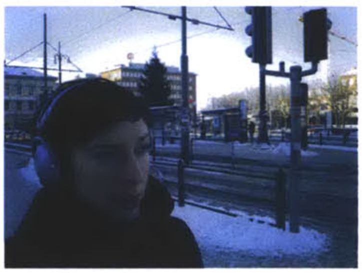

Figure 2.50. In *Sonic City*, the participants interactively create music as they walk and wear a headphone.

Sonic City invites audiences to interact with the urban environment by integrating musical creativity into everyday life, familiar places, and natural behaviors [Gaye et al, 2003]. Audience members carry a wearable computing system that creates electronic music in real time based on body gestures and environmental parameters. The type of sensors used in the wearable system are: a metal detector, an accelerometer, a pollution sensor, a temperature sensor, a sound pressure sensor, and a light sensor. Using these sensors, Sonic City transforms everyday behaviors into creative practice through playful interaction with the urban environment. The audience becomes expressive simply by walking around the city.

Figure 2.51. Participants walking with speakers in *Vicinity Songs*.

Circumstance is a collective of international artists known for the *subtlemob* form of performance [Circumstance, 2012]. The performance that they produce typically involves mobile electronics in public areas. They aim to create cinematic experiences in surprising locations. The experiences that Circumstances create take various forms such as mass participation performances, installations, intimate personal storytellings, books, and workshops. In *Vicinity Songs*, one of the projects by Circumstance, location sensitive speakers were carried by the audience for a guided walk (Figure 2.51.). The speakers produced spatial sound compositions based on the movement of the group. In *As If It Were The Last Time*, audiences took part in the experience given details of a time and a location and a specific mp3 file. They were split into two groups, each group playing back a unique sound track. One group is instructed to perform a simple act, while the other group hears and sees the scene as if it were a film scene. The roles switch between the groups and the audience participation becomes intimate as the performance continues.

UrbanRemix is a project for collaborative field recording, sound exploration, and soundscape creation. UrbanRemix provides a platform for mobile-device applications and web-based applications to have participants record and share geo-tagged sound and image recordings captured around their environment. Participants upload these media to the central server to browse, remix, and share the sound through an intuitive map-based interface. In addition, musicians and DJs can create electroacoustic music compositions, live performances, and installations using geo-tagged media.

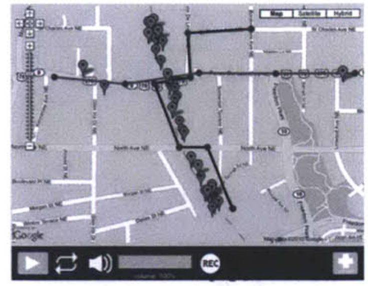

Figure 2.52. An UrbanRemix example interface.

What is intriguing about these projects are that the participants are 'playing the city as a musical instrument' [Gaye et al, 2003]. The soundscaping systems empower the participants to actively involve themselves in creating music through the interface or city that is fundamentally familiar to them. These projects augment participants' everyday experience with little effort as well: the participants equip themselves with the wearable computing system, a mobile device, or a custom soundscaping system that they do not have to consciously manipulate or learn about, making the interaction with the urban city transparent and intuitive.

2.3.3. Nightclubs

Nightclubs are intriguing environments where unique social interactions can be observed. In addition, nightclubs are usually friendly to new technologies [Gates and Subramanian, 2006]. We see this in many aspects of the club such as the design of clubs, the multimedia setups, and the popularity of electronic music in nightclubs. Such features are the organizing aesthetic principles of nightclubs. In this section, we cover innovative and interactive nightclub projects that provide the club community with interactive relationships between the DJ and the nightclub audience and opportunities to socially engage and interact in dancing. These projects enlighten us in forming the framework of the Hyperaudience system because they increase mutual relationship between the DJs and the audience to enhance awareness. They provide the DJs with information about the audience members' behaviors and music tastes and facilitate dialogue between the DJs and the audience as well as among the audience members.

Bayliss et al demonstrates the way to analyze and deconstruct performances in playful arenas, incredibly technology friendly playgrounds such as nightclubs, using the Performance Triad Model

(Figure 2.53.) [Bayliss et al, 2004]. Using this model, they explore digital technologies in a performance space that change the modes of interaction between audience and performers and exaggerate or separate the experience from those experienced in our daily life. Bayliss et al note that the playful arena is inherently a free and amusing space with intimate ubiquitous technologies that produce a new breed of performance. Their theory is drawn from computer science, performance theories, and club cultures to illustrate the Performance Triad model. The model is practical for the analysis and understanding of performance systems in playful arenas.

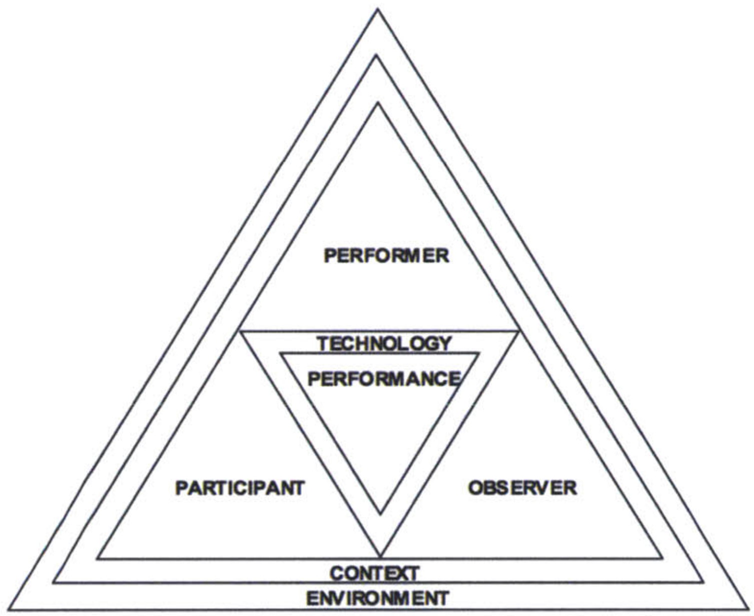

Figure 2.53. The Performance Triad Model.

The model is also useful for thinking about the framework of the Hyperaudience system because it is designed to encourage audience members to be communicative and participative, breaking the traditional relationship of performers and audience members.

Feldmeier and Paradiso developed disposable wireless motion sensors and used them to launch an interactive music experience for audience members in a nightclub setting (Figure 2.54.) [Feldmeier et al, 2002]. The sensors provided to a crowd track each participant's motion to determine sonic events, musical structures, and lighting controls. The system can collect data over a hypothetically limitless number of audience members, but it does not distinguish one sensor from another.

They also conducted a study in which interactive and non-interactive music environments were compared, and the result showed that people who participated in the interactive music event were more active and synchronized.

Figure 2.54. A disposable sensor used by the participants in Feldmeier et al.

codeBLUE is an interactive dance club system that utilizes Bluetooth devices [Hromin et al, 2003]. Dancers wear Bluetooth-enabled sensors on their clothing. These sensors measure information about the dancer's movements and transmit them through a Bluetooth data reader to a computer control system. The system maps dance movements into musical parameters in real time, modifying the rhythmic, melodic, and dynamic features of the music with MIDI data. Other audience participation based dance club systems include [Cliff, 205][Gluhak et al, 2006][Leitich and Toth, 2007][Quay, 2010][Ulyate and Bianciardi, 2002].

Most of these projects approach integrating new technologies in the club space from two perspectives: tools for interaction and communication, and tools for enhancing the performers' ability [Gates et al, 2006]. Many of these projects are interesting in terms of how they engage audience members to participate in a playful environment. They may be useful in different forms in the future nightclub space. However, in order to be truly useful, we need to reflect on the needs and desires of the audience and the performers in the technologically mediated social sphere. New technologies for the club space need to consider the expectations of the audience and how their awareness and communication can be enhanced in the space.

Gates and Subramanian provide us with many useful recommendations to follow in designing technology for nightclubs [Gates and Subramanian, 2006]. For example, they recommend 'facilitate mutual visibility between audiences and DJs, but not at the expense of privacy.' It is a good practice to help DJs and audience gain awareness of the entire nightclub, but exposing too much information can lead to personal privacy issues. We have much to learn from these recommendations in forming the framework for the Hyperaudience system.

2.3.4. Crowd Computing

Crowd computing is concerned with the interactions of crowds and how crowds can collaboratively or competitively produce some form of output in public situations [Brown et al, 2009]. We include crowd computing works in this chapter because they give us useful insight in designing a large scale audience participation-based performance system. From the points of view of social psychology and sociology, crowds act differently from smaller group formations. The projects demonstrated in this section consider systems for a crowd to interact and explore the elements that shape the interaction design for a large scale audience participation-based performance system. The audience participation systems given in this section depict important social elements that happen in a public space. The conceptual framework of the Hyperaudience system adheres to such systems because the participants cooperatively or competitively interact often by incorporating game elements.

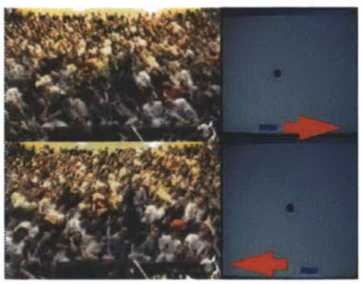

Figure 2.55. Audience members playing Pong together using a public display.

At SIGGRAPH in 1991, Loren and Rachel Carpenter demonstrated an audience participation system that enabled audience members to control a game on a public display using paddles of different colors [Carpenter, 1994]. Inspired by this system, Maynes-Aminzade et al presented new approaches that allowed audience members to participate in shared entertainment experiences [Maynes-Aminzada, 2002]. For example, audience members actively swayed in their seats to control an onscreen game of Pong, batted a beach ball which was used as a pointing device on screen, and pointed laser pointers at the screen (Figure 2.55).

Figure 2.56. Users interacting with City Wall.

City Wall is a large public display that is capable of tracking as many fingers and hands as can fit on the screen [Peltonen et al., 2007]. The computer vision-based tracking system also monitors hand gestures. The computer system then interacted with any users without requiring special skills to display media contents such as photos. The interaction models of the City Wall allow users to move, scale and rotate media content and have many users interacting with the display at the same time. The City Wall project helps us consider how urban and ubiquitous multimedia can be used in a large-scale event context to engage the crowd in and have them co-experience the event.

Affect in Public Spaces

Devices that measure human psycho-physiological signals, such as electrodermal activity measurement (EDA), electroencephalogram (EEG), electrocardiogram (ECG), or even computer vision systems can be used to infer information about the emotional state of an audience [Picard, 1997]. These devices can help a performance adapt its functions according to the audience emotional state. For example, a smart affective system can provide extra content to the audience member who is distressed or excited. This section covers systems that capture psycho-physiological signals from audience members in public events and utilize them to contribute to the collective experience.

Biofeedback

The purpose of biofeedback is to increase one's awareness of physiological functions using devices that provide information on physical activity and emotion [Durand and Barlow, 2009]. This is not strictly for public events, as most of the systems that use biofeedback in real time for entertainment purposes have been built for games. These systems for games use psycho-physiological signals to engage the player in the game and adjust the difficulty of the game based on the player's emotional state [Liu et al, 2009]. Kuikkaniemi et al studied two different biofeedback systems that influence gameplay: explicit and implicit feedback systems [Kuikkaniemi et al, 2010]. Explicit feedback happens when the players are aware of the feedback effects. If the players do not know about the biofeedback effects, the feedback is implicit. The results of Kuikkaniemi's comparison showed that the explicit feedback had bigger influence on a player and implicit biofeedback had little effect in the game play.

Kuikkaniemi et al also experimented with biofeedback in public events using PRESEMO (Figure 2.57.), a system where the audience could interact using mobile devices and a biofeedback system during a presentation. They were interested in whether social interactions using mobile devices and biofeedback systems, in this case a heart rate monitor, could have any effect on audience presence, attraction, and emotion [Chanel et al, 2010]. The result shows that explicit feedback, where participants are aware of the effects, such as chat texts, had a positive impact on the audience. The awareness of each other was obviously high when they could write messages to each other. The biofeedback also had an effect on viewers' awareness of each other during the presentation but was not significant enough to impact the audience's experience. Kuikkaniemi et al suggest that using different modalities, such as auditory feedback, may be more effective than visually giving biofeedback to the audience. When integrating biofeedback mechanism in a Hyperaudience system, it is important to consider the meaning of biosensor data and feedback mechanisms and their relationship to the existing ways audiences gain awareness of each other.

Figure 2.57. An interface example of PRESEMO.

Affective Computing

Picard and Scheirer introduced galvactivators, wearable sensors that sense and visualize the skin conductance level of a person's palm, and made them available to the audience at a symposium [Picard and Scheirer, 2001]. They collected the aggregated LED brightness level that was emitted from the galvactivators with a video camera. The data then was analyzed to explore the communication potential of the galvactivator (Figure 2.58.). The light indicator on the galvactivator was also visible to the audience, so they were also interested in exploring ways to light up the device. Some audience members would make themselves self-conscious to raise their skin conductivity so that the light level would go up. The galvactivator demonstrates a good example of biological signal communication and what impact this can have on inter-personal relationships in daily life settings as well as in public spaces.

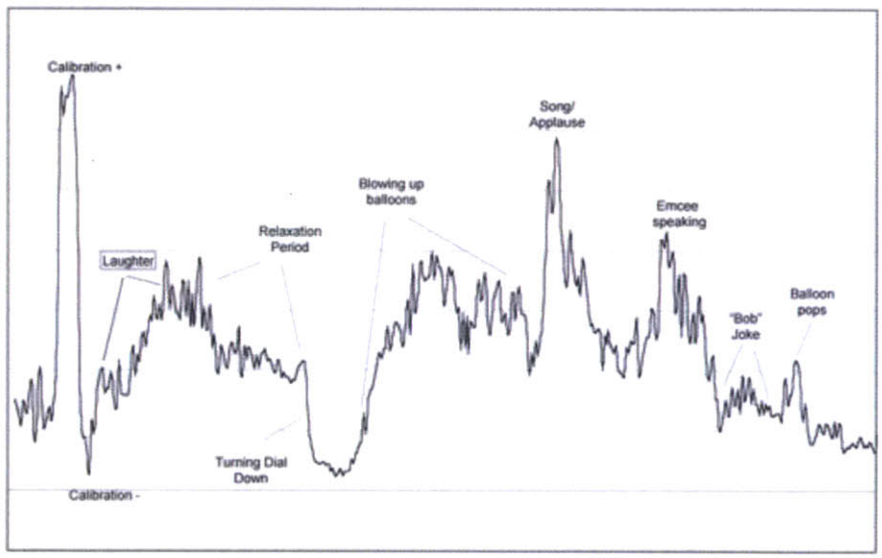

Figure 2.58. LED Brightness level of the Galvactivator from a segment of the audience.

Figure 2.59. Mood Meter public interface.

Mood Meter is a large scale public interactive installation that uses face recognition software to automatically detect human smiles [Hernandez et al, 2012]. The goal of Mood Meter is to quantify how friendly or welcoming a community is through smile detection. Mood Meter encourages passengers in a community to smile through its interactive display. The system for Mood Meter monitored and compared the emotional responses of people to several academic events within the MIT community. When the passersby experienced the installation for the first time, they noticed that their smiles triggered changes in the public display, so they would typically start experimenting with the system by not just smiling but also making frowning or sad faces. Some participants who had previously experienced the installation also experimented with drawings of smiling faces to see if the system would detect the smile. Regardless of who the passersby were, Mood Meter stimulated their curiosity and gave them a chance to be communicative with each other through facial expressions and conversations. A simple and intuitive interface for a public audience to engage in a performance is a good property for the Hyperaudience system.

3. DESIGN STUDIES

In this chapter, five projects that the author developed during my enrollment at the MIT Media Lab are presented. These projects include: Chroma District, DrumTop, SIILPE, *Sleep No More,* and *A Toronto Symphony*. The projects support the goal of our thesis: to design and implement a full Hyperaudience system. Based on the projects demonstrated in this chapter, as well as in the previous chapter, the conceptual framework of the Hyperaudience system is obtained in Chapter Four that connects performers and the audience as well as individual audience members and enhances the experience of the audience in a performance space.

Each project in this chapter represents a unique idea: the backgrounds of these projects are from the domains of site-specific interactive installation, music, and theatre performance. This section devotes a short section to each project. It covers the concept, interaction model, implementation, and the performance result of each project. Furthermore, each project's particular strengths and weaknesses, novel contributions, and challenges are also discussed. The projects are presented in chronological order based on the project completion date.

3.1. Chroma District

The first experimental project that explores the design space of the Hyperaudience systems is Chroma District: this project is a fully automated outdoor interactive artwork that responds with lights and sounds to pedestrians as they walk around the installation. The system supports active audience participation, as pedestrians contribute to shaping the real-time performance of the lantern installation.

Chroma District is a site-specific interactive installation that was presented as a part of the FAST festival—the MIT Festival of Art + Science + Technology [Chroma District, 2011][MIT, 2011]. This project was implemented by the author and Eyal Shahar with the help of Seung Jin Ham. It was exhibited for about three weeks at the courtyard in front of the new Koch Institute Building in MIT (Figure 3.1.). This is the area where the MIT campus meets Kendall Square. The area forms a pathway to the MIT Campus, directing visitors unfamiliar to the MIT towards the main campus area from Kendall Square.

Figure 3.1. The site of installation for Chroma District in front of Koch Institute Building in MIT.

The installation consisted of approximately forty lanterns hung from wires connected to two lines of street lamps (Figure 3.2.). The lanterns acted as nodes in a wireless network of physical pixels. They were illuminated with different colors, and each of them produced its own unique sound recorded in the train, at the train station, or at the MIT campus. Sounds were prepared to blur the boundaries between MIT and the campus surroundings. While the installation was in its idle state, each lantern softly played its sound and slowly propagated dim lights among lanterns. When a visitor approached a lantern, the sound and color of the lantern became lively and all the lanterns passed one from another the sound and color of the approached lantern, spreading bright lights and lively sounds.

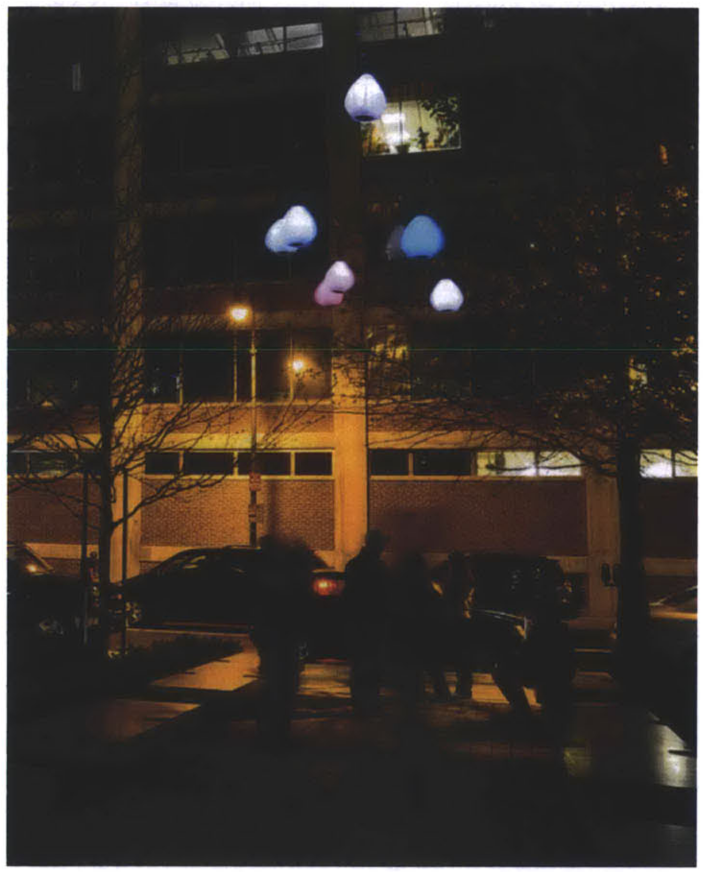

Figure 3.2. A partial view of the Chroma District installation. Lanterns are hung on wires attached to lines of street lamps. (©2011 Andy Ryan)

3.1.1. Background

In this section, the background for and related works that inspired Chroma District are presented. We look at the traditional culture of the paper lantern and some of recent lantern works as art pieces. Then we look at preceding site-specific interactive installation works. These works provided us ideas for conceptualizing the project and designing the lantern and installation configuration.

Paper Lantern Festivals and Designs

Paper lanterns in East Asian culture, such as China and Japan, are often associated with festivals. They are symbols of fertility in Chinese culture and have been closely related to the sacred and the cultural activities of Chinese people for more than two millennia [Siu, 1999]. Paper lanterns are often used in festivals to attract attention and give directions to people who take part in the festivals. They play a cheerful role in the festival, shining lights to community gatherings. The original conception of Chroma District follows this tradition: to welcome and to give direction towards the MIT Campus for pedestrians who attended the FAST festival.

Paper Lanterns in Various Festivals

Yuan-Xiao, the lantern festival, takes place on the fifteenth day of the first lunar month in the Chinese calendar [Huang,1991]. This is the last day of the Chinese New Year festival. People go out on the streets with a variety of lanterns under the full moon of night. On the streets, people watch lions and dragons dancing and light up firecrackers. The Chinese have evolved the festival lanterns into many different shapes and sizes. For example, lanterns may look like vegetables, animals, fish, men, and many other objects found in nature (Figure 3.3.).

Figure 3.3. Paper lanterns in *Yuan-Xiao*.

The paper lantern festival at Kuki city in Saitama, Japan uses real candles to illuminate paper lanterns (Figure 3.4.). They are extraordinarily piled up on top of a pulled rickshaw, requiring multiple people to pull the rickshaw on the road. When the rickshaw moves, so does the flame of candle, making lanterns look like they are alive [Kuki, 2012].

Figure 3.4. Lantern Festival in Kuki City. Lanterns are on a rickshaw.

Paper lanterns come in various forms and purposes depending on the types of the festival. For example, sky lanterns are often released into night sky for aesthetic effect at some Chinese festivals. Small paper bags that have candles inside them are often released to the river on Christmas in Hispanic communities. There are countless examples of the use of lanterns in festivals, but looking at the above examples gives us sufficient evidence that lanterns are often used in festival to attract people and please them with artistic illumination.

Modern Paper Lantern Designs

Figure 3.5. An early promotional photograph of akari lanterns, 1950's. © Isamu Noguchi foundation inc, New York

Lanterns are typically treated as commercial commodity products. Nonetheless, many recent designers have come up with stimulating lantern designs for the purpose of art and design. Isamu Noguchi is a well known twentieth century artists who expanded the traditional notion of sculpture to include the furniture, dance sets, gardens, and playgrounds. One of his famous works is *Akari Light Sculpture* (Figure 3.5.): Lantern sculptures that are constructed from bamboo and papers, fusing elements of Japanese art with Western modernism. Other designs include works by Kouichi Okamoto, who designed a bulb shaped lanterns in a lighting installation and Anthony Dickens who designed *Tekio* [Kyouei Design, 2012][Tekio, 2012].

Interactive Arts

We have already examined some interactive art systems and principles and method of implementing such systems in Chapter Two. In this section however, we will reiterate the philosophy of interactive arts and some examples of interactive art systems that are similar to Chroma District. These projects mostly deploy individual pixels in public spaces. In other words, they are urban display systems that enable communication and interactivity among audience members.

Interactive art refers to the way the object performs as well as the manner in which it appears to the audience [Edmonds et al, 2004]. In interactive art, the role of a computer is quite important in engaging the audience to play with the system because it transforms the role of the audience from merely being an observer to being a participant who actively shapes the artworks. The audience members are part of the artwork and the interaction between the audience and the artwork is the central component to the interactive piece of art. Chroma District also considers the audience as the central part of the installation and the design process of this installation focuses on the interaction between the system and the audience.

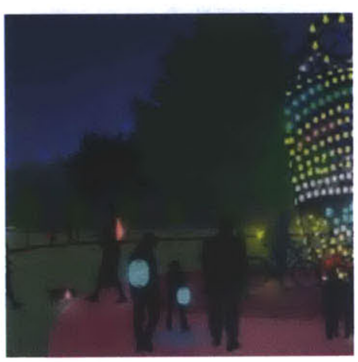

Figure 3.6. The conceptual image of SOL. © Susanne Seitinger.

Self-Organizing Lanterns (SOL) are hand-held, computerized lanterns that can be programmed to support the needs of individuals and public events [Seitinger et al, 2010]. The project is not strictly a work of interactive art, but the project reveals many similar aspects to Chroma District. In SOL, each lantern is a node in a wireless network that selforganizes on a sculptural charging station. Lanterns are meant to be carried by people and they contemplate the self-organizing nature of people in the public space. People borrow the lanterns from the charging station and enable different modes of operation. Chroma District is similar to SOL in that the implementation of each lantern is enhanced with a wireless device and light-emitting diodes (LEDs). Moreover, the project is like Chroma District from the social interaction perspective because it uses lanterns as the representation of social interactions among people in the public space.

Body Movies by Rafael Lozano-Hemmer (2002) was an interactive robotic projection that combined shadows of people who walk by the installation with the portraits of other people taken on the city streets [Lozano-Hemmer, 2011]. Through this interaction, the installation explored the intersection between urban space, technologies, and active audience participation. In the installation, a computer vision-based tracking system monitored the location of the shadows of visitors in real time, and when the shadows overlapped the projected portraits, the computer changed the scenery to the next set of portraits. The installation was 1200 square meters in size and it created an collective experience for up to sixty visitors at any given time. The installation was also capable of giving discrete individuals participation. Although the scale of Body Movies is large, Chroma District is similar to Body Movies in that pedestrians can simply walk up to the system and participate in the installation. Body Movies also reduces the distance between each participant which is also what Chroma District attempted to achieve.

Figure 3.7. A scene of the Body Movies installation.

White Noise White Light by Meejin Yoon (2004) is an outdoor installation with a grid of fiber optics and speakers [Yoon, 2012]. The installation interacted with visitors through sound and light fields based on the movement of people as they walk through it. The movement caused the white LED illumination to grow brighter while the white noise got louder. When a visitor's movement was not present, the light and sound pattern faded into dimness and silence. The interaction model of Chroma District is similar to this installation in that it demonstrated the transformative effect of light in a landscape and as a new landscape to be inhabited by visitors. The installation became alive when there was a pedestrian interacting with it.

Figure 3.8. White Noise White Light by Meejin Yoon (2004).

3.1.2. Interaction Model

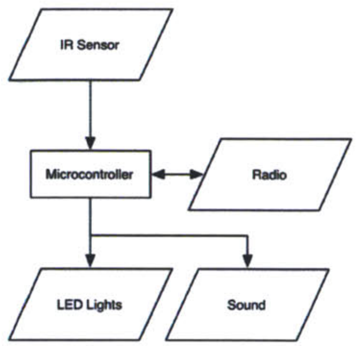

Figure 3.9. A basic interaction model diagram of Chroma District.

Chroma District has a simple interaction model (Figure 3.6.). The installation is fully automated, and each lantern used pedestrians' movement to trigger light and sound patterns. The movement of visitors was captured using infrared (IR) sensors installed on each lantern. When pedestrians stood underneath one of the lanterns, tricolor LED lights and a sound system reacted to them. The fluctuation of light and sound also spread through lanterns using the radio communication system, making a gradient effect of light and sound patterns across the installation area. Our objective was to connect people and places through active participation using the lanterns that communicated with each other along the pathway. Each lantern contained a unique light pattern and a sound source recorded around the MIT campus or collected from the MIT sound archives.

3.1.3. Implementation

This section documents the technical implementation of Chroma District: the highlights are the design of the lantern, the fabrication process, the electronic production, and the installation design.

Parametric Lantern Modeling

The final design of lantern was created in the computer-aided design (CAD) software called *Rhinoceros 3D*. Rhinoceros 3D is a non-uniform rational B-spline-based (NURB) 3D modeling software licensed by Robert McNeel & Associates [McNeel, 2010]. This software is typically used in designing architecture, industrial products, and jewelry. Rhinoceros 3D was also an ideal environment in designing a lantern in three-dimensional space.

A plugin for Rhinoceros 3D called *Grasshopper* is capable of producing generative objects based on relationships, rules, and properties defined by a visual programming language [McNeel, 2010]. The lanterns for the installation were designed using the plugin that is capable of producing 3D geometric generative algorithms. We iterated through the design of a lantern a number of times (Figure 3.10.) and decided that a simple shape was the best: we discovered that lanterns with complex shapes require a long process of manufacturing, sometimes requiring specialized skills and facilities such as injection and blow molding which we did not have access to. Thinking about the fabrication procedure was an important criteria for deciding the final design of the lantern.

Fabrication

The skin of each lantern was made from a sheet of high-density polyethylene (HDPE), a kind of plastic. The criteria for choosing the skin for the lantern was based on the safety and weather proofing. We were also pleased by the texture, softness, and translucency of the HDPE because out of all the samples we examined, it had the closest appearance and feel to paper while withstanding water and keeping a flexible and strong structure. A sheet of HDPE was thermoformed using vacuum forming equipment available for use at fabrication facility in Center for Bits and Atoms [CBA, 2001]. The mold for thermoforming HDPE was made of Medium Density Fiberboard (MDF) (Figure 3.11.). MDF is a processed material of wood fibers suited to be used for the vacuum forming process because of its porous internal structure: when we vacuum-form a plastic with MDF, the air could pass through the structure itself, making air suction and efficient thermoforming of plastic.

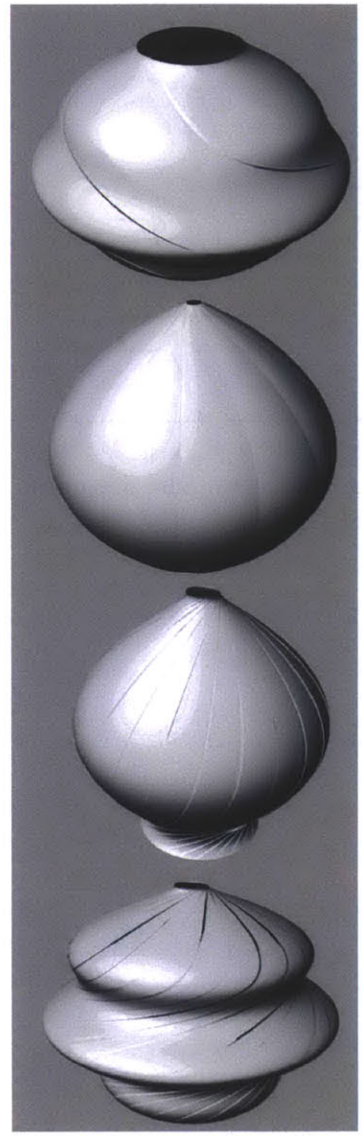

Figure 3.10. Early design ideas of parametrically designed 3D model of lanterns.

A mold made of MDF was originally fabricated with a three-axis CNC milling machine called ShopBot [Shopbot, 2012]. CNC machines typically accept computer design files, such as STL and IGES files, created with CAD software. Software accompaniments to these machines normally auto-calculate a milling path for an object. As previously mentioned however, the design of an object needs to conform to the limit of fabrication process: in this case three-axis milling machine.

Perhaps the assembling of the lanterns took the longest time since this was a manual process that did not utilize computerized tools. HDPE is soft and bendable while maintaining a strong structure. We decided to assemble one lantern using four separate parts of vacuum formed HDPE using rivets (Figure 3.14.).

Electronics

The installation was an automated system with each lantern acting as a node in the wireless network system. The IR sensors were the ideal sensors in Chroma District as opposed to ultra-sonic sensors because the installation was primarily active during the night; IR sensors provided a rather clear signals when pedestrians were approaching the installation. Lanterns were programmed to shut down when IR sensors had too much exposure to the Sun, because lighting a lantern was not visible during the day. At night, the lanterns became active and celebrated the pathway when visitors passed by.

Figure 3.11. An MDF mold for thermoforming HDPE.

Figure 3.12. The final circuit board design. A diffuser is on the top layer followed by the LED board, the main controller board, and the radio board.

Circuit boards were made of three parts: an LED lighting board, a radio board, and a main controller board. Three boards were stacked and connected together using multicore ribbon cables inside a lantern (Figure 3.12.). The LED lighting board comprised of eighteen super bright LEDs and numerous resistors for conditioning electronic signals. It required standard 3.3v voltage input and the current consumption was approximately 100mA/h. The LEDs were in tricolor configuration and red, green, and blue each had six LEDs. On top of this board, we also had a layer of diffusion to disperse the lighting inside the lantern.

The main chip running on the radio board was the Microchip MRF49XA ISM Band sub-GHz RF Transceiver [Microchip, 2011]. This chip is capable of radio signal communication through an antenna.The main controller board handled the inputs and outputs of lantern interactions. We used the Atmel ATMEGA32U4 low power 8-bit microcontroller [Atmel, 2011] to play back sounds stored in the MicroSD memory card, to generatively control lighting patterns, and to enable radio communication among lanterns. The three circuit boards were mounted inside the lantern using a latch that hung on the internal structure of a lantern.

Site specific Installation design

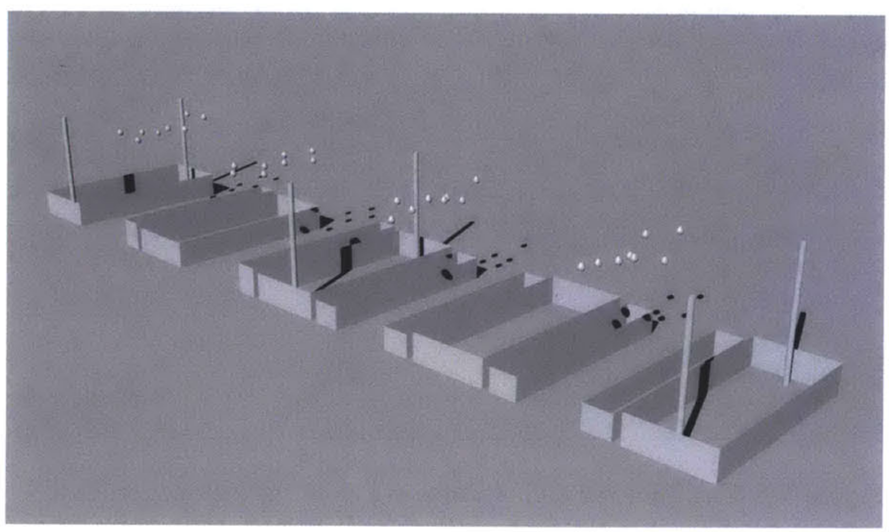

Figure 3.13. The 3D model of the installation. The model was viewable from any angle, making it useful to visualize the installation before the actual exhibition day.

Figure 3.14. (Top and middle) The final design of lantern after the fabrication from top and side view. (Bottom) The cover on the bottom of the lantern. It consists of a flat panel loud speaker and an infrared sensor.

The installation layout was also designed using Rhinoceros 3D software. The first step in designing the installation layout was to measure the actual dimensions of the area at the installation site. We can accomplish this task by either acquiring a detailed building plan of the area or by directly measuring the area with tools such as a tape measure and a laser measure. We chose the later approach and physically measured the three dimensional space of the site using a tape measure.

Later on the measurements were used to construct a three dimensional model of the site (Figure 3.13.). Designing the 3D model of the site helped us visualize the configuration of the lanterns in the area prior to actually carrying out the installation. The model also helped us to have a productive and fast-paced installation day with the facility people who were in charge of installing the lanterns, because we were able to communicate effectively with the facility people using the model. For example, we prepared the wires that lanterns were hang from based on the 3D model we built and this led us to reducing the time for installing the lanterns.

3.1.4. Execution and Result

Figure 3.15. The final test run of lanterns before the installation day.

Chroma District was exhibited from May 2, 2011 to May 15, 2011. Five days prior to the FAST Light festival, the finale event of the three months long FAST festival, the MIT campus and the Charles river were illuminated with lights demonstrated by over twenty installations by the faculties and students at MIT. Chroma District was one of them and illuminated the extension of the main campus of MIT, inviting visitors to the campus.

Installing the work spread over two days and we spent about ten hours installing approximately forty lanterns. Our software program on the microcontroller chips was upgraded a number of times during the installation period. Because of bad weather, during the installation period, some of the sound and lighting system inside some of the lanterns had broken, but most lanterns remained resistant to rain and wind.

Informal interviews with visitors, asking their experience of Chroma District, revealed to us that they had mixed opinions about the installation. Some said that changes in the lighting pattern were so subtle that it was often hard for them to know whether the lanterns were interacting with them or not. Others said that the sounds from lanterns were obscured by traffic noise that it was often difficult to hear them. On the other hand, some visitors mentioned that it was interesting to hang around the installation because people's movement was making the lanterns active and the area looked cheerful.

We observed that, although the installation sometimes may have been too subtle to notice the changes, visitors were actively participating in interacting with the installation, often with their friends and families. We felt that the installation created a place for the visitors to socially communicate.

Challenges

Maintenance

Installing a site-specific interactive installation requires maintenance, especially if the site is outdoor. The installation may fall apart from vandalism or bad weather. We also had to change the battery every three days to keep the installation running for approximately two weeks. Weather proofing the lanterns proved to be an important practice because it helped us from needing to execute any repair work on the lanterns.

Communication

We also found that coordinating the project with the curators and the facility people was extremely important towards making the installation successful. We learned that 3D modeling of the installation site was a good communication tool with the facility people to tell them how exactly we wanted the installation to be configured.

3.2. DrumTop

Figure 3.16. The DrumTop interface.

DrumTop is a tangible musical sequencer that takes advantage of everyday objects as a source of musical inspirations for musical novices. We include DrumTop in our thesis, because DrumTop is relevant in formulating the conceptual framework of the Hyperaudience: DrumTop demonstrates how a collaborative tabletop interface that is designed to be simple and intuitive to use for musical novices can enhance the social interactions among players through the use of everyday objects. In this section, we cover the original intentions of the DrumTop project, related works, the interaction model, and the implementation of the system. We then briefly discuss informal feedback given from the users.

The goal in making DrumTop was to create a simple physical interface that gives voice to everyday objects, affords self-expression and immediate engagement for novices, and encourages novices to explore the musical potentiality of their surroundings through musical interactions with everyday objects. Many new musical interfaces for novices focus on expressing music by means of electronic and digital sound productions [Blaine and Fels, 2003]. By building a prototype of DrumTop, we seek to expand the possibilities of new musical interfaces for novices that produce sounds from real world objects themselves in an intuitive manner. The DrumTop interface provides novices with ways to explore rhythm patterns, sounds, and their combinations through task-oriented hand gestures with everyday objects. In addition to hearing the rhythm patterns they create, players also visually and tangibly receive feedback through the objects.

Feedback from players suggests that DrumTop can be used to explore musical structures and interactions among different objects, sounds, and patterns. Using everyday objects as a central ingredient of a musical interface design facilitates a fun and exciting experience, encouraging experimentation and collaboration among players. The feedback also suggests musical novices, especially children, would see DrumTop as an accessible and playful way to learn musical patterns. In addition, performers and artists will find DrumTop a rich platform for collaboration.

3.2.1. Background

Everyday objects are a fascinating source of musical activities. It is not surprising that the idea of transforming everyday objects into percussive musical instruments is not new: new musical instruments often have their origins in household objects, natural objects, and crafting tools [Monache et al,2008]. The concept of transforming household objects into musical materials was explored by Erik Satie [Cox and Warner, 2004]. John Cage has frequently used found objects in his compositions such as Water Walk [Cage, 1959]. Many of us may have grown up playing and learning music through beating on buckets and kitchen utensils as composer Tod Machover did [Machover, 2007]. DrumTop makes full use of everyday objects to facilitate a creative musical experience for novices.

Figure 3.17. Beatbox (Top) and Duper/Looper (Bottom).

Automation

A number of related works explore transforming everyday objects into percussive instruments in an automated manner. Duper/Looper, Beatbox, and Buonda focus on a modular tangible drum machine interface that can simply be attached to or placed on top of physical objects (Figure 3.17) [Kuwakubo, 2001][Huntington, 2005][Iwasa et al, 2010]. Their interaction models are based on the repositioning of knockers, actuators typically composed of solenoids or servo motors, which act in the manner of the user's knocking hand gestures. The user simply places the knockers on top of objects or attaches them to the objects that they would like to generate a rhythm from. DrumTop resembles these projects in that the rhythmic patterns are automated and the sound production technique does not rely on digital signal processing but on the sounds of physical objects themselves.


Figure 3.18. The interface of Scrapple by Golan Levin.

Tabletop Synthesizer/Sequencer

Several works make use of physical objects to synthesize digital sound and generate rhythmic patterns by analyzing them on the fly. We pay special attention to the core mechanics of the interaction model that these projects emphasize. These projects freely and quickly move around physical objects on a tabletop surface to progressively affect the sound outcome. Golan Levin's Scrapple is a tabletop musical instrument where users arrange a group of physical objects with different sizes and shapes on the table (Figure 3.18.) [Levin, 2006]. The instrument scans the table and synthesizes sounds in real-time. It does this by interpreting the objects on the table as spectrographic sound-events. Reactable, a tabletop tangible musical interface, is capable of having multiple users locally or remotely collaborate to create electro-acoustic music (Figure 3.19.) [Kaltenbrunner et al, 2006]. Users move physical artifacts that have fiducial markers underneath them on the tabletop surface to construct and manipulate musical topologies.

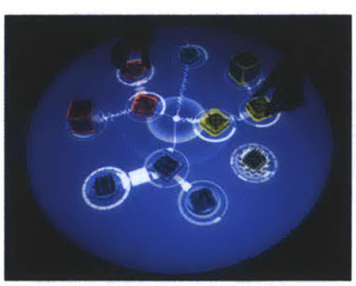
Figure 3.19. The Reactable interface.

Other examples of tabletop tangible musical interface projects include Audiopad [Patten,2002] and Jam-O-Drum [Blaine and Perkis, 2000]. The Bubblegum Sequencer is a step sequencer with a physical interface with which users create and perform percussive electronic music by arranging gumballs on a tabletop interface with gridded holes (Figure 3.20.) [Hesse and McDiarmid, 2008]. Sound samples, mapped to the color of the gumballs, are sequentially played at the appropriate time as users place gumballs on the holes of the interface. DrumTop is inspired by these tabletop interface design approaches that make the manipulation of music familiar and easy to understand for novices.

Figure 3.20. The Bubblegum Sequencer interface.

3.2.2 Interaction Model

Everyday Task-Oriented Gestures

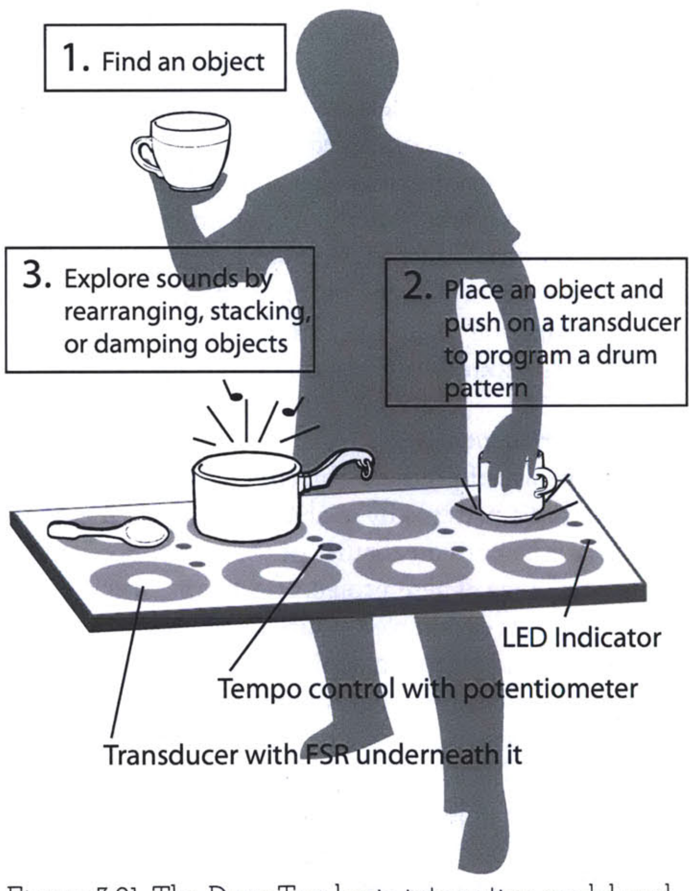

Figure 3.21. The DrumTop basic interaction model and building blocks.

Interacting with everyday objects is a daily routine for most of us. Simple non-communicative task-oriented hand gestures such as reaching, grasping, placing, and pushing come naturally to us without a conscious effort. DrumTop capitalizes on these gestures to engage players in musical activities. The players are capable of interacting with the interface by interacting with everyday objects in a way they normally do in their daily life. As depicted in Figure 3.21., the basic gestures to play with DrumTop are adaptable from the gestures most of us already employ in our daily life including finding and grabbing objects, placing and pushing them on the DrumTop tabletop surface to program drum patterns, and rearranging the objects on the tabletop surface to make changes to sound patterns.

Feedback

In DrumTop, everyday objects are the primary feedback source of sonar, tactile, and visual experience: the players hear the sound directly coming out from the objects; they touch the objects to feel the sound and change the acoustic properties of the objects; and they see the objects buzzing caused by a hit from the transducers. The coupling of the sound generation system and the physical interface with which the players interact, often missing in digital musical instruments [Marshall, 2008], offer immediate feedback to the players of DrumTop, leading to a creative, intuitive, and playful interactive musical experience.

Rapid sound exploration

In the design of DrumTop, special attention has been paid to the physical objects' manipulability to ensure that the players can quickly rearrange objects on the tabletop surface and program rhythmic patterns. While DrumTop is designed to be a step sequencer, its interface design borrows that of traditional electronic percussion pads with an intent to make hands-on manipulation of the physical object and sound associated with that object intuitive. DrumTop is capable of giving voice to everyday objects; we have tried various materials ranging from paperclip boxes, metal disks, mobile phones, and plastic toy balls. With combination of appropriate objects, the players can also create simple melodic patterns that may not necessarily follow the traditional Western musical scale. Therefore, the potential for creating a new sound combination is in the hands of the players; the creative expression of the players is stimulated by what they find around them and how they decide to play and combine everyday objects.

3.2.3. Implementation

DrumTop was designed to be relatively low-cost, simple, and robust. The tabletop interface consists of a 2x4 array of circular pads. Within each pad, a transducer, an audio exciter from HiWave Technologies [HiWave, 2012], equipped with a force sensitive resistor underneath it is placed facing up at the center (Figure 3.22.). The eight pads represent a measure in musical structure. Each pad represents one eighth note in a measure of music. An Arduino board [Arduino, 2012], a platform of DrumTop hardware and software implementation, loops through each pad in a sequence creating an eight beats per measure structure. As the loop continues, LEDs next to each pad indicate which pad is currently being activated.

Figure 3.22. A force sensitive resistor under a transducer for detecting a push input from the players. An LED indicator at the top of a pad signals players that the pad is currently activated.

3.2.3.1. Programming drum patterns

As the players place physical objects on the circular pads and press on the transducers, force sensitive resistors underneath the transducers signals the Arduino board that a push from the players has been communicated. A preprogrammed drum pattern immediately loads from the board memory, producing a unique hit pattern each time the transducers are pressed. The transducers are operated with digital output pins from the Arduino board to produce a short impulse. When the impulse is transmitted to the physical objects, they produce sounds with their unique acoustic properties.

3.2.3.2. Tempo

At the center of the tabletop surface, a potentiometer is placed to control the tempo of the step sequencer. The players change tempo at will by twisting the potentiometer knob, and the visual feedback of an LED sequence helps anchor players in their beat making and provides a consistent indication of the current tempo.

3.2.4. Execution and Result

3.2.4.1 The interface and player's feedback

Based on our preliminary demonstration, people tend to find DrumTop surprising but quickly understand the basic concept of the system. By the time players have constructed a basic rhythm pattern, they are usually smiling and seeming to enjoy the whole creative experience. DrumTop seems to stimulate players' curiosity with everyday objects and their sound, since the most common action players take with DrumTop is to look in their pockets or around them to explore the sound of different objects on DrumTop. One player even took out a

Figure 3.23. A mess after a DrumTop session showing enthusiasm of novices.

wallet from his pocket to place all his cards and money on DrumTop to experiment with sounds by stacking and rearranging them. DrumTop also appears to spark collaboration among players as players discussed about, shared, and agreed upon objects that would go on top of the interface as they enjoy themselves with DrumTop. These are exactly the type of exploratory interactions that we hoped to bring out from the players with DrumTop.

3.3. Social Influences on Individual's Live Performance Experience

In this section, we present Social Influences on Individual's Live Performance Experience (SIILPE). In this project, we conducted an experiment to see whether a real-time social influence during a live music performance could affect an individual's performance experience. Specifically, we wanted to know whether or not a social influence could have enhanced the performance experience of the individual audience members even if they did not know about each other prior to and during the live performance.

Figure 3.24. The conceptual model of a mobile interface that the participants used in the experiment.

The experiment was executed by measuring the electrodermal activity and a self-reported measurement of emotional states of the subjects during the observation of videos on live music performances to assess their engagement level with the performance. Moreover, we also asked subjects to fill out surveys after each video session that asked about subjects' emotional states for the assessment of the performance experience. The result of the experiment did not show us any significant trends in subjects' live performance experience when real-time social inputs reported from mobile devices (Figure 3.24.) were present on the large screen display. We suspect that the results were not promising because the subjects did not know about each other.

We include SIILPE in this project because the performance simulation system built for this project reveals important properties of the conceptual framework of the Hyperaudience system. In addition, this project also demonstrates integrating an evaluation system within the the performance system to quantitatively assess how successful the performance is through measuring the audiences responses and experience.

3.3.1. Introduction

Social networking services, music recommendation systems, and online music distribution systems are continuously shaping the way we experience recorded music. Our experience has become increasingly interactive and collaborative as we see from popular new services such as Turntable.fm [Turntable.fm, 2012] and SoundCloud [SoundCloud, 2012]; we collaboratively listen to music by commenting on, rating, and sharing the music as we listen. The increasing popularity of these new services reminds us that the creative music experience can be enhanced by structuring social activities around it. Nonetheless, as recorded music and social networking services spark new models of creative music experience online, the model of experience for a live concert performance remains mostly the same due to the large audience normally in attendance, the real-time nature of the performance, and the physical and technological limitations of venues [Freeman, 2010].

A number of people have been designing collaborative music performance environments for audience members to have social interactions during a live performance among themselves or between performers and audience members partly from the belief that inducing a social interaction among audience members during a live concert performance makes the performance experience more engaging. Moreover, they think that such performance systems could encourage audience members to discover alternative ways to be expressive and to become aware that each performance is special, partly because of their involvement in the live performance.

In this study, we investigated whether or not social interactions among audience members during live performances could lead to a higher audience engagement level for a live performance on an individual basis than the engagement level for live performances without social interactions. We designed the experiment by simulating live performances and social interactions in a controlled environment, and measured the level of audience engagement level using electrodermal activity (EDA) sensors, continuous self-reporting measurement systems (CSR), and survey reports. The experiment did not take advantage of a real live performance setting and we understand that the engagement level of the audience may have been lower in the simulated performance [Latulipe et al, 2011]. Nonetheless, we wanted to design an environment where the experiment is precisely controlled to collect useful data from the audience members for the purpose of analyzing their engagement level.

3.3.1. Background

Social Influence

Herbert Kelman identifies three broad varieties of social influences: *Compliance, identification,* and *internalization* [Kelman, 1956]. *Compliance* is when people appear to be in agreement with others, but actually keep their differences of opinion private because of social pressures. *Identification* is when people are influenced by someone who is liked and respected. Social influence can play a role in this situation because behavior or attitude change becomes "reward" by relating someone to the liked or respected person. *Internalization* is when people accept a belief or behavior and agree both publicly and privately because the content of the influence is intrinsically rewarding to them.

Social influences such as ratings, friend recommendations, and expert opinions affect individuals' media consumption habits, neural mechanisms, and emotions [Abbassi et al, 2011] [Berns et al, 2010] [Egerman et al, 2009]. Zeinab Abbassi et al conducted empirical studies of the effects of social influence on online choice making. The study concludes that an additional rating star from the general public and negative opinions from friends' influence an individual's item selection. Gregory S. Berns et al experimented with fMRI to explain the neural mechanisms associated with social influence on adolescents with regard to music consumption. The results of his study suggest that a principal mechanism whereby popularity ratings affect consumer choice is through the anxiety generated by the mismatch between one's own preferences and those of others. Hauke Egermann et al studied whether emotional experience induced by music can be manipulated by social feedback. He conducted a web-based experiment in which listeners rated their emotions according to arousal and valence dimensions. 3315 participants were randomly assigned to two groups: one group received feedback from preceding participants while the other group was used as a control condition. The result of the study shows that feedback from preceding listeners significantly influenced participants' ratings.

Methods of measuring audience engagement level

Latulipe et al., conducted an experiment to examine if the galvanic skin response (GSR), a measure of human skin conductivity, gathered from audience members during a live performance is a valid representation of audience engagement by correlating the GSR data with self-report scales [Latulipe et al, 2011]. The participants in the experiment were presented with a video-clip of a live dance performance while their GSR data was collected. Their findings gave strong correlations to the two measurements, confirming that interpretation of GSR is a valid representation of audience engagement.

Measuring the impact of music performances on audience members using a self-report method has been conducted by IRCAM [McAdams et al, 2004]. One of the researchers' foci was on the the emotional force felt by the listeners as a function of musical structure. The listeners continuously responded to the music by moving a physical slider in a live concert setting. The study revealed that emotional force reduced with repetition of the musical material and computer-processed sounds had an impact on the emotional force of the audience members.

3.3.2. Interaction Model

Participants

Eight adults, who are students and staff members at the MIT Media Lab (5 male and 3 female), were recruited in the study. We had two study sessions in which four people were assigned to each session. Their ages ranged from 20 to 50. All participants were paid for their participation.

Method

To investigate the social influences on an individual's live performance experience, we simulated a live performance and social interactions with video projections. Since watching videos of a live concert performance is not the same as the experience of attending a live concert performance, we configured the environment to increase the participants' sense of immersion, which included projecting the performance onto a large projector screen, having the participants listen to fairly loud sounds from ceiling mounted speakers, and watching the videos in a dimly lit room.

Each participant wore an Affectiva Q sensor, which measures electrodermal activity, temperature, and physical activity, on the palm of their non-dominant hand. Their dominant hand was used to self-report their valence and arousal level during the live performance using a virtual two-axis slider on a tablet PC. We encouraged participants to not look at the slider interface during the observation of the videos. We labeled the arousal axis with *Calm* and *Exciting*, and the valence axis with *Negative* and *Positive* (Figure 3.25.). The meaning of each axis was explained to the participants prior to the study.

Figure 3.25. What subjects saw on the iPad interface for self-reporting their emotional states. The X-axis represents the valence level while the Y-axis represents the arousal level. The application was a web application which could be accessed through a browser on the iPad.

Participants watched four videos: two video excerpts about nature (about Alaska and ocean from National Geographic), and two videos of Queen's live performance, "We are the Champions" and "Bohemian Rhapsody." The sequence of the video playback was the same in both studies: 1) Alaska, 2) We are the Champions, 3) Ocean, 4) Bohemian Rhapsody (Figure 3.28.). We asked participants to fill out survey questions at the end of each video experience. The surveys consisted of rating the overall performance experience with self-assessment manikin scales [Juslin and Sloboda, 2001] and Love/Hate (LH) Likert scale measurements for assessing components of the performance such as music, performers, and video production (Figure 3.26. and 3.27.).

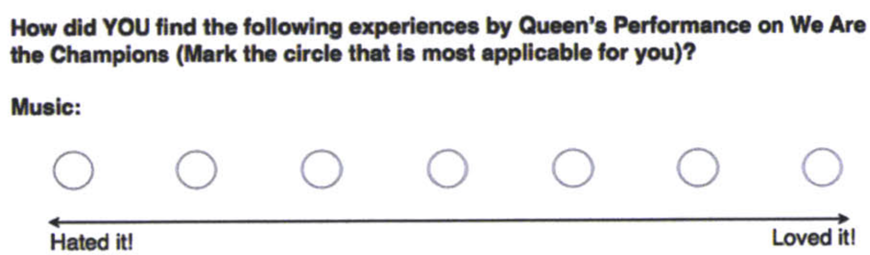

Figure 3.26. A Love/Hate scale asking subjects to rate the components of a live performance.

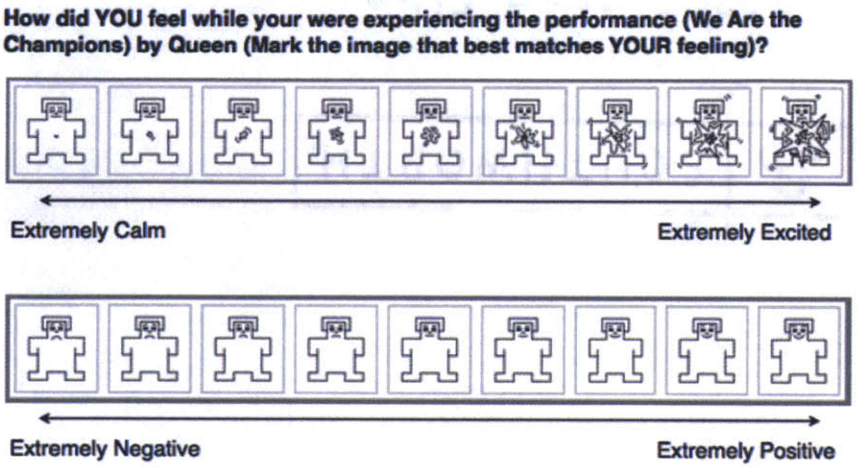

Figure 3.27. Rating a performance experience with self-assessment manikin scale.

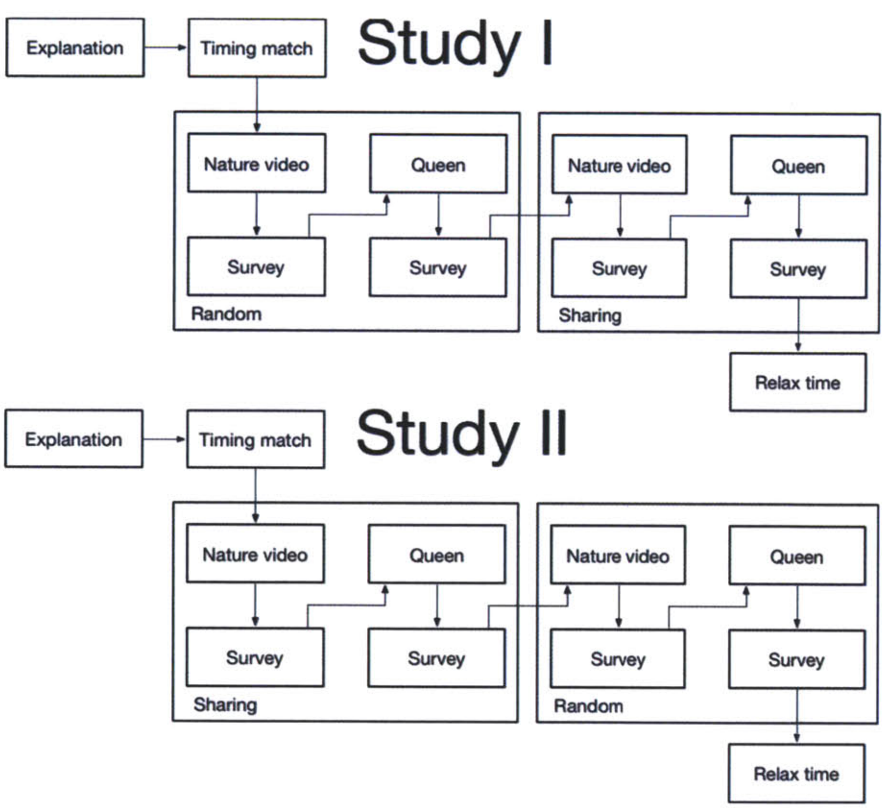

Figure 3.28. The study sequence for the Study I and II. The sequence of videos was the same but the order of displaying the self-report measurements on the screen was different between the two groups.

The experiment ran as a between-group study, with participants randomly assigned to one of the two groups. Participants within each group were present in the same room to capture any of the social effects that occur in a true performance setting. In fact, we attempted to magnify the social effects by directly displaying the participants' self-report measurements on the edge of the projector screen for two videos (one nature video and one performance video of the four videos) (Figure 3.29. and 3.30.). The other two videos also displayed the bars on the edge of the projector, but they were randomly moving and did not reflect the participants' self-report measurements.

Figure 3.29. The example image of what the subjects saw on the screen. The center is where the video was projected, and the self-report measurement was directly displayed on the edge of the screen.

Social interaction and non-social interaction were distinguished by whether to have the self-report measurement directly appear on the screen or not. This decision was made to factor out the visual cognitive load among the video experience. Participants were told prior to the study about the self-report measurement sharing and the random visual display on the edge of the projector screen. We explained this using images similar to Figure 3.27. and 3.28. to show what videos they were going to see, how the peripheral bar display would work, and for which of the four videos they would see their rating on the display.

The two groups were presented with different orders of the display conditions while the order of the video sequence remained the same. The subjects were able to identify their ratings on the screen because the bars were numbered the same as the numbers on the EDA sensors.

The bars were also the same color on the dots appearing on the iPad interface so that the subject could identify themselves by the colors. For the purpose of the study, we kept all the subjects anonymous from each other. Nobody knew each other prior to the study or was able to tell another person's rating on the projector screen.

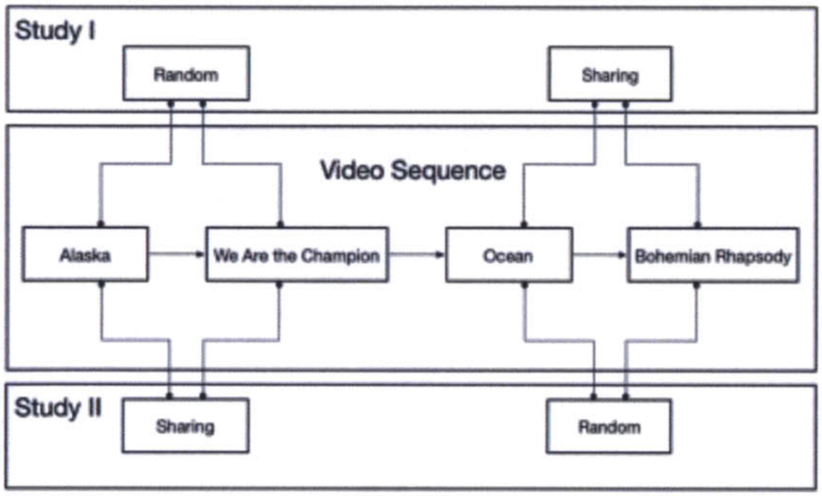

Figure 3.30. Random means non-sharing: The subject did not see their self-report measurement directly on the projector screen. Instead, the screen was showing randomly moving bars.

Measures

EDA samples were taken every 125 milliseconds. Our study resulted in eight participants' data consisting of 50 minutes worth of EDA data. After collecting the EDA data, we applied the exponential smoothing to the entire duration of the original EDA signals ($\alpha = 0.1$) to remove a noise factor from the data using the equation:

$$Y[n]=\sum_{n=1}^{N-1} \alpha X[n] + (1-\alpha)Y[n-1] \qquad \text{(Equation 3.1.)}$$

X is an EDA signal. Then we again reapplied exponential smoothing ($\alpha = 0.001$) to obtain the contour of EDA signals. We subtracted the smoothed EDA signals with an alpha value of 0.1 from EDA contour data to obtain a flattened version of EDA signals since we were interested in looking at the peaks that occurred in the EDA signals and not the amplitude of the signal (Figure 3.31.). After the subtraction, EDA signals were normalized from 0 to 1, and we extracted sections of the normalized EDA signals that were relevant to the video experiences.

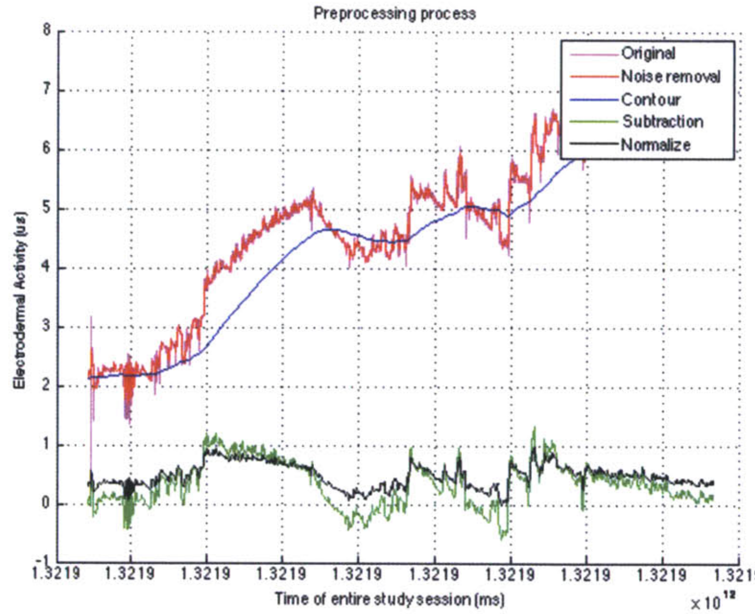

Figure 3.31. Example of a preprocessed EDA Signal.

The two-axis slider ratings that came from the iPads were sampled with varying rates of 125 milliseconds to 1000 milliseconds due to network and computer program issues, but every sample was timestamped to compensate for the varying sample rate. The clock source for the two-axis slider ratings, EDA signals, and video playback all came from a single computer, which made the post synchronization process much more efficient.

The survey report for the Love/Hate (LH) likert scales was on a scale of 1 to 7. The data was converted to a 0 to 3.5 scale by subtracting 3.5 from all the report values and taking their absolute value:

$$\text{LH} = |LH - 3.5| \quad \text{(Equation 3.2.)}$$

This decision was made because the absolute value measurement of a LH scale can give us arousal level information [Latulipe et al, 2011]. Therefore, we could use this data to measure the engagement level of each component of the video experience. The components of the experience were video production, randomized/shared bar display, self-reporting, music, and performers.

Hypothesis

The main goal of this study was to find out whether or not social interactions among audience members during live performance could make the experience more engaging. We anticipated that subjects' video experience while sharing their feelings (S) on the display would result in a higher overall engagement level than the video experience with the randomized non-sharing visual display (R). We also anticipated that the videos of the live performances (P) would result in a higher overall engagement level than the nature videos (N). Based on these hypotheses, we have four conditions (Figure 3.32.). In addition, we looked into our hypotheses in three datasets: the EDA data, the self-report measurement (SCR) data, and the data from the survey results. If our hypotheses are correct, then we shall see the highest engagement level on the cell S and P (SP), and the lowest engagement level on the cell R and N (RN) (baseline) in all three datasets. In addition, the results of each case shown in Figure 3.31. should be significantly different from each other.

	S	R
P	data	data
N	data	Baseline data

Figure 3.32. A table of comparison. S stands for sharing feelings through a bar display while R stands for a random bar display. P is the performance videos and N is the nature videos.

Hypotheses:

H1: $S(EDA) > R(EDA)$
$P(EDA) > N(EDA)$

H2: $S(SCR) > R(SCR)$
$P(SCR) > N(SCR)$

H3: $S(Survey) > R(Survey)$
$P(Survey) > N(Survey)$

3.3.4. Implementation

In the process of implementing the experiment setup, we paid careful attention to the synchronization of all collected data in time. The collected data must perfectly align with the time of performance, so every program built in this process had a mechanism to record time and to be accurate with the time.

The Tablet Web Application

The main interface for the iPads was built using a web browser platform. We utilized HTML5, Processing.js, and PHP to build the web application that the audience used in the experiment. HTML5 is a markup language to build and present content to web browsers, and is a core technology of the Internet. The HTML5 environment permited us to use Processing.js to create the main interface that displayed the two dimensional slider. Processing.js is a Javascript based programming language and environment built for the media arts community on the web [Processing.js, 2012]. Processing.js runs in the HTML5 canvas element; the entire web application was a canvas based website. PHP handled capturing audience input via AJAX and storing the input on the disk. The data was composed of the position on the two dimensional axis, the user id, and the capture time of the data. The same set of data was also routed to the performance simulator via Open Sound Control (OSC) [Wright and Freed, 1997]. A library, OSC for PHP, allows us to easily implement the OSC messaging system from PHP [OSC.phps, 2012].

The Live Performance Simulator

The live performance simulator played the videos of Queen's live performance and views of nature. Along with the performance, we also displayed the rating bars on the perimeter of the screen. This program was made with openFrameworks; an open source C++ toolkit for creative coding [openFrameworks, 2012]. The program played videos and recorded the times of the beginning and the end. While this was happening, it was also receiving data from the audience via OSC to display their ratings when the time was appropriate.

3.3.5. Result

We first obtained the standard (STD) error of the number of peaks per minute in the EDA signals for each video session (Figure 3.33.), and we concluded from this that no significant trends were found in the pattern. A two-way ANOVA was also applied on the number of peaks per minute in the EDA signals and we found that p-value was much higher than the critical value of $\alpha = 0.05$ (Figure 3.34).

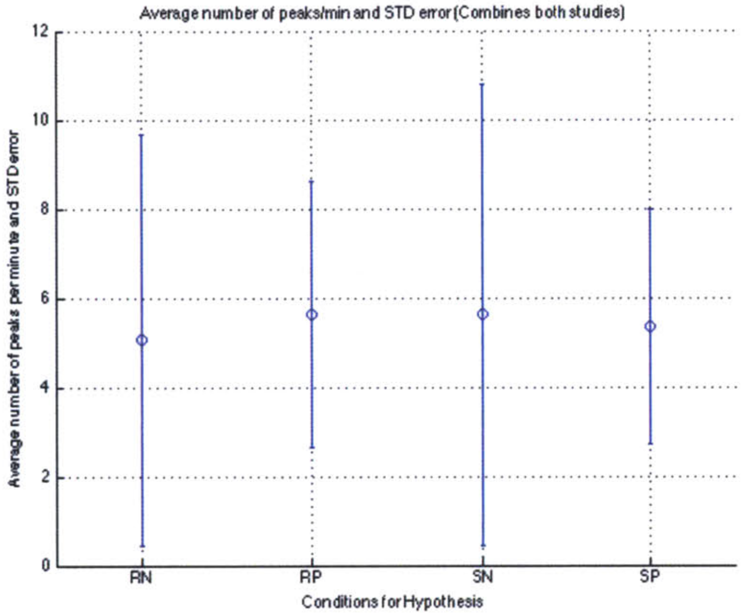

Figure 3.33. The standard error for the number of peaks per minute in the EDA signals.

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	0.17	1	0.1704	0.01	0.9237
Rows	0.176	1	0.1759	0.01	0.9225
Interaction	1.418	1	1.4182	0.08	0.7825
Error	511.218	28	18.2578		
Total	512.983	31			

Figure 3.34. The two-way ANOVA on the number of peaks per minute on the EDA signals.

We then looked into the average self-report measurement of the subjects' arousal level. Looking into the standard error tells us that the subjects were much more excited about the nature videos (both S and R cases) than the live performance videos (Figure 3.35.). This is the opposite outcome of what we had hoped and it may require us to revisit the way we processed the data. When we looked at the individual self-reporting data, the videos of nature tend to have less movement as opposed to the live performance videos. We think that this is because the nature videos were less exciting for the subjects and the videos had less development compared to the live performance videos. The data also informed us that subjects moved the slider more during music performance than when they observed nature videos. Because of human error, a few people were not able to use the iPad to report their feelings on a couple of video sessions. Therefore, the sample size did not match up in order to run an ANOVA test on the data.

Finally, we looked into the overall arousal level reported on the survey results. The standard error of the average arousal level was much more promising (FIgure 3.37.), since it showed a significant increase in excitement for the live performance videos than the nature videos. Running two-way ANOVA on this data improved the p-value to p=0.159, but the value still did not break the critical value of alpha = 0.05 (Figure 3.36.).

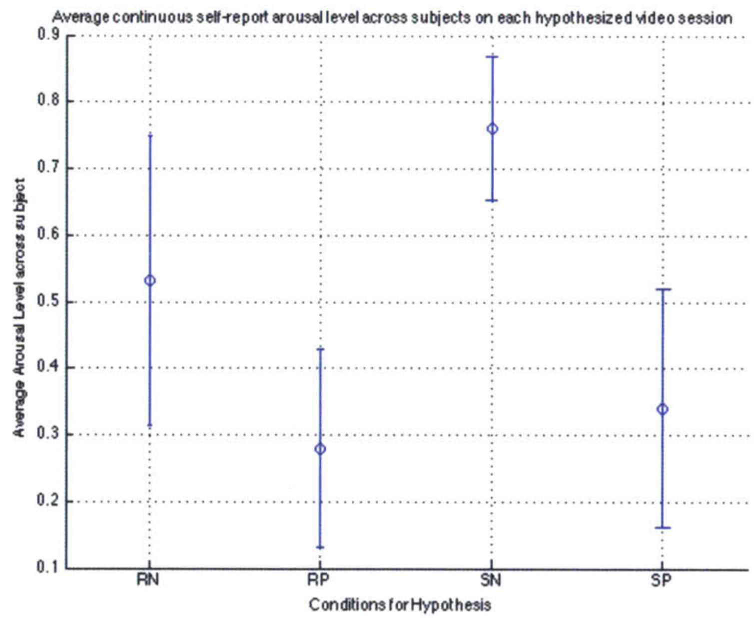

Figure 3.35. The standard error for the average arousal level from CSR.

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	1.125	1	1.125	1.18	0.2871
Rows	120.125	1	120.125	125.74	0
Interaction	2	1	2	2.09	0.159
Error	26.75	28	0.955		
Total	150	31			

Figure 3.36. The ANOVA test on the survey result for the average arousal level.

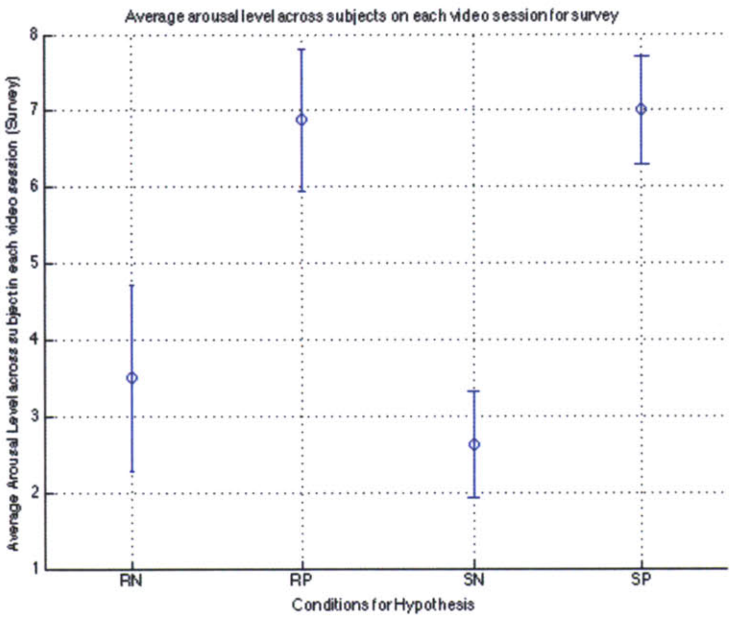

Figure 3.37. The standard error from the survey result for the average arousal level.

3.3.6. Discussion

The question that motivated this study was whether or not inducing social interactions among audience members during a live performance makes the performance experience more engaging for the audience members. However, our experimental results did not show significant tendencies that could back up our hypothesis. We think that the experiment design we have come up with in this study did not motivate the audience members to have any kind of social interaction or influence even though subjects were informed by self-report scales on the edge of the projector screen for some of the video experiences.

Social influence takes the form of reward or pressure [Kelman, 1956]. Thus, in our study, we think that the experiment design was not correctly designed because it did not involve any form of reward or pressure to the subjects to change their attitude as Kelman suggests. We also think that the fact the subjects did not have any acquaintance with each other was a part of the problem. The subjects did not know about each other and they did not care enough about each other's rating to have any kind of social interactions between them. The free comment section of some collected survey reports revealed this reality. One of the subjects responded about viewing other subjects' feelings:

"It was interesting to see when others respond the same or at the same time to the video. Still somewhat distracting, but could be really interesting especially if friends could watch and share responses together."

This subject is reflecting on the fact that having an element of identification for social influence could have made the performance experience different. Another subject was frustrated by the behavior of other subjects when s/he was able to see other subjects' feelings:

"It was fun to see the 'other's feeling' but also disturbing. Like, 'Why do they feel different?' and 'who is number 1?'"

If we could have given more personal information to the point that each subject could actually care about other subjects, such as telling who exactly was "number 1," the subject might have immediately understood the reason why "number 1" was feeling different than herself/himself. Once again, having a form of identification in social interaction could have brought a different experience for all the subjects who participated in this study.

Many questions arise for future study: was displaying the feeling bars at the edge of the projector screen more engaging in the shared feeling condition (SH) than when it was randomized (RD)? How well did the EDA signal and the CSR measurement correlate? How does overall mean value of EDA signal look like? Based on the mistakes we have made in this study, can we come up with a better study case? Our work represents a fundamental step in understanding the social influences that happen in live music performance and how that could be used to enhance the experience of audience members. Our future work will continue to build upon this understanding through several different facets to create a richer picture of audience experience and engagement in live concert settings.

3.4. *Sleep No More*

Sleep No More, one of the most recent *Punchdrunk* productions taking place in Chelsea, New York, is a theatre performance inspired by Shakespeare's Macbeth and narrated in a Hitchcock style [Sleep No

More, 2012]. *Sleep No More* is an immersive, site-specific, and interactive work of theatre. In the performance, audience members wear a mask and freely walk around in the performance space: The audience members can choose to follow characters, themes, or simply explore the world of *Sleep No More*, treating the production as a large work of art.

Figure 3.38. A scene from *Sleep No More*.

The work presented in this section is a collaborative project between Punchdrunk and MIT Media Lab; a project which merged theatre on an online platform and partnered the on-site participants with the online participants. The project explores a unique way of encouraging close relationships between the online and on-site participants who essentially are strangers to each other. Moreover, the project also explores ways to enhance the experiences of both participants through the environment that exist only at the intersection of the real and the virtual worlds.

In this project, we developed an accompanying online virtual world of the *Sleep No More* experience in which the online participants partner with the on-site participants to explore and experience the interactive immersive performance together [Remote Theatrical Immersion, 2012]. This project pushes the state of the art technologies of wireless network communication systems and web standards by delivering a personalized multimedia content, encouraging each partner to have a unique experience co-created in real time by their own actions.

We include this collaborative project in the thesis because the project aimed to deliver *Sleep No More* experience beyond the physical performance space by encouraging audience members to be communicative and participative. Although the section covers the overall production of the experience, the primary focus is on the author's involvement and work carried out in the production of the performance. For those of readers who are interested in reading more about Punchdrunk and *Sleep No More*, we suggest visiting the section on site-specific performances in Chapter Two.

3.4.1. Background

Following the definition proposed by Benford and Giannachi, the collaborative project between Punchdrunk and the MIT Media Lab can be called a mixed reality performance: the staging of the performance exists both in the real and virtual worlds [Benford and Giannachi, 2010]. The performance encompasses both real and virtual elements realized through mobile and ubiquitous technologies. We have already covered some of the related works about mixed reality performance in Chapter Two, but in this section we reiterate the works of such performance and study the literature of mixed reality performances that are similar to the collaborative project between Punchdrunk and the MIT Media Lab. In addition, we focus on how these performances orchestrate participatory experience for the audience.

Figure 3.39. Scenes from *Kidnap* by Blast Theory.

Kidnap (1998), by Blast Theory, provides an example of a mixed reality performance and audience participation by merging online performance through using the Internet and video streaming in the physical performance space [Blast Theory, 2012][Kattwinkel, 2003]. In the performance, potential audience members first applied to be kidnapped by the Blast Theory. The performance group then chose the participants at random and stalked each participant. The stalking was then recorded on a web site where anyone who was interested in the performance could view. The group then chose two people to kidnap and brought them to unknown location somewhere in Britain. They kept the two participants captive for two days and the online audience members could visit the Kidnap site through the Internet. The online audience members were able to interact with the kidnappers through the email and they also had control over the video cameras that were recording and web streaming the room where the hostages were kept.

Ulrike and Eamon Compliant (2009), by Blast Theory and the Mixed Reality Lab, is a mixed reality performance based on the lives of Ulrike Meinhof (Red Army Faction) and Eamon Collins (Irish Republican Army) [Benford and Giannachi, 2011]. The performance involves real world events and participants were invited to take the role of Ulrike or Eamon. The participants walk through the city while receiving phone calls. The series of phone calls requested the participants to go to a particular location in the city or told them to act out signaling gestures to confirm their locations. For example, one of the phone calls asked the participants to 'Stand in the middle of the bridge and turn to look at the church towers. Can you see them? If you can see them nod you head slowly.' These phone calls made the participants think that they were being watched and this contributed to the sense of surveillance and a moment of potential intimacy with a complete stranger.

Figure 3.40. A participant in *Ulrike and Eamon Compliant.*

Figure 3.41. A Performer waiting for a participant in *Ulrike and Eamon Complaint.*

The participants had the freedom to deny any of the instructions given from the person on the phone. If they denied the request, a final phone call that told the participants they had failed to take the responsibility and how disappointing the decision they made was. If the participants followed through all the instructions, they met a performer in the real world who then took the participants to a room where interviews were carried on. The interview made the participants choose their action as Ulrike or Eamon whether they regret the decision they made or to defend their act of evil.

These two projects demonstrate excellent case studies of a mixed reality performance. The projects inhabit both the real and virtual worlds and establish an intimate participatory experience for both the online and physical participants. Benford et al write that in order to establish such participatory experience, the performance requires orchestration: a behind the scenes management of participants' activities [Benford et al, 2003]. In addition, they discuss the issues of orchestrating a performance and these include: 'admission to an experience, training and familiarization, establishing engagement, avoiding fractures in engagement, monitoring, intervening, coordinating behind the scenes activity, managing pace and timing, and closing an experience.'

The orchestration in a mixed reality performance typically features human orchestrators, facilitators, or operators who support the performance from behind the scene. For example, *Ulrike and Eamon Compliant* had four street orchestrators and an entrance hall staff responsible for facilitating participants' experience [Benford and Giannachi, 2011]. The street orchestrators followed the participants while carrying a PDA from different strategic points along the performance space and they were responsible for triggering sequences of calls to the participants. Although the orchestrators in *Ulrike and Eamon Compliant* tried to remain invisible to the participants, they also had to make sure that order of participants' experience was somewhat correct and helped the participants when they get lost.

In *Kidnap*, the performers/kidnappers were the facilitator of the performance in connecting the "kidnappees" and the online audience members. The online audience members could affect the performance by making suggestions to people who were in control of kidnappees, telling them what questions to be asked in the interrogation, when to feed the kidnappees, and what to feed them. These instances show us that the orchestration of a mixed reality performance is an important feature of the performance and software and experience designers need to consider the techniques and tools for orchestrating a successful mixed reality performance.

3.4.2. Interaction Model

The overall interaction model of the performance system is shown in Figure 3.42. This model represents interactions between an on-site and a remote participant. In the actual performance, two to five instances of the same model were running in parallel to allow multiple pairs to journey through the world of *Sleep No More*. Each on-site participant did not communicate with each other during the performance. Moreover, the same condition was also applied to the online participants. Only the pair could communicate with each other through the operators and the performers. The operators and performers were always the mediators of the communication between the pair of an on-site and online participant. The main reason why for such condition was because we wanted to always maintain the quality of the performance and have an on-site and online participant communicate with each other in the context of the *Sleep No More* world. Hence, avoiding direct communications between the pair was necessary to provide the optimal participatory experience to the pair of an on-site and online participant.

Figure 3.42. The overall interaction model of the *Sleep No More* project.

Figure 3.43. A mask the audience wears in the *Sleep No More* performance.

On-site Participant

A Mask and the Wearable Computing System

As a part of the role of *Sleep No More*, the on-site participants were required to wear a mask, and asked to be silent during the show as they freely walked around the building. This provided us a unique opportunity to come up with alternative methods to have the remote communication possible with the online participants through the operators. One way we accomplished this task was to implement noninvasive wearable computers, sensors, and actuators inside the mask. The basic interaction model of the wearable computing system that we built is shown in Figure 3.44. To capture the activities, expression, and mind state of the on-site participants, the computer equipped with sensors—such as a microphone, a temperature sensor, a heart rate monitor, an EDA sensor, a Bluetooth location sensor, and a Radio-Frequency Identification (RFID) tag—were used to capture the state of the on-site participants.

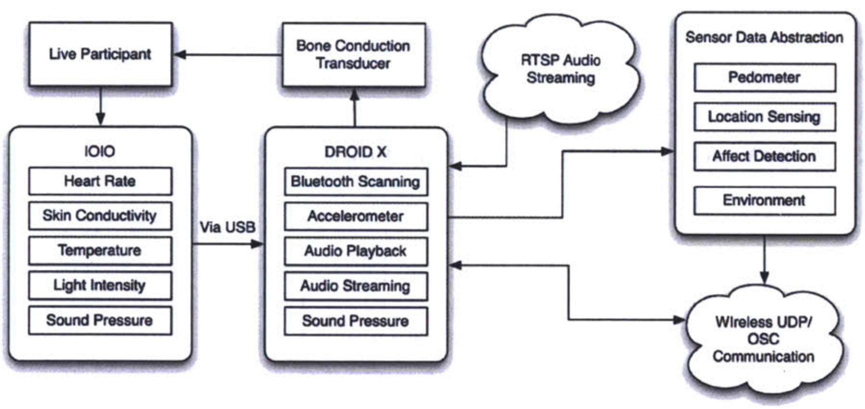

Figure 3.44. The basic interaction model of the live participants through the wearable system.

Figure 3.45. An on-site participant wearing a mask that has the wearable computing system integrated.

In addition to implementing the sensors on the wearable computer, we also integrated a bone conduction headset, an audio actuator through the bones of the skull, in the mask so that the operators could send audio messages to the on-site participants through the bones near the ears. The bone conduction headsets were ideal for this project because they kept the participants' ears free, and it contributed in maintaining

Figure 3.46. The typewriter portal placed on the desk. In addition to typewriter, a hidden microphone captured the voice of an on-site participant.

the on-site participants' immersive audio experience within the physical performance space.

Portal objects

In addition to making communication happen through the wearable computing system inside the mask, we also made additional communication systems for the on-site participants through physical objects around the performance space. These objects acted as a gateway for the on-site participants to be able to communicate with the online participants. Although they were of antique quality, these objects were typically everyday objects such as a telephone, a typewriter, a radio and mirrors. In addition to these objects, computerized ouija board was also used as a portal object when an on-site participant first enter the performance space. For the on-site participants, encountering the portal objects were special moments that allow them to connect to the remote participants and find out more about the story behind the *Sleep No More* performance.

The basic portal object interaction model is shown in Figure 3.47. Depending on the portal objects, the direction of the communication between the pair was limited. For example, one of the mirror displayed a computerized hand writing when an on-site participant passed through. This was sent from the operators to give the on-site participant additional clues to finding the story behind the *Sleep No More* performance. On the other hand, although the modality of the communication differed between the on-site and online participants, the typewriter was able to realize bidirectional communication between the pair. The online participant's key board typing could be typed on the paper installed on the typewriter while the on-site person was able to talk to the online participant.

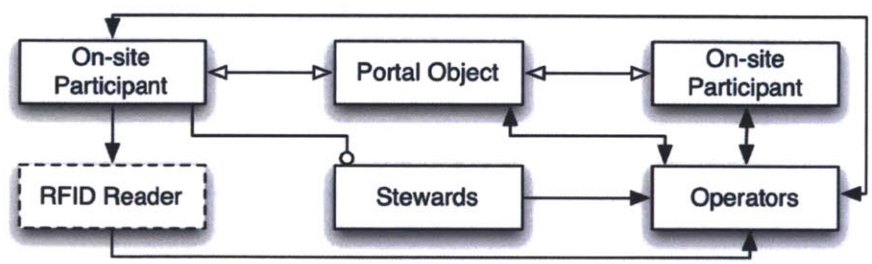

Figure 3.47. The basic portal interaction model. White arrow heads represent the direction of communication may not exist depending on the type of the portal object. A white circle represents that stewards were always monitoring the position of the on-site participant. The RFID reader is represented with a dotted box because some portal objects were not equipped with the reader.

Human stewards and RFID readers were used to detect the on-site participants' presence near the portal object so that the operators could prepare for the portal interaction between the on-site and online participants. Some of the portal objects were not equipped with the RFID reader, but Stewards were almost always present near the portal objects to report the situation of the on-site participants to the operators.

Remote Participant

Web Browser

The primary interface the remote participants used to experienced the performance was through the web browser (Figure 3.50.). The participative online environments were created using a virtual environment similar to Multi-User Domains (MUDs). In a MUD, the communication and interaction occur among the online particpants through chat room like environment and fictional characters created in the online world. However, In the *Sleep No More* virtual world, the online participants did not communicate with each other but the primarily interaction took place with the operators who were at the physical *Sleep No More* performance space. Moreover, the online participants were also immersed in: the dynamic images—evolving photos mostly taken from the physical *Sleep No More* performance space—that constantly changed in the background of a chatroom like environment; prerecorded video playback and real-time video streaming from the physical performance site; and the binaural audio environment that played the same immersive sonic world of *Sleep No More* in the physical space.

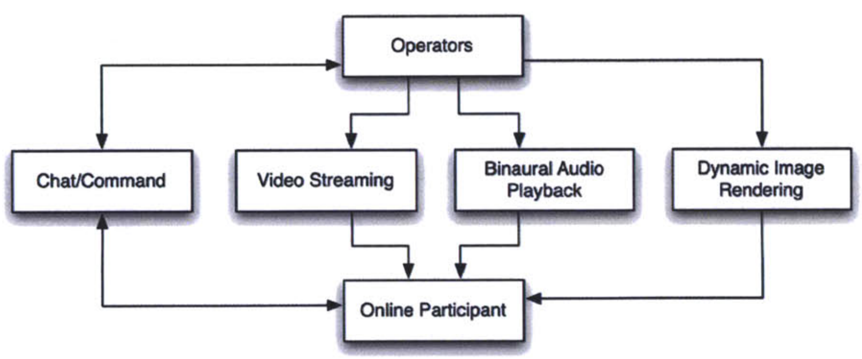

Figure 3.48. The basic interaction model of an online participant using a web browser.

The computer system was programed to automatically parse the text inputs from the online participants when they were navigating through the online virtual world, but the operators were constantly monitoring the activities of the online participants to deal with uncertain text inputs, to connect on-site and online participants when the time was right, and to facilitate participatory experience.

Before the experience started, we gave a specific guideline for the online participants how to set up their environment to prepare for the show. For example, we asked the participants to only use Google Chrome, a web browser made by Google, for this experience. We also suggested to them to be in a dimly lit, quiet room with few distractions from the outside world during the experience. The online participants also provided us their phone number, and we asked them to have the phone next to them so that the operators and performers could call them when the time was right.

3.4.3. Implementation

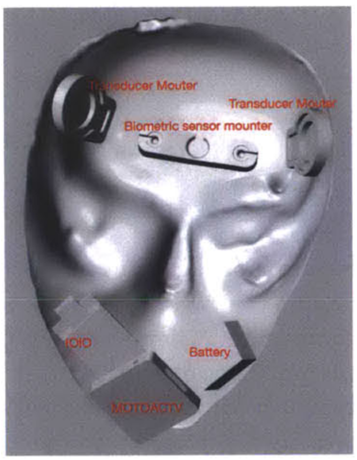

Figure 3.49. The conceptual prototype of the first wearable system integrated in the mask.


Figure 3.50. A prototype of the wearable system. Only the sensors and actuators remained in the mask. The main computing parts had to be separated from the mask.

This section covers the technical implementation of the performance system created for the *Sleep No More* experience. However, we will only cover the part that the author worked on. The author's involvement in the production mostly evolved around developing technology for the on-site participants including the wearable computing system.

A Mask Design and Wearable Communication System

As we explored the approaches in building a wearable technology for the on-site audience members, we compiled a number of guidelines that we followed in developing the system. These are:

1. The wearable system has a way to communicate with the operators and the online audience members.

2. The system shall work around the general *Sleep No More* conventions such as "Audience wears mask" and "Audience cannot talk."

3. The system shall be invisible to the general on-site audience members who are not part of the experiment and as unobtrusive as possible to the on-site audience member who wears the system.

A mask used in the current the *Sleep No More* performance (Figure 3.43.) was the central element for designing the wearable system and every aspect of the system was built with some considerations on how to integrate the system within the mask itself. Furthermore, our original aim was to include all technologies into an existing mask used for the *Sleep No More* performance (Figure 3.51.). However, because of the engineering problems, time, and money issues, we iterated through the design of the wearable system. The final design of the wearable system is shown in Figure 3.52. through 3.55. The main technologies used in this system are bone conduction transducers for auditory feedback, and biometric, physical, and environment sensors for capturing on-site audience members' experience. The following sections describe each technology that was incorporated in the final wearable system in detail.

Figure 3.51. Masks and the wearable systems ready to be worn before the performance begins.

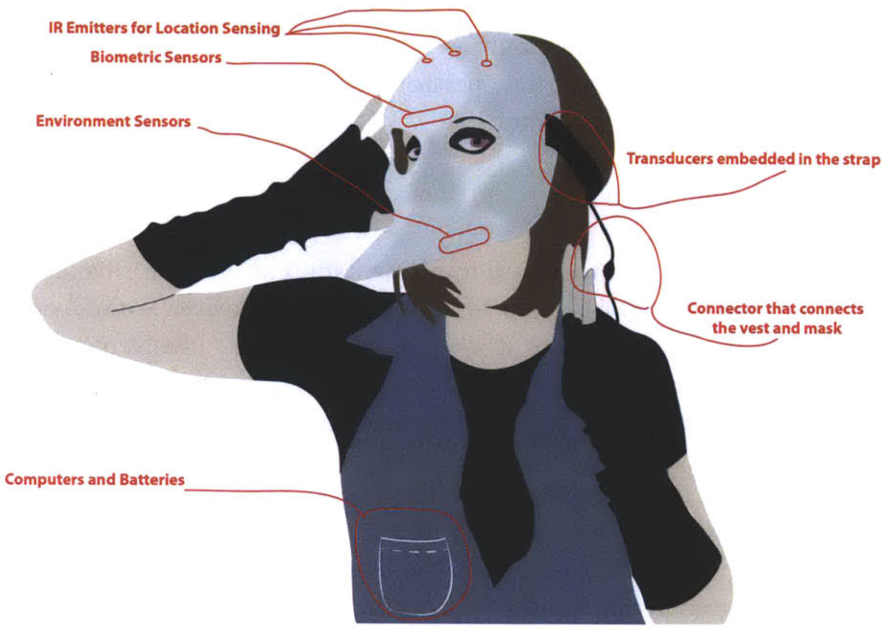

Figure 3.52. A conceptual prototype of the final wearable system integrated in the mask and the clothing.

Figure 3.53. The final design of a wearable computing system. The on-site participants carried this box in a fanny pack which was then connected to the sensors and actuators in the mask.

Bone Conduction Headsets

After a number of brainstorming sessions, we came up with several approaches to convey information to the on-site participants such as a tongue display, bone conduction transducers, ear phones, head-mounted displays. We have decided that bone conduction headsets—headsets capable of conducting sound to the inner ear through the bones of the skull—were the most noninvasive device, undetectable interface, and realistic technology that we could employ to convey information to the on-site participants during the performance through the network communication system.

We experimented with commercially available bone conduction headsets, such as Audio Bone [Audio Bone, 2012]. Nonetheless, the mechanical construction of these headsets limited how loud the

Figure 3.54. An early experiment with the bone conduction transducers.

Figure 3.55. Transducers integrated in to a headband strap.

transducers can get; they would simply distort the sound to the point it was inaudible when we apply a large voltage. As a result, we decided to use the audio transducers normally used for a flat panel loudspeaker system [Hiwave, 2012]. With these transducers, we experimented with the placement within the backside of a mask to find the optimal position to translate vibrations into eardrum including the forehead and temples (Figure 3.56.).

Figure 3.56. The back side of the mask with sensors. A heart rate monitor, a skin temperature sensor, and an EDA sensor are positioned on the forehead. A microphone, a temperature sensor, and a light sensor are positioned at the bottom of the mask.

Through the experiment, we found that the closer the bone conduction transducers are to the ears the better vibration translation that a person would experience. The position could either be the front or the back side of the ear. As a result, we decided to integrate bone conduction transducers into the thick strap (Figure 3.57.) that can be worn individually around the head like a headband or integrated as a mask strap. This allowed us to keep the transducers invisible from the rest of the general audience members and to place the transducers in the ideal position with the best audio experience.

Figure 3.57. A web-based software interface developed for visualizing the on-site participant's experience.

A Wearable Sensor System for Capturing Experience

As on-site participants were not allowed to speak during the show, initiating a direct communication from the on-site to the remote participants remained difficult without the use of the portal objects installed in the performance space. The portal objects only existed in limited locations within the performance space, and we also wanted to have alternative ways of establishing communication between the pairs of participants. One solution to deal with this problem was to capture the experience of an on-site participant and transmit that experience to an online participant so that s/he can indirectly feel the presence of the on-site participant. We prepared sensors that measured environment (loudness of sound, brightness of light, and temperature), physical states (a location and a pedometer), and physiological states (a heart rate, a skin conductance, and a skin temperature). Captured sensor data was filtered, analyzed, and plugged into the computer model of the on-site participant to finally translate the data into the context of the remote participant's experience.

Bluetooth Indoor Location Tracking System

As previously mentioned, we also tried to track the physical location of the on-site participants during the show so that we have a better understanding of where in the performance space they are and when to connect the on-site and remote participants. The two location tracking system we deployed in the performance space were the RFID-based and Bluetooth-based location tracking system. The reason why we deployed two systems for tracking a location of the on-site participants was because of the granularity of their distance measurement and the feasibility of the deployment. The RFID system was strictly use to detect a person who was near the portal objects while the Bluetooth location tracking system gave the estimation of the room in which the on-site participants were in. We primarily worked on the Bluetooth location tracking system in the performance space and we cover the implementation details of the system.

Figure 3.58. A Bluetooth audio receiver that was used as the location tracking device.

Figure 3.58. shows an instance of the Bluetooth devices used to track a location of a person within the building using mobile device. This device is originally made as an audio receiver: In a normal use case, household consumers use this device to play music by wirelessly transmitting signals from computers. Nevertheless, such Bluetooth device typically wirelessly emit a Radio Signal Strength Indication (RSSI) which is a measurement of the power present in a received radio signal. The RSSI can be used to estimate the distance between the position of the RSSI emitter and the receiver [Martin et al, 2010]. We used the RSSI emitted from the Bluetooth devices to create a Bluetooth Location Network (BLN) [Gonzalez-Castanoandm and Garcia-Reinoso, 2002]. The estimation of the location of the on-site participants was done on a room by room basis using the Bluetooth scanning capability of the mobile device that was provided by us to the participants during the experience. Such technique has been experimented by many researchers in the past [Derr and Manic, 2008] [Martin et al, 2010][Liu et al., 2007]. The Bluetooth device we used was a custom location tracking system and it proved to be the cheapest solution out of all commercially available solutions.


Figure 3.59. Charging batteries for Bluetooth audio receivers to create a Bluetooth Location Network in the performance space.

Based on the RSSI, we created a location fingerprinting system. The location fingerprinting system consists of a database that contains the measurements of RSSI at some reference points (RPs) [Wang et al, 2005]. We created RPs using the relative coordinate positions of each RP against the size of each floor (Figure 3.60). Because we were only concerned with estimating the room where the on-site participants were in, the RPs also had an associated room number where each RP was in. Based on the location fingerprinting system, the location of the on-site participants was estimated by comparing RSSI measurements with the reference data. We generated the database by physically standing on each RP and collecting the RSSI with an appropriate coordinate.

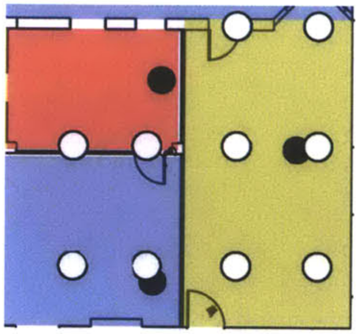

Figure 3.60. The example coordinate system used in configuring the BLN system. White dots were the RPs, and black dots are where the Bluetooth receivers were placed.

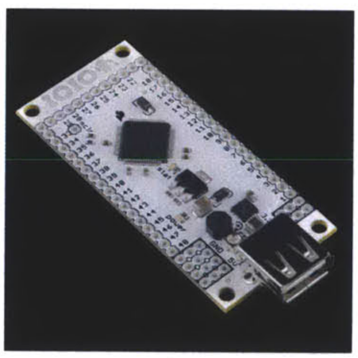

Figure 3.61. The IOIO board.

As for the algorithm for estimating the location, we tried many different methods such as Closest Point (CP), Nearest Neighbors (NN), K-Nearest Neighbors (KNN), and Neural Networks with K-Nearest Neighbors (NNKNN). We decided that the KNN algorithm was the most ideal approach in our use case because the algorithm is relatively simple and fast, and also gave better result than CP or NN. Moreover, using the NNKNN method did not significantly improve the location estimation and made the calculation unnecessarily slower.

KNN is a standard machine learning algorithm that uses either euclidean distance or Manhattan distance. In our case, we used Manhattan distance:

$$MH = \sum_{i=1}^{N} |RP(i) - TP(i)| \qquad \text{(Equation 3.3.)}$$

MH stands for Manhattan distance and TP is the test point that was collected from the mobile device when on-site participants were walking around the performance space. We then collected the K closest distances and estimated the room that the on-site participants were in based on the number of RPs found in a given room.

Mobile Software System for Intercommunication

In addition to the wearable system and the location tracking system, a software system for aggregating and interpreting the sensors and location data and intercommunicating with the operators was developed. The software is entirely written in Java for the Android OS systems. As of this writing, the Android OS is the only smartphone system that can easily be used to add external sensors through devices such as IOIO (Figure 3.61.)[IOIO, 2012].

3.4.4. Execution and Result

The trial run took place between May 15 to 19, 2012. Prior to running the trial, we spent about two weeks installing the performance systems at the *Sleep No More* performance space such as the portal objects and the working station for the operators. In addition, we have also conducted numerous testings before the actual trial days to make sure that all technologies for the performance are working the way they should. The trial run ended with thirteen pairs of participants experiencing the new *Sleep No More* world over five nights. At the end of each trial, we had an informal feedback session with both online and on-site participants and this gave us an opportunity to keep improving the experience throughout our trial run. The following subsections describe some of the challenges we encountered during the course of the trial run and comments and suggestions made by both the on-site and online participants.

Challenges

Time

Perhaps, the amount of production development time we had was the biggest obstacle in deploying the trial performance. Although the sensors and the hardware electronics were ready to be used, we were not able to fully integrate the affective remote communication system that we envisioned because of a lack of time in developing a functional software that successfully interprets the sensor data and creates a rich interaction between the on-site and online participants based on the on-site participants' emotional feelings.

A lack of time also affected calibrating the BLN system to an optimal condition in the performance space. In fact, this was both a technical and time problem: the algorithm, the KNN method, heavily depended on the training data set collected within the performance space. This means we had to physically collect sample points around the five story high building and the process took us almost five days. In the future implementation of such a location tracking system, we can also consider training the BLN system using a 'kriging' method which could not only accomplish accurate estimation, but can also reduce the workload of training the system [Wang et al, 2005].

Human

The operators need to be familiar with the stories behind the *Sleep No More*. They also need to be a good communicator as the interaction often involves facilitating exploration in the performance environment. A number of operators indicated that facilitating exploration for the online participant can be exhausting because of the cognitive load that the operators need to take up. In our trial, one operator dealt with a pair of an online and an onsite participant. Increasing the number of operators per pair may be something we want to consider in the future work.

We also had far few people working on this massive project. As a consequence, many people who were involved in this project took up many responsibilities. In the case of the author, a wearable computer system, a location tracking system, and software to interpret the on-site participants' experience were all done by the author. While we are capable of implementing these systems, with the combination of the lack of time, testing and deploying all these systems became harder as the time passed. From this lesson, we learned that a massive project such as *Sleep No More* requires a large number of people to working on different aspects of the project, especially when we have little time to deploy the project.

Informal Feedback

As previously mentioned, we had an informal feedback session with both online and on-site participants after each trial run, and we describe some of the comments made by the participants and findings we made through these sessions. As the project was about merging theatre on an online platform and partnering the on-site participants with the online participants, we focus our description on the relationships that were created or not created between the on-site and online participants.

On-site Participants

On-site participants had an enormously different set of backgrounds on *Sleep No More*. Some had never experienced the performance prior to our trial run while others have been to *Sleep No More* as many as twenty times. In general, the experience of the on-site participant was enriching because they were immersed in the spectacular *Sleep No More* physical world where multiple performers and a few hundred audience members were active.

One of the most common comments from the on-site participants was that they felt very special in the performance space because they were on their own journey separate from the rest of the on-site audience members and they were wearing the special mask prepared for this trial. One participant commented it was 'satisfying to be on ones individual path, making different decisions from general audience, rather than choices of follow herd.' However, some participants, especially the first timers, were confused with what to do in the performance space. For example, while this was not true, one participant thought that the performance experience was linearly prepared for them and there were always clues left behind for them that tell what they were supposed to do in the space.

Many of participants also addressed discomfort towards the mask we designed for the trial. Even though we had warned not to wear glasses for the trial, the biggest complaint came from the glasses wearers. The tight mask on the participants with glasses made the experience painful because the mask was pushing in the glasses towards their face. Some commented on the experience of the bone conduction headsets and their comments were mixed because the headsets often were loose. The looseness of the headset caused the participants' head to feel ticklish. The experience of the headsets can be very enriching, but we need to work on solving the engineering problem of how to constantly and firmly attach the bone conduction headset on the participants' skull while making them feel comfortable wearing the mask.

Online Participants

The background of the online participants were also mixed. Some had no previous experience of *Sleep No More* while others had a lot of experience in the story behind the performance. The general experience of the online participants was mixed: some were very engaged while others felt frustrated or lacking in experience. One participant said '[I] thought I'd only be giving about 20 percent of attention, but [I] was completely absorbed' in the experience. The disengaged participant notes that 'I found [the experience] a bit flat. The story was text mostly and very setting based. But, since it wasn't a novel, there wasn't enough description to get any sense of this setting.'

Most participants also demanded more communication with the on-site participant and connection with the real *Sleep No More* world. One participant said that 'the main thing for me was about feeling a genuine connection with the real world, which I didn't really get.' Most participants were satisfied with the story, but many note that they felt remote and disconnected from the real world.

The participants also had mixed feelings about the visual esthetics of the online world. Some complained about issues related to the user interface experience, such as text rolling off the screen and there was no way for them to scroll down to see the off-screen texts. Some participants liked the subtly changing fonts and background images as they virtually move around the scene. The videos and images also made many participants feel that they were more immersed in the online experience.

3.5. *A Toronto Symphony*

The main agenda of *A Toronto Symphony* project is to collaborate with people in the city of Toronto to compose a new symphony piece. The piece will be premiered by the Toronto Symphony Orchestra on March 9, 2013, at the New Creation Festival. Some of the music will be composed by people from the city of Toronto, some by my advisor

Tod Machover, and some shaped by both. The hope is that we will create something new that neither participants nor composer could have not done without each other, and that it will be a surprising music portrait of the city of Toronto.

The project presented in this section is a subset of *A Toronto Symphony* experiments we conducted during the MIT Media Lab sponsor week on April 23, 2012. Tae-Hyung Kim, the winner of 5th LAUREATE PIANO 2010 at the Queen Elisabeth International Music Competition of Belgium, improvised music based on a real-time notation system and votes casted by the online audience members. The audience members were able to participate in the piano performance through the web interface, and they also were able to see the entire performance through a real-time video streaming. Along with the author, Ben Bloomberg and Peter Torpey also were involved in building architectures for the video streaming system and the entrance website. The majority of the background on this project is covered in Chapter Two: the section on computer music performances, shared sonic environments, and social music listening. We will omit the background of this project and focus on the interaction model, implementation, and the execution for this project.

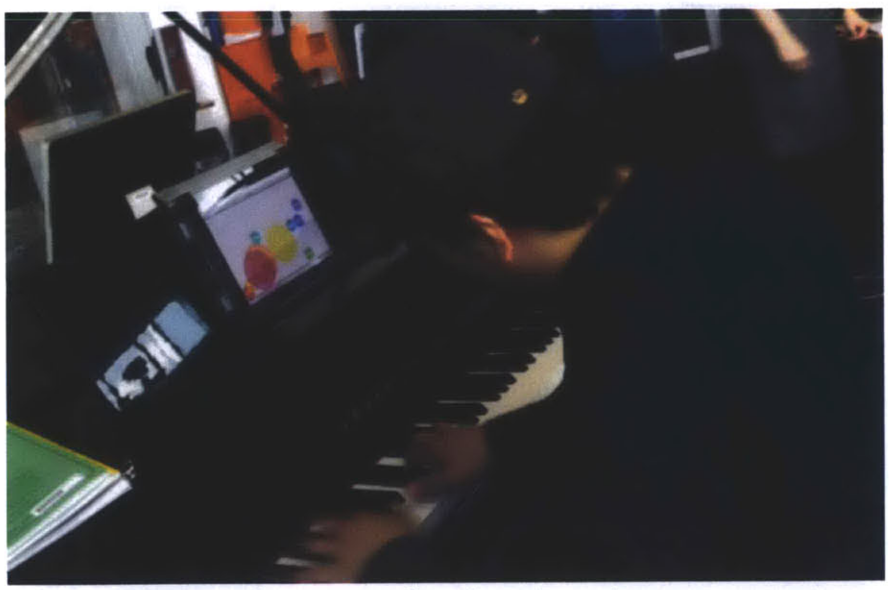

Figure 3.62. Tae performs piano based on the real-time music score presented on iPad.

3.5.2. Interaction Model

The basic interaction of the performance is shown in Figure 3.63. We make a couple of assumption regarding the performer/audience interaction: the Pianist improvises based on the preference of the audience; the audience can participate in the performance from anywhere and from any kind of computer and mobile devices; and the audience can see the performance in real-time through video streaming. The pianist also had control over choosing the total average of audience preference or the latest audience preference, and the audience were always seeing the same score as the pianist through the web interface. The audience also saw the piano performance through the video streaming.

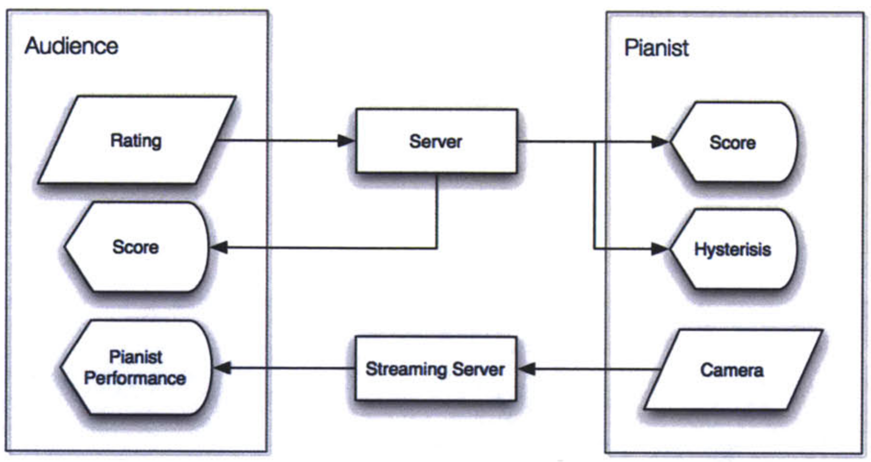

Figure 3.63. The system architecture for the live remote audience participation.

Ten excerpts of music were presented to the audience. They were excerpts from: Bach, Beethoven, Beatles, Blues, Debussy, tea-for-tatum, Schoenberg, Casablanca, RadioHead, and Chopin. From these music pieces, the pianist mixed the style of music based on the ratings from the audience.

3.5.3. Implementation

The web-based system for audience participation is built with a number of extensions for HTML5 and Javascript [Processing.js, 2012] [JQuery, 2012][Nowjs, 2012][Node.js, 2012]. The audience was able to view the web-based system from any type of devices that have a web browser application, and the pianist used iPad as the main interface to read the score. Processing.js is a javascript or java based programming language and environment build for the media arts community on the web. Processing.js runs in HTML5 canvas element and the entire website was a canvas based website. We used the Processing.js library to construct our main score view that represents each music piece with a bubble. The bubbles changed their size according to the submission for the audience online. The same view was used on both the pianist side and the audience side so that the audience knew exactly what the pianist is seeing.

JQuery was used to create a music player for the audience. The main music player consists from a music playback system and a rating slider. Ten columns of music players were displayed to the audience each containing a different song (Figure 3.64.).

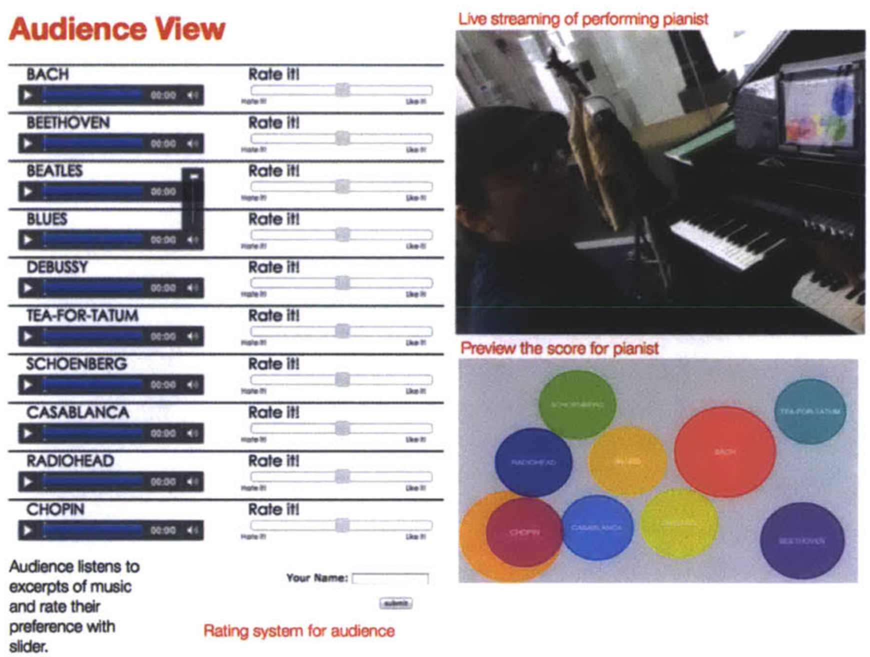

Figure 3.64. The interface design for the online audience members.

Node.js is a platform built on Javascript runtime engine for Chrome [Google Chrome, 2012]. It is meant to accelerate developing fast and scalable network applications. Node.js uses an event-driven and non-blocking input and output models. This makes the platform fast and efficient. The plat form is suited for data-intensive real-time applications. Node.js is also suited for building real time remote music systems as well, especially if we expect a large number of the network traffic to a particular website. We used Node.js as our main server architecture to handle the translation of the audience input to score representation. The server also kept the record of each audience member's submission in the local file for later analysis.

Nowjs is a framework build on top of Node.js. NowJs is capable of connecting the client side and server side Javascript easily. This is because the core of NowJS functionally depends on the *now* object. The now object exists on both the server and the client which means variables we set in the now object are automatically updated between the client and the server. Server functions can also be directly called on the client and vice versa. We used the framework to simplify our code and helped us in reducing the development time.

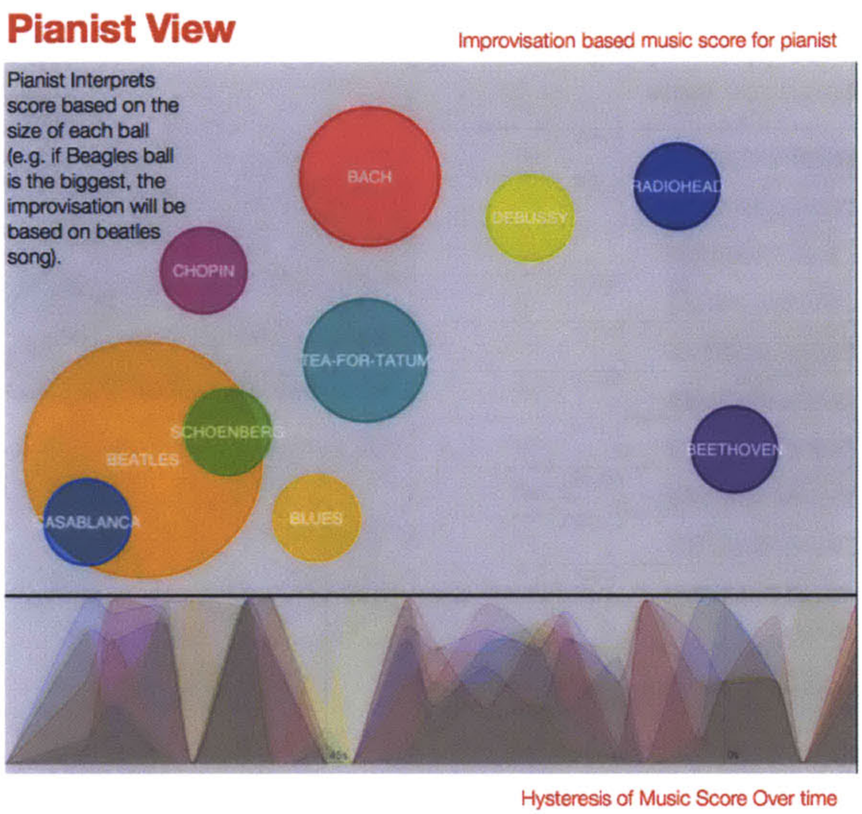

Figure 3.65. The interface design for the pianist.

3.5.4. Execution

The performance was about two hours, and about fifty people participated in the performance over the Internet. A countless number of visitors also experienced the performance on site. Technically speaking, the performance was overall success without any major catastrophe. The score varied often during the course of two hours as shown on Figure 3.66.

As we analyzed the audience submission data, some participants were submitting posts numerous times. We think this is because these particular participants were trying out if the music really did change when they submitted their musical preferences. From the visual perspective, a human pianist making changes to the music was very exciting. An abstract concept such as musical genre was cleverly interpreted by the pianist, and the pianist was very responsive to the score changes done by the audience.

Figure 3.66. The history of score changes over two hours. Different colors represent different musical excerpts presented to the pianist and the online audience members.

3.5.5. Future Plan

The architecture we built for this project is extensible without rapidly changing the code set. Theoretically, the system is capable of handling a large number of participants in the performance.

The web technology is becoming flexible enough to let us freely draw musical score in anyway we would like on a web application. In the future, we may consider implementing a library set for a real Western musical notation system or a 3D graphic score system that can be controlled in real-time.

In the future, we are considering to use a similar performance system with a real orchestra in a real concert hall. In this scenario, we will be accommodating hundreds of audience members to participate in the performance. The interface for large audience participation in the concert will most likely use a similar interface used in SIILPE using mobile devices. The two dimensional sliders taking up the entire screen can keep the attention of the audience to the performance while allowing them to affect the musical outcome through their preference.

3.6. Summary

This chapter presented five projects that the author developed during enrollment at the MIT Media Lab. These projects include: Chroma District, DrumTop, SIILPE, *Sleep No More,* and *A Toronto Symphony.* They explored ways to make an audience socially communicative and participative in a performance to enhance their experience. They also support the goal of our thesis because in the next chapter they are analyzed and compared to conceptualize the framework the Hyperaudience system.

4. TOWARDS A FULL HYPERAUDIENCE SYSTEM

This chapter undertakes analysis on each project presented in Chapter Three and discusses characteristics and shortcomings of each performance system. We also consider ways to compare each system to measure the relative success of each system. These analyses give us an understanding of the ideal Hyperaudience system: a system that enables the audience members to participate and communicate, blurs the boundaries between performers and audience, and engages audience members to intuitively participate in manipulating the performance system.

This chapter is divided into three sections: *Interaction Design Patterns* discusses some of the common design patterns, taken from the systems in Chapter Three, that make up the Hyperaudience system; *Comparison* gives relative measurements of each system presented in Chapter Three to study the strengths and weaknesses of each system; *Challenges* describes some of the design patterns that are useful and issues that need to be considered in the design process of an Hyperaudience system; and *Evaluation* measures works presented in this thesis as a whole using a set of appropriate standards.

4.1. Interaction Design Patterns

This section demonstrates interaction design patterns that are common to each system presented in the last chapter. These patterns give us a description, guideline, and template of solutions for designing a Hyperaudience system. Along the way, we also demonstrate and explain the mechanism and design patterns of active participation and co-experience.

4.1.1. Overview of the Interaction Model

All systems that support this thesis use three basic components to construct audience participation based performance: *capture*, *effect*, and *performance model* (Figure 4.1.). This model is similar to the universal Model-View-Controller (MVC) design pattern often used in computer science for building a computer software program. In this universal design pattern, the representation of information is separated from the user interaction into three parts: *controller* mediates input from a user and converts it to commands for model and view; *model* handles the command according to data and the rules of application; and *view* is the output that represents the data handled by the model such as charts and graphs [Gamma, 1995].

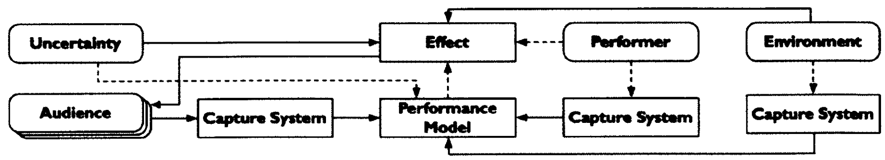

Figure 4.1. The interaction model overview. Dotted lines show connections that might not exist in the final design of a system.

Similar to *controller*, *capture* mediates audience members' and performers' control input. *Effect* is closer to *view* in that it represents the result of manipulations executed by audience, performers, and other factors such as environment and uncertainty. *Performance model* processes inputs and translates them to outputs based on the application. These components describe different technologies for piecing together inputs and outputs of a system, and have important connections to the degree to which audience members participate in a performance.

4.1.2 Capture

The first common component of the systems, *capture*, is responsible for sampling and recording inputs. Inputs can be any relevant data that contributes to a performance such as audience and performer activities, environments, and backstage operations. Capturing inputs from audience members is crucial in the design of the Hyperaudience system. However, the types of input from audience are contextually dependent on the types of a performance. For instance, they can be a body movement, a touch screen display interface on a mobile device, or a hyperlink on a webpage in a standard desktop computer setting at home. The process of capturing is best when the interface is simple and intuitive for the audience because most of them are likely to be first-time users and have no time for a learning curve. The tendency in many of the works presented in Chapter Two was to use everyday objects and devices familiar to the general public or to use a noninvasive interface that automatically collects activities of people.

All of the computer mediated performance examples in the background section have capture mechanisms for audience members. For example: Jason Freeman's *Glimmer* uses flickering of light sticks to capture audience activity; in *Can you see me now?*, participant's activities were captured through a computer program with standard mouse and keyboard; and in the *PRESEMO* by Chanel et al, audience member's activities were captured through mobile devices and a Polar band heart rate monitor. These are just a few examples where capturing mechanisms are kept quite simple and easy for audience members to grasp.

All systems presented in Chapter Three also had capture mechanisms for the audience: Chroma District used infrared sensors to capture the movement of passengers; DrumTop had force sensitive resistors for programming drum patterns and a knob for controlling tempo; SIILPE used a two dimensional slider on a tablet device to have the audience report their feelings; the *Sleep No More* capture systems include portal objects, location tracking systems, and wearable sensors for live participants and a keyboard and a mouse for online participants; and in *A Toronto Symphony*, we deployed a webpage as a platform for audience members to vote their preferences of music for the live pianist. Having a way to capture intentions of audience members is a first step towards active participation and communication.

4.1.4. Effect

Effect includes the main component of the performance that the audience experiences such as the performer's intentions, environments, actuations of objects, unexpected performance incidents, and changes in the images, graphics, and sounds on a laptop computer [Reeves et al, 2005]. Effect may also include feedback systems that are not directly part of the main performance but help mediate the performance. These feedback systems may be, for example, a user interface on a web browser for navigation, a message to a mobile device for a status notification, or a custom bone conduction headset employed in *Sleep No More.* Effect combines performance and feedback to create the source of immersion for the audience.

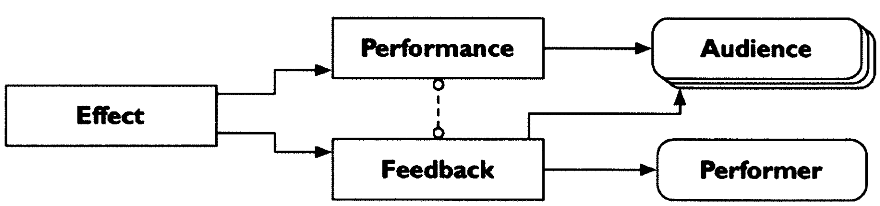

Figure 4.2. Effect Overview. A line with circles represents a possible joining of two components in some performance systems.

In Figure 4.2., we separated the feedback system from the main performance component. However, the boundary of these two may be become destabilized in some cases while in other performances, they are clearly separated. Examples from Chapter Two inform us that the degree and the method of administering the main component of the performance and the feedback system varies with the type of the interaction design and the performance. In mixed reality performances, feedback systems are quite important because the performance usually takes place simultaneously in different locations and feedback is the only way to know the status of the performance for the participants.

In *Uncle Roy All Around You*, online players journeyed through the parallel 3D model of the street player's environment. The online players listened to audio messages sent from the street players and received chat messages from other online players while immersing themselves in the 3D virtual environment. These feedback systems supported the main experience of the online players leading them to finding clues and useful information for the street players. Similar feedback systems are also evident in *Sleep No More*: live audience members traveled the five story high building with a custom bone conduction headset, making it possible for the operators to send information when the live participants came near the portal objects or the important locations.

In the audience participation-based music performances, the tendency has been to limit or to have no direct feedback systems to audience members. Instead, feedback is typically combined with the main components of the music performance such as changes in the course of the music structure, the output of real-time notation system for sight-reading, and the accommodated audiovisual displays. For instance, in *TweetDreams*, audience members participated in the real-time music composition piece by sending Twitter messages. Then, their messages were given special musical and visual accommodation in the performance. In *No Clergy,* a computer software stochastically generated music notations for each musician based on votes cast by the audience members on laptop computers. Musicians then played the real time generated music notation from a computer screen.

4.1.3. Performance Model

A performance model consists of performance data and rules for handling incoming performance events. These incoming events, as mentioned in the previous section, can come from audience members, performers, and environments. The performance model interprets the state of a real-time performance as an intermediate representation and applies the product that representation to *effect*. In other words, the interaction of elements in the performance are defined in this model. These elements are audience, performers, environments, uncertainty, and their interaction plan or context, and we treat each element in the performance model as sub-models that communicate with each other (Figure 4.3.).

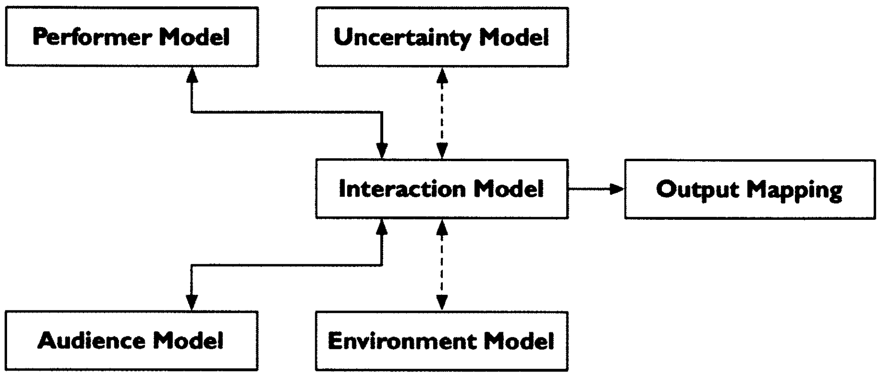

Figure 4.3. The performance model overview. The dotted lines show that the models do not need to exist in the final design depending on the context of a performance.

These sub-models are based on performance elements found in the works of researchers such as Bayliss and Benford [Bayliss et al, 2004] [Benford et al, 2005]. In our performance model, the uncertainty and the environment models do not need to exist in the performance. Some of the systems presented in Chapter Three also are missing the uncertainty and the environment models because the context of the performance did not require such models. These two models are flexible and can be disregarded depending on the context of a performance. Nevertheless, the design of the Hyperaudience system must always have models for audience, performers, and their interactions to define the properties and behaviors of a performance.

4.1.3.1. Audience Model

The audience model is always present in all the non-digital and digital audience participation-based performance systems presented in this thesis. The model makes assumptions about the behaviors, emotions, expressions, and gestures of the audience. These elements then typically take a central role in the construction of the Hyperaudience system.

As an example of the audience behavior, *Mood Meter* measured the friendliness of communities across different departments in MIT by counting smiles. Smiles were captured by a computer vision based software system that automatically detected and counted smiles in a public setting. [Hernandez, 2012]. The implementation of an audience model in *Mood Meter* expects that the audience interacts with the system using their amused facial gesture. Their smiling behavior is what really mattered for the system to engage the general public to participate in this cross campus community event.

In Chroma District, microcontrollers were programmed to react to the movement of pedestrians: we measured the time people spent underneath a lantern and triggered the light and sound patterns across all other lanterns. DrumTop has a rather active audience model: the interface calls for players to find objects, push actuators, and rearrange the objects on top of a tabletop surface to create unique drum patterns. In SIILPE, the audience model was carefully defined according to the experimental conditions to collect useful data from the subjects. Even through the subjects were in the same room observing the same performance, they did not have physical contact. They rated their feeling of performance using tablet PCs while seeing other people's feelings on a projected display.

4.1.3.2. Performer Model

As with the audience sub-model, a performer sub-model always exists in the performance model. The performer model defines the properties, behaviors, and abilities of a performer. In this model, a performer can be a real human or a machine programmed to execute a performance. If the performers are humans, they often need feedback from the performance system that supports their performance. This conforms to one of the principles of human-computer interface (HCI) design practice: support the user with evidence of closure and satisfy the interactions that the users expect when they are engaging with the interface [Perez-Quinones, 1996].

In many interactive installations, the performers are normally the computers that facilitate interactions with audience members through generative digital technology systems [Edmonds et al, 2004]. For instance, in *RE:MARK*, by Levin and Lieberman, the audience member's voice was visualized in realtime on a large projector screen appearing out of a shadow of a participant [Levin and Lieberman, 2004]. The performer model in this performance is the visualization mapping system based on the classification of uttered phonemes that eventually produced letters on the projection screen. The objects on the screen capture the attention of the audience, forming a basic audience/performer relationship between the people and the computers.

In Chroma District, the performer model was the automated microcontrollers inside the lanterns that changed the light and sound patterns according to the walking movement of the audience members. In DrumTop, the performer model is the tabletop interface with transducers and a software music sequencer program running on a microcontroller. In *A Toronto Symphony*, the performer model is the pianist himself. The performer model for the SIILPE is the live concert video by Queen projected on the screen.

4.1.3.3. Environment Model

The environment is the surroundings, space, and conditions in which the audience is situated in the performance. Environment modeling can be useful to compare and infer the state of the audience within the environment or to monitor potential hazards and unpredictable events. Otherwise, the model can be used as an additional parameter to engage the audience in the performance. In *Sleep No More*, the environmental information such as lighting conditions, noise levels, and room temperature were collected on the wearable computing system to compare with the internal and the physical state of the live participant. In Chroma District, infrared sensors were useless under extreme light exposure from the Sun, so microcontrollers were programed to shutdown when they had too much exposure to an infrared light input from the Sun.

4.1.3.4. Uncertainty Model

A live performance always involves some levels of uncertainty because, at any time during a show, a performer or technology supporting the performance may fail to execute a correct set of performance procedures [Cox and Warner, 1999]. In the case of audience participation-based performance, the uncertainty may come from the audience themselves, since the audience participation tends to be a spontaneous and improvisational activity. The important example of the uncertainty model is the role of the operators in *Sleep No More* and *Uncle Roy All Around You*. The operators in *Uncle Roy All Around You* moderated text messages from the online participants to appropriate the language of messages for the other online participants.

The performance system may include a natural language processing (NLP) system when constructing an audience model. Nonetheless, NLP systems can misinterpret the meaning of messages sent from the online participants at any time. In such cases, the operator can deal with the machine error. In this way, human interpreters can be preferable in some performance situations to regulate the flow of a performance, especially when the performance involves many uncertain inputs from audience members and elsewhere.

4.1.3.5. Interaction Model

In the interaction model, we plan the interactions of previously mentioned sub-models. It is a model that shapes the context of a performance. The interaction model is familiar with all the models and is able to assemble the state to come to the final output representation. The result of interactions in this model may influence to change the state of other sub-models or affect the final output representation intended for the audience. The elements of the performance models found in Chroma District are audience, performer, and environment models. The activities of audience, machine performers, and environment were all put together in the interaction model to determine the final outcome of the light and sound patterns for the lanterns. DrumTop had audience and performance models. They are tightly integrated within the interaction model that it blurs the boundary between the two model. In *Sleep No More*, all sub-models presented in this section existed in the performance system. The interactions of each model were carefully implemented prior to the performance.

4.1.4. Active Participation

Active participation is achieved when the audience interacts with the system and the performers, resulting in changes in the performance or the feedback systems. Figure 4.1. demonstrates the interaction design pattern for active participation. A typical flow is to capture the audience input through the capture system, passing data to the performance model, which then maps the data from the audience members to an appropriate output. Through the effect, the system is able to express or give feedback to the audience. Intuitive changes in the performance or feedback are important. Otherwise, the audience may not know that they are participating or contributing to the performance.

The active participation design pattern is extensively seen in the previous works that we have studied in Chapter Two. For example, in *Stelarc*, the audience controlled the body movement of Stelarc using a series of electrical impulses sent from a touchscreen device. In this case, the capture system is the touch screen, the effect propagates to audience through the movement of *Stelarc*, and the performance model is mapping the interactions between the performer and the audience. In

Glimmer, a large number of audience members contributed to the changes in musical process of each instrument section in the orchestra using light sticks. Flickering of light sticks was collected by the computer vision capture system which then the performance model processed according to the seating section of the audience. The flickering activity in each subdivided section was then mapped to the different instrument sections of the orchestra. In this case, musical changes that audience heard from the orchestra was the result of audience participation and the contribution of the audience members in the performance. The number of participants may vary according to the type of performance, but the interaction design pattern for an active participation remains consistent across different performances.

In Chroma District, infrared sensors beneath the lantern were used as the capture system to detect the movements of people who walk under the lanterns. The performance model made an assumption that the pedestrians who briefly stand under a lantern would like to activate the light and sound patterns. Every time when someone stood under a lantern, changes in color and sound patterns occurred across all lanterns. In *A Toronto Symphony*, a web browser was the capture system. The audience rated their preference of music with graphical sliders which then the performance model translated into a music score for the pianist. The audience member experienced changes in improvisation style through a video streaming service on a web browser.

4.1.5. Co-experience

Battarbee suggests that co-experience "is the user experience, which is created in social interaction" [Battarbee, 2003]. She suggests that co-experience leads us to creative and collaborative experience. This is also true in performance, as we have seen in many of the previous work presented in Chapter Two. To be exact with the use of the word co-experience, we mean co-experience happens when collaboration, communication, and coaction in the performance exist.

Our interaction design pattern provides a platform for co-experience even when the audience is participating from a remote location. Although the active participation design pattern is a pattern for interactions between audience members and performers, the flow of interaction for co-experience is the same as active participation. Instead the co-experience is concerned with the interaction among audience members. In *Sleep No More*, one of the agendas of the experiment was to establish co-experience between the online and live participants. The performance explored ways to pair online and live participants and encouraged them to co-experience the story behind the performance. The online participants used a web browser platform to communicate with live participants while the live participants typically interacted through portal objects placed around the live performance space.

In *A Toronto Symphony*, the audience members co-experienced the performance through the web browser. Anytime an audience member rated their preference of music, the pianist changed the style of the piano performance. Everyone in the audience saw the changes in each other's rating through the music score visualization. In addition, they also experienced changes in the performance style of the pianist through a video streaming. We believe that in *Sleep No More,* the degree of co-experience in the performance could have increased if the audience members had known each other's identity.

DrumTop demonstrates a rather obvious example of co-experience for the audience members. People collaboratively find objects and experiment with the interface. Blaine and Sidney suggest that the opportunities for social interaction and collaboration among participants through collaborative musical instruments can create an engaging musical experience for novices [Blain and Sidney, 2003]. In DrumTop, co-experience is achieved through intimate collaboration between the players.

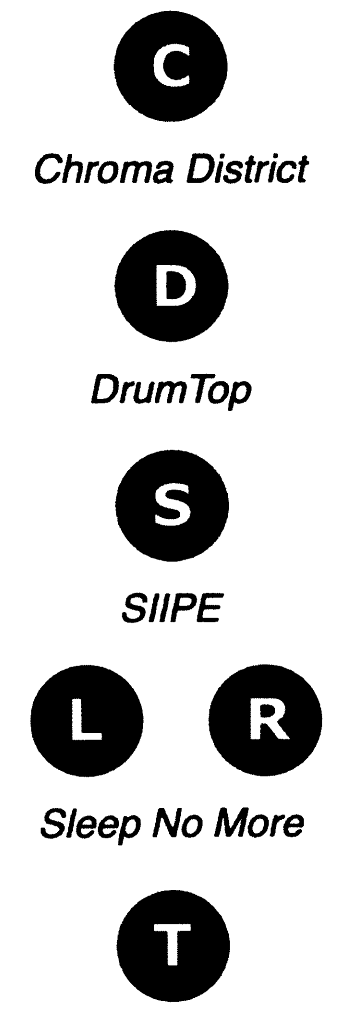

Figure 4.4.. Icons used for comparison.

4.2. Comparison

In this section, we compare each system that was presented in Chapter Three. A number of subjective analytic axes are used to reflect on how some of the approaches we have seen in each project differ from one another. The comparisons of these systems are based on the following axes: *frequency of participation, frequency of co-experience, expressiveness,* and *learnablity*. Through these comparisons, we explore the limitations and the characteristics of audience participation-based performances. We use images shown in Figure 4.4. as icons for comparison in each diagram. We note that *Sleep No More* has two icons: *L* represents the live participants and *R* represents the remote participants.

4.2.1. Conventions

We make assumptions about some projects to make the comparison easier. For SIILPE, we only consider the case when the audience was actively sharing their feelings on a display while they watched a video performance by Queen. For DrumTop, we only consider when more than two players are simultaneously interacting with the interface.

4.2.2. The Frequency of Participation

In this section, we look at the frequency of audience participation that happened in the performance for each system. This frequency refers to how often the audience contributed to and influenced a performance. The frequency of participation is an important and useful attribute for determining the success of the Hyperaudience systems. We use two comparison metrics in a two dimensional axis chart: the maximum time of performance experience against the frequency of participation and the scalability of performance against the frequency of participation.

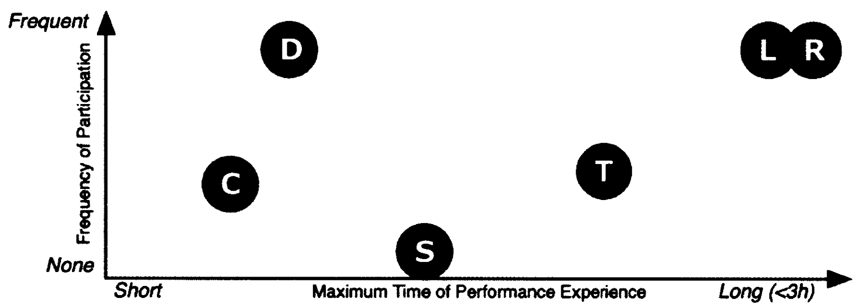

Figure 4.5. Comparison of each project using the frequency of participation and time span of each performance.

In the first comparison shown in the Figure 4.5., we see that each project has a varying maximum time of experience, but this does not correlate well with the frequency of audience participation. This chart illustrates that the time span of a performance is not directly related to the frequency of participation. The relationship on the chart rather explains that the involvement plan of the audience is much more important than the time they experience the performance. For instance, DrumTop and *Sleep No More* have the most frequent participatory activities among all other projects while their time span of the performance is significantly different. What is common between the two project is the extensiveness of the audience modeling: the performance model substantially relies on the audience model for directing the future course of the performance. DrumTop does not initiate the interaction with the player when they face the interface for the first time, but the performance is created through the interactions between the player and DrumTop. The curiosity of audience towards everyday objects and a drum sequencer carries on the performance and results in highly engaging participatory activities.

The live and remote participants in *Sleep No More* engaged in the performance for approximately three hours. Despite the long hours, they were highly engaged in the performance for the entire duration of the performance for the most part. The experience of the participants in a mixed reality performance takes the form of a journey. This journey is the form of participation in a mixed reality performance because the journey decides the course of the performance. The participant's journey can be explained with a similar experience trajectory that is demonstrated by Benford in Figure 4.6. This figure illustrates the analysis of the structure of the participant's experience in

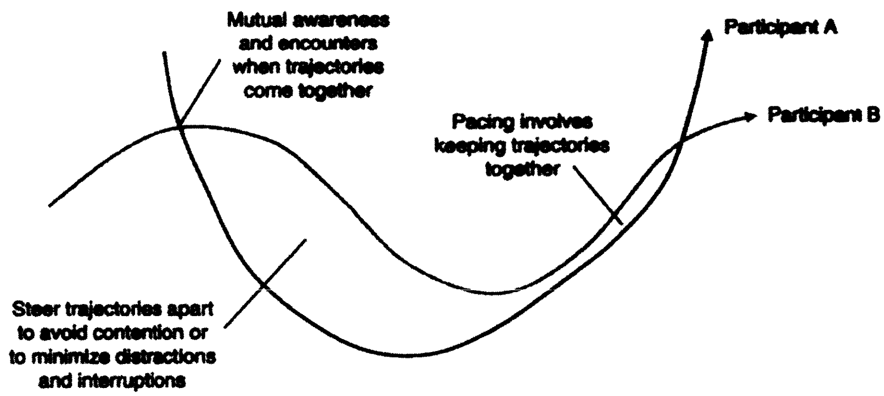

Figure 4.6. The trajectories of participants show moments of encounter and isolation.

their mixed reality performance [Benford and Giannachi, 2010]. The online and live participants in *Sleep No More* similarly encountered each other on their journey and had moments of isolation, involving themselves in different performances but experiencing the same story behind the performance. They were immersed in the performance and actively participating in shaping the performance.

The chart in the Figure 4.7. is a comparison between the frequency of participation and the maximum amount of participants allowed in the performance. This chart explains why the frequency of participation on Chroma District, SIILPE, and *A Toronto Symphony* is comparatively less frequent to the other projects. These systems were designed to accommodate a large number of participants, by which we mean more than ten people at once per performance. As Weinberg notes, one of the problems with audience participation-based performance systems is that as the number of audience members becomes large, individual contributions to the performance become obscured by the large quantities of participants and it is often difficult, if not impossible, to represent every single contribution made by the individual audience members [Weinberg, 2005].

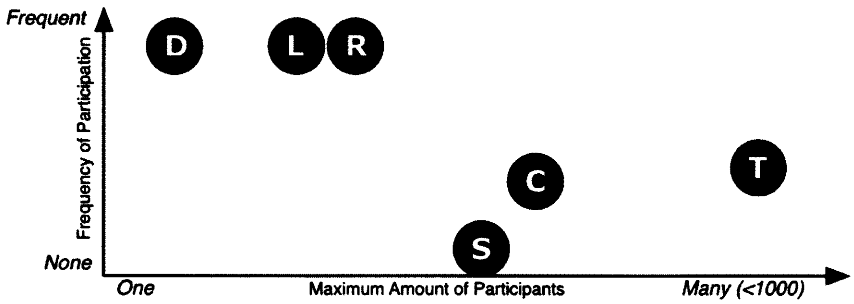

Figure 4.7. Comparison of each project using the frequency of participation and maximum amount of participants.

In SIILPE, the audience never contributed to the simulated performance. This is because the project was design to examine co-experience rather than participation, and the audience had no control over shaping the course of the performance.

4.2.3. The Frequency of Co-experience

In this section, we look at the frequency of co-experience that occurs in the performance for each project. The frequency of co-experience includes collaboration, coaction, and communication time during the performance. The metrics used here are the frequency of co-experience against the frequency of participation. We then discuss some of the characteristics of each system regarding co-experience.

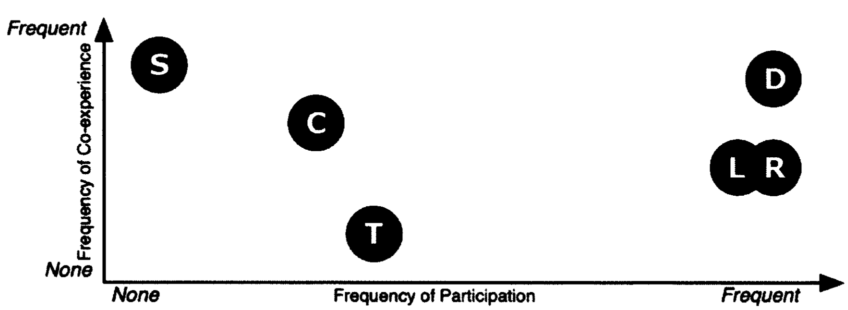

Figure 4.8. Comparison of each project using the frequency of co-experience and the frequency of participation.

SIILPE was designed to measure co-experience in live performance and examined if we see any significant changes in the engagement level of audience members. The project did not reveal any significance, but the design of the system was meant to enhance co-experience in the performance. The co-experience factor on Chroma District is relative high because people who came to see the installation were physically present to each other. The audience often came in groups to see the installation and they talked about and played with the interactive installation together.

4.2.4. Expressiveness

This section looks at the systems' capability is to enable the audience to be expressive. The audience expressiveness one of the conditions of the Hyperaudience framework that needs to be satisfied and we compare the relationship of expressiveness with the frequency of participation and co-experience to examine how well each system encourages the audience to be expressive.

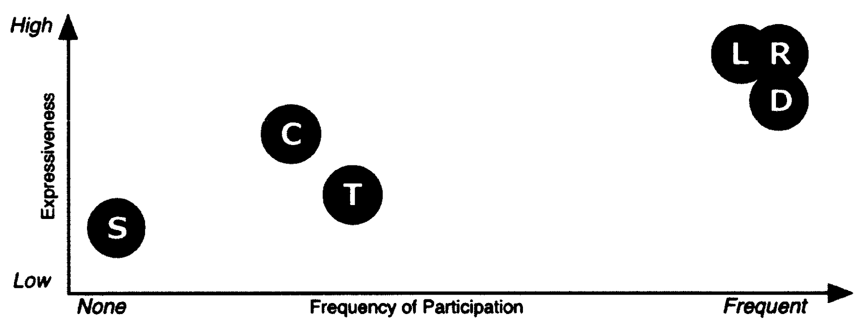

Figure 4.9. Comparison of each project using the expressiveness and the frequency of participation.

In Figure 4.9., we see that the relationship between expressiveness and the frequency of participation is almost linear: the more expressive the audience is the more involved the audience is in the performance. This means that the system's capability to encourage participation applies directly to the systems capability to enable the audience to be expressive.

On the other hand, self-expressiveness and the frequency of co-experience do not show clear relationships to each other (Figure 4.10.). SIILPE was an experimental project for quantitative analysis of the audience and may not exhibit expressiveness from the audience at all.

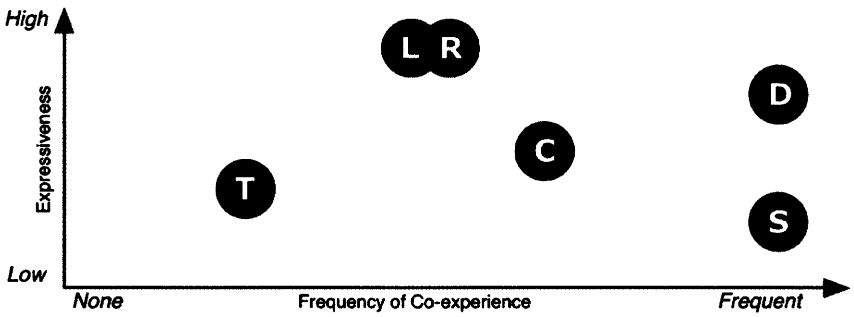

Figure 4.10. Comparison of each project using the expressiveness and the frequency of co-experience.

We may say from this that the relationship between the frequency of co-experience and expressiveness is weaker than between expressiveness and the frequency of participation. DrumTop ranks high on expressiveness, and this is because the performance is based on the collaboration between the players: they collaboratively look for objects and explore the sound quality of those objects enabling both participation and co-experience for the audience. We have mentioned three elements of co-experience: collaboration, communication, and coaction. In addition, out of all the co-experience factor, collaboration seems to give the strongest expressiveness to people.

4.2.5. Learnability

In this section, the learnability of each system is compared against the frequency of participation and co-experience. For the audience to easily participate in the performance, the system ought to be simple for the audience to learn. The conceptual framework of the Hyperaudience system catalogs the ease of learning curve as an important factor in the process of building a successful Hyperaudience system.

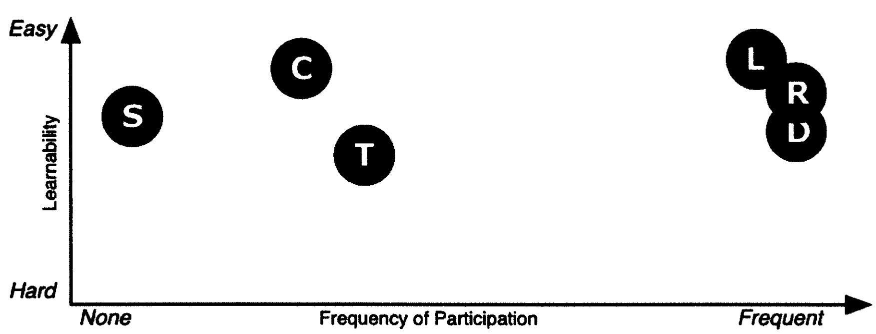

Figure 4.11. Comparison of each project using the learnability and the frequency of participation.

As we see in the Figure 4.11. and the Figure 4.12., each system has its own learning curve. The interfaces for Chroma District and the live audience members from *Sleep No More* are the easiest to pick up. In fact, almost no learning is required for the participants to involve themselves in the performance. Chroma District relies on the movement of pedestrians; once they realize that lanterns react to them when they stop, people can play with the system as long as they wish. The live participants for *Sleep No More* carry unobtrusive wearable computers that give feedback to them through a bone conduction headset. The wearables also automatically collect data about the live participants such as location and heart rate. The participants did not have to learn anything, but simply wear the computer system.

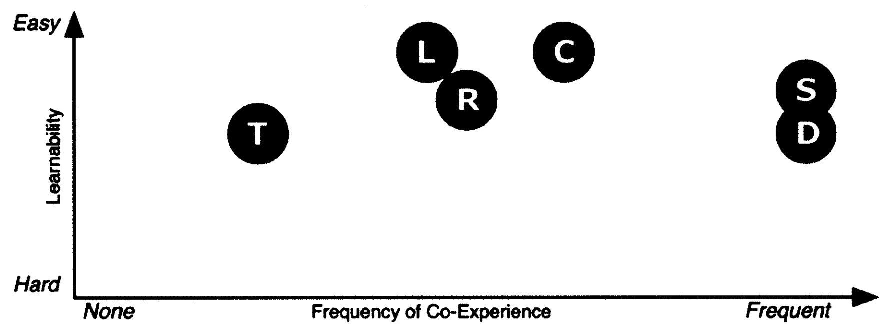

Figure 4.12. Comparison of each project using the learnability and the frequency of co-experience.

One of the characteristics we see in these figures is that interfaces that are not necessarily easy to learn can lead to frequent participation and co-experience. Sacrificing the learning curve of the performance interface can often make the experience of participation more engaging because such interfaces typically have extra functionalities that the participants can use.

4.3. Challenges

In this section, we identify some of the challenges that are important to consider in the course of designing audience participation-based performance systems. These are challenges that some of the systems supported this thesis were not able to overcome and we describe some examples. In addition, we also present possible solutions to these examples.

4.3.1. Scalability

Considering the roles and skill levels of both audience and performers as well as the performance environment and coherence is essential in order to deliver an effective performance [Cook, 2001][Freeman, 2010]. Individual contributions in an audience participation-based performance are often obscured by the large quantities of participants and it is often difficult, if not impossible, to represent every single contribution made from individual audience members [Weinberg, 2005]. Therefore, the works in this field often focus on the analysis of large-scale group interaction patterns and the coordination of multiple input sources into a meaningful musical outcome.

In order for any audience members to be able to participate in a performance, the degree of experience, skill, practice, or talent involved in participation needs to be taken into account [Freeman, 2005]. The availability of new sensors and computer interfaces can take into account nearly all parts of our body [Blaine and Fels, 2003][Cook, 2001], and participation methods for audience members can be as generalizable as possible so that it will not require any special skills for audience members to participate.

4.3.2. Social Elements

The effective audience participation-based performance system often contains social elements that connect the participants either cooperatively or competitively. Many works in the past explicitly or implicitly incorporated game elements to bring in social elements to the designed system [Freeman, 2010][Feldmeier et al, 2002][Benford, 2006]. Audience members may play only a small role in the performance, but incorporating social elements enriches the performance for both audience and performers.

4.3.3. Uncertainty

We also need to deal with uncertainty associated with performance such as technological failure and performance mistakes. Wearable sensors attached to live audience members can produce error, jitter, and latency, and wireless communication technologies are constrained by limited coverage. Richard Schechner notes that one of the challenges in audience participation is that neither audience nor performers are trained for participation [Schechner, 1971]. For this reason, the improvisational nature of audience participation may also bring uncertainty to a performance. We need to consider if uncertainty is going to be part of the performance or if we are deliberately going to eliminate this problem.

Orchestrating a performance in real-time from behind the scenes poses another challenge. Successful orchestration requires tools for managing the status of participants, for example, knowing their connection status and last known position and presence, and also for subtly intervening without disrupting the performance, such as filtering out messages.

4.3.4. Feedback

We also need to consider the configuration of feedback systems to the audience. For example, the performance may be intimately tied with the local setting, such as *Sleep No More*. In this project, we had to think through whether we were going to integrate rich local performance information such as maps, plans, images, and sounds into the online content or not. In addition, the decision was to limit the amount of information from the local performance space to the online participant, but use this limited information effectively with appropriate timing during the performance.

A successful feedback system requires tools for managing the status of the audience. For example, knowing their location, ability, and status can help the performance improvise feedback to the audience to keep them engaged in the performance.

4.3.4. Flexibility

The Hyperaudience system ought to be flexible and robust enough to accommodate the changes that happen in the development of a production and in spontaneous participation by the audience. The flexibility can be achieved through considering uncertainties associated with the performance. For example, the production may require us to modify our basic communication protocol during the course of development; the system could easily accommodate the request if the system already supports different types of communication protocols.

The ideal situation that we have learned through this experience is that keeping the core component of projects as software makes it is easier to port to a different machine. Keeping the software modular is the key to the flexibility: have the software receive any kind of message and data type such as OSC, MIDI, DMX, and so forth, and be ready to send messages to other systems through common protocols.

4.3.5. Evaluation Methods

To determine whether or not an interactive performance project is successful can be hard to assess. Nonetheless, the performance can be evaluated by examining a series of performances and the audience responses for each performance.

Firstly, we can determine if the system is capable of running the show coherently; does the system integrate rich local information and appropriately configure network and sensing technologies for smooth interactions between on-site and remote audience? Is the system able to deal with the uncertainty associated with, for example, wireless and sensing technologies? We believe that examining a series of performances will reveal the weakness and strength of the proposed system, and evaluate the system for the future improvement.

Secondly, we can collect participation data from the audience such as sensor data and computer input devices. This data can be quantitatively and statistically analyzed to reveal the tendency of the audience behaviors. This can be particularly useful if we are measuring the affective qualities of the performance to establish basic comparison methods. To measure the success of Hyperaudience systems, we can focus on the analysis of a system's capability to promote participation and enhance social co-presence among participants. The data can be compared among each performance to measure the differences in the participation rate and social co-presence.

Lastly, we can also conduct general survey research with the audiences who have participated in the performance, for example, Likert-style questions and space for free-response comments. From such data, we can assess whether the audience felt connected to each other, felt creative, and realized that the performance was unique, partly because of their contributions to the performance. However, in some occasions getting survey reports from the audience may not be possible, perhaps in order to maintain the quality of the performance. In this case, we can also think of ways to integrate the evaluation algorithms directly into the performance system itself according to how the audience acts in the performance.

4.4. Evaluation

To evaluate the successfulness of the works presented in this thesis, we must first consider the context in which these works are positioned and according to what standards they should be measured. This is difficult because of the interdisciplinary nature of the work: The systems that strengthen this thesis exist in a domain at the intersection of art, design, science, and the engineering of tools and interfaces. As works of art, these works fit within and extend established interactive performance systems. Systems presented in this thesis were built as ways for the author to explore, develop, and present a strictly unique personal language of design practice. Along the way, we have suggested new technological solutions for audience-performer interaction in the context of real-time interactive performance.

4.4.1. Third Party Attention

Some of the projects in this thesis have been made possible because of support from others. Chroma District was made possible because of the founding by the Council for the Arts at MIT (CAMIT). This means that we have made this project happen because our project proposal was accepted by the international volunteer group of alumni and friends who support the arts at MIT. We are confident that the project contributed to the development of the arts-related research in the MIT community.

Our collaboration project with Punchdrunk, *Sleep No More*, was founded by the National Endowment for Science, Technology, and the Arts (NESTA). NESTA is an independent endowment in the United Kingdom with a mission to help people and organizations bring great ideas to life. They fund the project to develop a live online experience connected to Punchdrunk's *Sleep No More*.

In terms of media coverage, DrumTop has been commentated by various media including National Public Radio (NPR) and Engadget [NPR, 2012] [Engadget, 2012].The project we have done with Punchdrunk has been covered by the *New York Times*, *Gizmodo*, the *Guardian*, and various other media [The New York Times, 2012] [Gizmodo, 2012][the Guardian, 2012].

4.4.2. Informal Feedback

The informal feedback from players suggests that children and musical novices would see DrumTop as an accessible and playful way to learn musical patterns, and that DrumTop can be used as a tool for music performers and artists for collaboration and interactive performance. Tina Blaine and Sidney Fels suggest that the opportunities for social interaction and collaboration among participants through collaborative musical instruments can create an engaging musical experience for novices [Blaine and Sidney, 2003]. We believe that encouraging players to collaborate can further enhance the creative musical experience.

In *A Toronto Symphony* experimental project, the only way for us to know that performance was successful is through the amount of access we had from the audience in this performance. SIILPE was rigorously evaluated and we know that the performance was unsuccessful in facilitating social interactions among audience members during the performance: we are looking for ways to improve the experiment conditions for the future studies.

4.4.3. Discussion

The works that support this thesis have much in common with the Hyperinstruments goals: embrace artistic activities, master the technological craftsmanship, and design powerful and interactive entertainment systems for the general public. We think that the most important question here is: do the systems succeed in their own ways? That is, do the systems demonstrate solutions to the challenge proposed in this thesis: to build a system that facilitates participation and communication. Through the comparison of each project, we know that some had succeeded while others did not in different criteria. Through these weaknesses and strengths, we also show how future implementation could improve the project and the design of the Hyperaudience systems.

5. CONCLUSION

5.1. Summary

This thesis explored the design of systems that make real-time audience participation and interaction possible in a technologically mediated performance environment. We defined the concept of the Hyperaudience as the audience who actively participates in a performance and may be connected through technologies to experience a performance in and beyond the performance space. We studied the history of real-time interactive performance systems that invite audience members to participate and connect using various technologies. In addition, we also studied examples of a performance that encourage audience participation without using any technologies but exercise social interactions extensively in the performance space. Then, we presented five systems the author was involved in building that explored the properties of a Hyperaudience system: Chroma District, DrumTop, SIILPE, *Sleep No More,* and *A Toronto Symphony.* Furthermore, we presented the conceptual framework of the Hyperaudience system and each project was discussed with respect to this framework. We analyzed these systems: The interaction design patterns that depict the characteristics of the Hyperaudience system were discussed, and comparison of each projects were given. We then discussed challenges and the evaluation of each project.

5.2 Conclusions

Throughout this thesis, we've encountered countless examples of performance works where the audience has had a direct and immediate influence in the performance. These performances were either designed to include audience members, or they themselves were created with the contribution from the potential audience members using participatory technologies or simply through social interactions between performers and the audience as well as among the individual audience members. Some performances targeted a very specific audience in mind and they clearly have no purpose of existence without the presence, contribution, and interaction of these specific audience members in the performance space. All the performance works presented in this thesis question the role of the audience in the performance, often by transforming their roles to be co-creators of the performance experience from just merely being passive observers.

The reasons why artists, researchers, and experience designers accommodate audience responses and make their performances interactive are as diverse as the styles of performance they are situated in. Because of this, the performance works that incorporate audience participation and interactive social co-experience seem to be hard to assemble into one unifying concept. As we studied and explored these performances however, we have found and defined the emerging new audience in the modern performance space, namely the Hyperaudience. The Hyperaudience exists in a technologically mediated performance space: they use participatory technologies, such as mobile devices, to augment their experience by contributing to a performance and connecting with other people in and beyond the performance space. A performance that accommodates such new audience members needs a set of principles to build upon in order to have the Hyperaudience effectively participate and communicate in a performance space in meaningful way. We have just done that in this thesis and we called such organizing principles the Hyperaudience system.

The conceptual framework of the Hyperaudience system draws upon theories and practices found in preceding performance systems for audience participation. We have attempted to cover all relevant forms of performance systems that feature some aspects of the conceptual framework of the Hyperaudience system through exploring the audience in various performance spaces including music, theater, and public spaces. We also developed performance systems ourselves to explore how and in what way the Hyperaudience comes to existence through interactions with these performance systems. The styles of intended audience participation in all performance systems presented in this thesis vary radically from each other. Nevertheless, we captured an extensive view of how such performance systems include the audience in a technologically mediated performance space.

Whatever design techniques we use to build a performance system, it should empower the audience to be expressive, support active participation, encourage audience members to be communicative and co-creative, and modulate itself to deliver personalized experience through an interface that is inherently transparent and user-friendly to the audience. If the performance system achieves these conditions, then we have successfully created a Hyperaudience system.

Our sincere hope is that this new breed of the audience feels like they are creating and expressing common feelings and emotions along with the performers and each other with the conviction that they are connected to each other, contributed significantly to a performance, and because of this, their physical engagement strengthens the mental engagement and vice versa. We wish that Hyperaudience systems become coextensive with our everyday life, and empower people to engage and communicate more deeply with themselves and others.

5.3. Future work

Future work involves researching more possible ways to encourage audience members to engage with an interactive performance systems, perhaps by integrating the technology more fully into activities people are already very comfortable performing in their daily lives. This could make systems palatable for the audience to participate in the performance and enhance audience-performer interactions.

As extensions of SIILPE, conducting experiments on real-time social interactions among audience members and performers in performance space could lead us to observe genuine behaviors of audience members' performance experience when participation and social interaction are involved in the performance. This will be beneficial for refining the framework for the Hyperaudience system because this give us a clue to provide more fully integrated knowledge of audience behaviors, such as social psychology and affective computing, into the audience model in our design pattern.

In general, projects presented in support of this thesis are still primitive. This makes it ideal for us to rethink some of the most important and outstanding ways in which audience participation systems can be improved. *A Toronto Symphony* is an on going project as of today. We are planning to perform a symphony orchestra that involves a mass audience participation system. This will be a good opportunity for us to learn about whether scaling up of the audience affects the framework of the Hyperaudience system.

DrumTop is continuing to be expanded and improved upon to accommodate collaboration between participants more tightly. Our future plan is to conduct a formal study to evaluate DrumTop as a tool to teach and perform music for music novices.

5.2.1. Example Applications

We have come up with number of other projects that were unfortunately not implemented as of this writing. We include them here as example applications as they are relevant to the interaction design pattern of the Hyperaudience system. These projects use currently available technology at the MIT Media Lab and the author would like to perhaps implement someday. Thinking about the design process is fun in general and good for refining the Hyperaudience system for the future.

AuDJ

This is a dance club project in which we will design a system that enhances the musical interaction experience of both audience members and DJs. Audience members request songs from DJ's playlists through their mobile device. Audience members also socially engage in dancing to ask for musical controls to DJ based on sensor data acquired from mobile devices. A music recommendation system and an audience activity monitor aids DJs in the process of choosing songs requested from audience members and keeps track of who, among audience members, are actively participating in the performance so that DJs can reward them by giving musical controls, controlling aspects of music such as complexity, intensity, and style of music. Visual displays that may act as a public bulletin board support DJ and audience interaction.

DJRoom

Turntable.fm is a website where people can connect with their friends in a real time music listening experience environment. The experience takes place primarily in a 2d display environment where each person chooses an avatar that represents him or her and listens to music that their friends pick as they wander around virtual rooms. With the indoor location tracking system we built for this project, we can build a real world turntable.fm in which people would walk through the building and hear different music on the headphones as they switch rooms

SongLog

What songs did we encounter today? Song Log is a mobile application that listens to music through out a user's daily life. It is a similar application to the life-logging concept but your experience is recorded in the context of music metaphor. The application listens to music and identifies songs that you may have heard at the cafe, office, classroom, or even walking on the street. Along with geotagging, songs are logged so that users can later retrieve information and listen to music if they like.

5.2.2. Moving Forward

The concept of the Hyperaudience gives us a novel perspective on the performance and audience. As increasing amounts of interactive performance systems are presented in the public space, design methods and ideas presented in this thesis can help make the task of finding one's way in this multidisciplinary field more easier. We are not the first people to try to create an interactive performance system, and we we will not be the last as well. Our hope is that interactive performance systems will come to feel more coextensive with our everyday life as the field develops, and empower people to engage and communicate more deeply with themselves and others.Our sincere hope is that this thesis will be useful to some people who continue the journey of research in interactive performance systems.

Bibliography

Abbassi, Z., Aperjis C., Huberman A. B. Swayed by Friends or by the Crowd? (September 22, 2011). Available at SSRN: http://ssrn.com/abstract=1932244

Al-Deen, H. N., The Evolution of Rai Music. Journal of Black Studies, Vol. 35, No. 5. pp. 597-611. May, 2005.

Arduino. Available: http://www.arduino.cc/. 2012.

Ascott, R. Behaviourist Art and the Cybernetic Vision. Cybernetica: Journal of the International Association for Cybernetics (Namur) 9(4), 247-264. 10(1), 25-56 1967. Excerpted in: Packer, R., Jordan, K. (eds.) Multimedia: From Wagner to Virtual Reality, pp. 95-103. Norton, New York. 2001.

Atmeal ATMEGA32U4 8-bit microcontroller. http://www.atmel.com/Images/doc7766.pdf. 2011.

Attali, J. Noise: The political economy of music. Minneapolis: University of Minnesota Press. 1985.

Audio Bone. Available: http://www.audioboneheadphones.com/. 2012.

Barbosa, A. Displaced Soundscapes: a survey of networked systems for music and sonic art creation. Leonardo Music Journal 13: 53–9. 2003.

Battarbee, K. 2003. Defining co-experience. In Proceedings of the 2003 international Conference on Designing Pleasurable Products and interfaces (Pittsburgh, PA, USA, June 23 - 26, 2003). DPPI '03. ACM Press, New York, NY, 109-113.

Baird, K. C. Real-Time Generation of Music Notation via Audience Interaction Using Python and GNU Lilypond. Proceedings of the 2005 International Conference on New Interfaces for Musical Expression (NIME05), Vancouver, BC, Canada. 2005.

Barrett, G., Winter, M., and Wulfson, H. Automatic notation generators. In: Proceedings of the 2007 international conference on new interfaces in musical expression (NIME), 6 – 10. 346–351. New York, 2007.

Bayliss, K. A.; Lock, S,; Seridan, J.G. Augmenting Expectation in Playful Arena Performances with Ubiquitous Intimate Technologies. Pixel Raiders 2, 2004.

Benford, S. and Giannachi, G. Performing Mixed Reality. MIT Press. 2010.

Benford, S., Crabtree, A., Flintham, M., Drozd, A., Anastasi, R., Paxton, M., Tandavanitj, N., Adams, M., and Row-Farr, J. Can You See Me Now? ACM Transactions on Computer- Human Interaction (TOCHI). Vol. 13, Issue 1, March 2006. New York, NY, USA.

Benford, S., Magerkurth, C., and Ljungstrand, P. Bridging the Physical and Digital in Pervasive Gaming. Communication of the ACM - The disappearing computer. Vol 48. Issue 3. March 2005.

Benford, S., Drozd, A., Greenhalgh, C., Fraser M., Schnadelbach, H., Koleva, B., Anastasi, R., Flinthm, M., Hemmings, T., and Crabtree, A. Orchestrating Real-Time Participatory Experiences. Equator Technical Report. 2003.

Benford, S., Flintham, M., Drozd, A., Anastasi, R., Rowland, D., Tandavanitj, N., Adams, M., Row-Farr, J., Oldroyd, A, Sutton, J. Uncle Roy All Around You: Implicating the City in a Location-based Performance. ACM Press. 2004.

Benford, S., Bowers, J., Chandler, P., Ciolfi, L., et al. Unearthing virtual history: using diverse interfaces to reveal hidden virtual worlds. Proceedings of Ubicomp 2001, Atlanta, 2001.

Berns, S. G., Capra, M. C., Moore, S., and Noussair, C. Neural mechanisms of the influence of popularity on adolescent ratings of music. NeuroImage, Vol. 49, No. 3. pp 2687-2696. 2010.

Bjork, S., Falk, J., Hansson, R., Ljungstrand, P. Pirates! Using the Physical World as a Game Board. Interact2001. http://civ.idc.cs.chalmers.se/publications/2 001/pirates.interact.pdf. 2001.

Blaine, T., and S. Fels. Collaborative Musical Experiences for Novices. Journal of New Music Research. 32. No. 4. pp 411-428. 2003.

Blaine, T., and Perkis, T. The jam-o-drum interactive music system: a study in interaction design. In Proceedings of the 3rd conference on

Designing interactive systems: processes, practices, methods, and techniques, DIS '00, pages 165–173, New York, NY, USA, 2000. ACM.

Blast Theory. Available: http://www.blasttheory.co.uk/bt/index.php. 2012.

Blowhole Theater. Available: http://xroads.virginia.edu/~UG02/altman/coney_island_webpage/blowhole.html. 2012.

Brewster, B., and Broughton, F. Last Night A DJ Saved My Life: The History of the Disc Jockey. Grove Press, New York, USA, 2000.

Brown, B. et al. Crowd computer interaction. In Proc. CHI (Extended Abstracts), pp. 4755-4758. ACM Press, 2009.

Burk, P. Jammin' on the Web: A New Client/Server Architecture for Multi-User Musical Performance. In Proceedings of the International Com- puter Music Conference (ICMC) pp. 117–120. 2000.

Burnham, Jack. Real Time Systems. Artforum, Vol. 7, pp 49-55. September, 1969.

Cage, J. Water walk, January 1959. http://www.johncage.info/workscage/waterwalk.html.

Cage, J. Silence: Lectures and writings by Jon Cage. Middletown, CT: Wesleyan University Press. 1984.

Carlson, M. Places of Performance: the Semiotics of Theatre Architecture. Ithaca: Cornell University Press, 1989.

Carpenter, L. Cinematrix, Video Imaging Method and Apparatus for Audience Participation. US Patents #5210604 (1993) and #5365266 (1994).

Caygill, H. Stelarc and the chimera: Kant's critique of prosthetic judgment. Art Journal, Vol. 56. No. 1, Aesthetics and the Body Politic. pp 46-51. 1997.

Chafe, C., and Gurevich, M. Network time delay and ensemble accuracy: Effects of latency, asymmetry. In Proceedings of the AES 117th Convention, 2004.

Chanel, G., Klerkels, J. J. M., Soleymani, M., and Pun, T. Short-term emotion assessment in a recall paradigm. International journal of Human-Computer Studies, 67, 8. 2009.

Chanel, G., Pelli, S., Ravaja N., and Kuikkaniemi K. Social interaction using mobile devices and biofeedback: effects on presence, attraction and emotions. BioS-Play Workshop 2010. Fun and Games Conference.

Chatterton, Peter and Hollands, Robert. Urban Nightscapes: Youth Cultures, Pleasure Spaces and Corporate Power. Routledge, New York, USA, 2003.

Cheok, A. D., Goh, K. H., Liu, W., Farbiz, F., Fong, S. W, Teo, S. L., Li, Y., and Yang, X. B. Human pacman: A mobile, wide-area entertainment system based on physical, social, and ubiquitous computing. Personal Ubiquitous Computing 8, 2, 71-81. 2004.

Chroma District. http://arts.mit.edu/fast/fast-light/fast-installation-chroma-district/. 2011.

Circumstance. Available: http://productofcircumstance.com/. 2012.

Cliff, D. hpDJ: An automated DJ with floorshow feedback, hp Labs report HPL-2005-88, 2005.

Concert Companion Prototype Test: Aspen & Saratoga. Summary of Post-Performance User Discussions. Available at: http://www.splashblog.com/documents/prototype_report.pdf. 2003.

Cook, P. Principles for designing computer music controllers.Proc. ACM CHI, 2001, Seattle, WA, 2001.

Cowie, R., Douglas-Cowie, E., Tsapatsoulis, N., Votsis, G., Kollias, S., Fellenz, W. and Taylor, J. G. Emotion recognition in human-computer interaction. IEEE Signal Processing Magazine, 18, 1, 2001.

Cox, C., and Warner, D. Audio Culture: Readings in Modern Music. Continuum. New York. 1999.

Dahl, L., Herrera, J., and Wilkerson, C. TweetDreams: Making Music with the Audience and the World Using Real-Time Twitter Data. In

Proceedings of the International Conference on New Interfaces for Musical Expression (NIME). Oslo, 2011.

Dery, M. Fractal Flesh: Stelarc's Aesthetic of Prosthetics. Available: http://www.lehman.cuny.edu/vpadvance/artgallery/gallery/talkback/stelarc.html. 2012.

De Nora, T. How is extra-musical meaning possible. Music as a place and space for work. Sociological theory 4, 84-94. 1986.

Derr, K. and Manic, M. Wireless Indoor Location Estimation Based on Neural Network RSS Signature Recognition (LENSR), in Proc. 3rd IEEE Conference on Industrial Electronics and Applications, Singapore. June 3-5, 2008.

Dixon, S. Digital Performance: A History of New Media in Theatre, Dance Performance Art and Installation. MIT Press. 2007.

Durand, V. M., and Barlow, D.Abnormal psychology: an integrative approach. Belmont, CA: Wadsworth Cengage Learning. pp. 331. 2009.

Edmonds, E., Turner, G., and Candy, L. Approaches to Interactive Art Systems. Proceedings of the 2nd international conference on Computer grahpics and interactive techniques in Australasia and South East Asia. Singapore. 2004.

Egermann, H., Grewe, O., Kopiez, R., and Altenmüller, E. Social Feedback Influences Musically Induced Emotions. Annals of the New York Academy of Sciences. Vol 1169. pp 346-350.
2009.

Farbood, M., Pasztor, E., Jennings., K. Hyperscore: A Graphical Sketchpad for Novice Composers. IEEE Computer Graphics and Applications, January-March 2004.

Feldmeier, M., Malinowski, M., and Paradiso, J.A. Large Group Musical Interaction Using Disposable Wireless motion sensors. Proc. International Computer Music Conference, 2002, 83-87

Festival of Art + Science + Technology. Massachusetts Institute of Technology. http://arts.mit.edu/fast/. 2011.

Fields, B., and Lamere, P. Finding a Path Through the Juke Box: The

Playlist Tutorial. Given at International Conference on Music Information Retrieval (ISMIR), Utrecht, The Netherlands, 9 August 2010.

Fish, T. The donkey show, and: *Sleep No More*, and: *Best of Both Worlds*. Shakespeare Bulletin 28(3). 403-412. 2010.

Freeman, J. Large Audience Participation, Technology, and Orchestral Performance. Proc. International Computer Music Conference. Barcelona, 2005.

Freeman, J. Creative Collaboration Between Audiences and Musicians in Flock. Digital Creativity, Vol. 21, pp. 85-99. 2010.

Gamma, E., Helm R., Johnson, R., and Vlissides, J. Design patterns: elements of reusable object-oriented software. Addison-Wesley, 1995.

Gaonkar, S., Li, J., Choudhury R. R., Cox, L., Schmidt, A. Micro-Blog: Sharing and Querying Content Through Mobile Phones and Social Participation. Proc. 6th International Conference on Mobile Systems, Applications, and Services. pp. 174-186. 2008.

Gates, C., et al. DJs' Perspectives on Interaction and Awareness in Nightclubs, in Proceedings of the 6th conference on Designing Interactive Systems 2006, ACM: University Park, PA, USA. p.70-79. 2006.

Gates, C. and Subramanian, S. A Lens on Technology's Potential Roles for Facilitating Interactivity and Awareness in Nightclubs, 2006, University of Saskatchewan: Sasaktoon, Canada.

Gaye, L., Holmquist, L. E. and Mazé, R. Sonic city: the urban environment as a musical interface, Proceedings of NIME '03. 2003.

Geocaching website http://www.geochaching.com/

Gibson, M. Secret Cinema: Where You Don't Know the Movie Until You're on Set. The Time. Available: http://www.bfi.org.uk/news/sightsound/secret-cinema-18. 2012.

Gluhak, A., Bandara, U., Presser, M., Moessner, K., and Morikawa, H. UbiClub: A Context-Aware Environment for Nightclub Entertainment and Management. Capturing Context and Context Aware Systems and

Platforms - Joint e-SENSE, MAGNET Beyond, DAIDALOS, and CRUISE Workshop, Mykonos Island, Greece, June 8, 2006.

Gockly, R., Simmons, R., and Forlizzi Jodi. Modeling Affect in Socially Interactive Robots. The 15th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN06), Hatfield, UK, September 6-8, 2006.

Godøy, R. I., Jensenius, A. R. Body Movement in Music Information Retrieval. Proc. 10th International Society for Music Information Retrieval Conference. 2009.

Gonzalez-Castanoandm, F. J., and Garcia-Reinoso, J. Bluetooth Location Networks. In Proc. IEEE Global Telecomm. Conf., Taipei, Taiwan, R.O.C., pp. 233–237. Nov. 2002.

Google Chrome. Available: https://www.google.com/intl/en/chrome/browser/. 2012.

Goto, M. Music Listening in the Future: Augmented Music-Understanding Interfaces and Crowd Music Listening. Proc. AES 42nd International Conference on Semantic Audio, pp. 21-30, July 2011 (Invited Paper).

Gresham-Lancaster, S. The Aesthetics and History of the Hub: The Effects of Changing Technology on Network Computer Music. Leonardo Music Journal vol. 8, pp. 39-44. 1998.

Hasse, J. Moths. Visible Music, Euclid, OH, 1986.

Hernandez, J., Hoque, M. E., Drevo, W., Picard, R.W., Mood Meter: Counting Smiles in the Wild. To appear in the 14th International Conference on Ubiquitous Computing (Ubicomp), September 2012.

Hesse, H., and McDiarmid, A. The bubblegum sequencer. In Proceedings of the Conference on Computer Human Interaction (CHI), 2008.

HiWave Technologies. Audio Exciters. Available: http://www.hi-wave.com/products/audio-exciters.php. 2012.

Hromin D., Chladil, M., Vanatta, M., Naumann, D., Wetzel, S., Anjum, F., Jain, R. CodeBLUE: A Bluetooth Interactive Dance Club System. Proc. GLOBECOM, 2003, 2814-2818.

Huang, S. Chinese Traditional Festivals. The Journal of Popular Culture, 25: 163–180. 1991.

Hungtinton, A. Beatbox, 2005.http://extraversion.co.uk/?p=188.

idsoftware. Quake. Available: http://www.idsoftware.com/games/quake/. 2012.

IOIO. Available: https://github.com/ytai/ioio/wiki). 2012.

Iwasa, K., Kotaki, H., Nagata, S., and Yamano, H. B. Buonda, 2010. http://buonda.ifdef.jp/top.htm.

Jennings, K.. Toy Symphony: An International Music Technology Project for Children. Music Education International, 2. pp.3-21. 2003.

JQuery. Available: http://jquery.com/. 2012.

Kaltenbrunner, M., Jorda, S., Geiger, G., and Alonso, M. The reactable*: A collaborative musical instrument. In Enabling Technologies: Infrastructure for Collaborative Enterprises, 2006. WETICE '06. 15th IEEE International Workshops on, pages 406 –411, june 2006.

Kasson, J. F. Amusing the Million: Coney Island at the Turn of the Century. New York: Hill and Wang. 1978.

Kattwindel, S. Audience Participation: Essays on Inclusion in Performance. Westport, Conn.: Praeger Press, 2003.
Leitich, S., and Toth, M. PublicDJ: Music Selection in Public Spaces as Multiplayer Game. Proc. Audio Mostly 2007, 2007.

Kelman, H. C. Compliance, identification, and internalization: a theoretical and experimental approach to the study of social influence. Mimeographed. 1956.

Kennedy, D. The Spectator and the Spectacle: Audiences in Modernity and Postmodernity. Cambridge: Cambridge University Press. 2009.

Kneehigh Theatre. Available: http://www.kneehigh.co.uk/. 2012.

Kuikkaniemi, K., Laitinen, T., Turpeinen, M., Saari, T., Kosunen, I., and Ravaja, N. The influence of implicit and explicit biofeedback in first-person shooter games. Proc. of CHI'10, ACM , 859–868. 2010.

Kuki City, Saitama, Japan. Lantern Festival. http://www11.plala.or.jp/den003/index.html. 2012.

Kuwakubo, R. Duper looper, 2001. http://www.lucymackintosh.ch/oeuvre.php?id=272&artiste_id=kuwakubo.

Kyouei Design. Available: http://www.kyouei-ltd.co.jp/. 2012.

Latulipe, C., Carroll A. E., Lottridge D. Love, Hate, Arousal and Engagement: Exploring Audience Responses to Performing Arts. Proc. 2011 Annual Conference on Human Factors in Computing Systems. New York, NY, USA. 2011.

Laurel, B. Computers as Theater, Reading, MA: Addison-Wesley. 1991.

Levin, G. The table is the score: An augmented-reality interface for real-time, tangible, spectrographic performance. In Proceedings of the International Computer Music Conference, 2006.

Levin, G., and Lieberman, Z. In-situ speech visualization in real-time interactive installation and performance. In Proceedings of The 3rd International Symposium on Non-Photorealistic Animation and Rendering, pages 7-14. ACM Press, 2004.

Levin, G. Dialtone: A Telesymphony. Premier at Ars Electronica Linz Austria. Available at www.flong .com/telesymphony/. 2001.

Listening Room. Available: http://listeningroom.net/. 2012.

Liu, C., Agrawal, P., Sarkar, N. and CHen, S. Dynamic Difficulty Adjustment in Computer Games Through Real-TIme Anxiety-Based Affective Feedback. Int. J. Human-Computer Interaction. 25,6, 2009.

Liu, H. et al. Survey of Wireless Indoor Positioning Techniques and Systems, IEEE Transactions on Systems, Man, and Cybernetics, vol. 37, no. 6, pp. 1067 - 1080. Nov. 2007.

Lozano-Hemmer, R. Body Movies. Relational Architecture No. 6. http://www.lozanohemmer.com/body_movies.php.2011.

Machover, T. Brain Opera. http://park.org/Events/BrainOpera/. 1996.

Machover, T. 'Hyperinstruments: a progress report', MIT Media Lab White Paper. 1992.

Machover, T. "My Cello" in S. Turkle's "Evocative Objects: Things to Think With". MIT Press, 2007.

Marshall, M. T. Physical Interface Design for Digital Musical Instruments. PhD thesis, MCGILL UNIVERSITY, 2008.

Martin, E., Vinyals, O., Friedland, G., and Bajcsy, Ruzena. Precise Indoor Localization Using Smart Phones. In MM, 2010.

Maynes-Aminzada, D., Pausch, R., Seitz, Steve. Techniques for interactive audience participation. Forth IEEE International Conference on Multimodal Interfaces (ICMI). Pittsburgh, 2002.

Mayton, B., Dublon, G., Joliat, N., and Paradiso, J. A. Patchwerk: Multi-User Network Control of a Massive Modular Synthesizer. In proceedings of New Interfaces for Musical Expression (NIME) conference, 2012.

McAdams, S., Vines, B. , Vieillard, S., Smith, B., & Reynolds, R. Influences of large-scale form on continuous ratings in response to a contemporary piece in a live concert setting. Music Perception. 22 (2004): 297-350.

McAllister, G., Alcorn, M., and Strain, P., 2004. Interactive performance with wireless PDAs. In: Proceedings of the 2004 international computer music conference (ICMC), 1–6. 702–705. Miami, November 2004.

McNeel, R. 2010. Grasshopper - Generative Modeling with Rhino, McNeel North America, Seattle, USA. (http://www.grasshopper3d.com/).

McNeel, R. 2010. Rhinoceros - NURBS Modeling for Windows (version 4.0), McNeel North America, Seattle, WA, USA. (www.rhino3d.com/).

Microchip MRF49XA ISM Band sub-GHz RF Transceiver. http://ww1.microchip.com/downloads/en/DeviceDoc/70590C.pdf. 2011.

MidiBall. Available: http://www.jamodrum.net/performance.html

Monache, D. S., Polotti, P., Papetti, S., and Rocchesso, D. Sonically augmented found objects. In Proceedings of New Interfaces for Musical Expression (NIME) conference, 2008.

Moori. Available: http://www.bubblyfish.com/thesis/. 2012.

MUMU Player. Available: http://www.mumuplayer.com/. 2012.

Muramatsu, J. and Ackerman, M. Computing, social activity, and entertainment: A field study of a game MUD. Journal of CSCW 7, 87-122. 1998.

Muse, H. J. Flash Mobs and the Diffusion of Audience. Theater 40, no. 3: esp. 11 – 12 on pervasive spectatorship. 2010.

T. Nakano, S. Murofushi, M. Goto, and S. Mor- ishima. DanceReProducer: An automatic mashup music video generation system by reusing dance video clips on the web. In Proc. of the 8th Sound and Music Computing Conference (SMC 2011), 2011.

Neuhaus, M. The Broadcast Works and Audium. In Zeitgleich. Vienna: Triton. http://auracle.org/docs/Neuhaus_Networks.pdf. 1994.

NICO NICO DOUGA. Available: http://www.nicovideo.jp/. 2012.

Node.js. Available: http://nodejs.org/. 2012.

nowjs. Available: http://nowjs.com/. 2012.

O'Hara, Kenton, and Barry Brown. Consuming Music Together : Social and Collaborative Aspects of Music Consumption Technologies. Dordrecht: Springer, 2006.

O'Hara, K., Lipson, M., Jansen, M., Unger, A., Jeffries, H., Marcer, P. Jukola: Democratic Music CHoice in a Public Space. Proc. DIS2004. pp. 145-154. 2004.

Oh, J., Wang, G. Audience-Participation Techniques Based on Social Mobile Computing. Proc. International Computer Music Conference 2011, University of Huddersfield, UK, July 31 - August 5, 2011.

openFrameworks. Available: http://www.openframeworks.cc/. 2012.

Orth, M. Interface to architecture: integrating technology into the environment in the Brain Opera. Proceedings of the 2nd conference on Designing interactive systems: processes, practices, methods, and techniques. 1997.

OSC.php. Available: http://opensoundcontrol.org/implementation/open-sound-control-php. 2012.

Peltonen, P., Salovaara, A., Jacucci, G., Ilmonen, T., Ardito, C., Saarikko, P., Batra, V. Extending Large-Scale Event Participation with User-Created Mobile Media on a Public Display. In: MUM 2007, pp. 131–138. ACM, New York. 2007.

Processing.js. Available: http://processingjs.org/. 2012.

Prometheus. Available: http://www.prometheus-movie.com. 2012.

Reeves, S., Benford, S., O'Malley, C.,Fraser, M. Designing the spectator experience. In: Proceedings of CHI. 2005, ACM, New York, 2005.

Remote Theatrical Immersion. Available: http://opera.media.mit.edu/projects/sleep_no_more/. 2012.

Robertson, J., Quincey, D. A., Stapleford, T., and Wiggins, G. Real-Time Music Generation for a Virtual Environment. Proceedings of ECAI-98 Workshop on AI/Alife and Entertainment. 1998.

Paradiso, J., A. The Brain Opera Technology: New Instruments and Gestural Sensors for Musical Interaction and Performance. Journal of New Music Research. 28:2, 130-149. 1999.

Patten, J. Audiopad: A tag-based interface for musical performance. pages 11–16, 2002.

Picard, R. Affective Computing. MIT Press, 1997.

Picard R W and Scheirer J. The Galvactivator: a glove that senses and communicates skin conductivity, Proceedings from the 9th International Conference on Human-Computer Interaction, New Orleans. August, 2001.

Quay, D. Y. Interactive Music 3.0: Empowering People To Participate musically Inside Nightclubs. 2010

Quay, D. Y. Interactive Music 2.0: User-driven ad hoc dance clubs. 2010.

Schechner, R. Audience Participation. The Drama Review: TDR, vol. 15, No.3 (Summer, 1971), pp. 72-89.

Schechner, R. Happenings. The Tulane Drama Review, Vol. 10, No. 2. pp. 229-232. 1965.

Schmit, T. Sanitas No. 35 (1962). Available: http://www.artnotart.com/fluxus/tschmit-sanitasno.35.html.

Secret Cinema. Available: http://www.secretcinema.org. 2012.

Schafer, R. M. The Tuning of the World. New York: Knopf, 1977.

ShopBot. Available: http://www.shopbottools.com/index.htm. 2012.

Siu, Kin Wai Michael. Lanterns of the mid-autumn festival: A reflection of Hong Kong cultural change. Journal of Popular Culture, Popular Culture Center, Bowling Green State Univ., OH. 33:2. Fall 1999, 67-86.

Sleep No More. Available: http://sleepnomorenyc.com/. 2012.

Smule. Available: http://smule.com/. 2012.

SoundCloud. Available: http://soundcloud.com/. 2012.

Stone, R. M. Performance in Contemporary African Arts: A Prologue. Journal of Folklore Research, Vol. 25, No. 1-2. pp. 3-15. 1988.

Tekio. Available: http://anthonydickens.com/tekio.htm. 2012.

The Center for Bits and Atoms (CBA). Available: http://cba.mit.edu/about/index.html. 2012.

Thomas, B., Close, B., Donoghue, J., Squires, J., De Bondi, P., Morris, M., and Piekarski, W. ARQuake: An Outdoor/Indoor Augmented Reality First Person Application. Proc. 4th Int'l Symposium on Wearable Computers, pp 139-146, Atlanta, Ga, USA, Oct 2000.

Thomas, B., N. Krul, B. Close, and W. Piekarski. Usability and Playability Issues for ARQuake. in Special Session of International Workshop on Entertainment Computing. Makuhari, Japan. 2002.

Thomas, D. W. Lou Harrison's "Double Concerto for Gamelan, Violin and Cello": Juxtaposition of Individual and Cultural Expectations. Asian Music, Vol 15, No. 1. pp. 90-101. 1983.

Turner, C. Palimpsest or potential space? Finding a vocabulary for site-specific performance, New Theatre Quarterly, 20: 373-390. 2004.

Turntable.fm. Available: http://turntable.fm. 2012.

Toy Symphony. Available: http://www.toysymphony.net/. 2012.

Ulyate, R., Bianciardi, D. The Interactive Dance Club: Avoiding Chaos in a Multi Participant Environment. Computer Music Journal: Vol 26, no.3. MIT Press 2002, 40-49.

Universal Orchestra. Available: http://www.chromeweblab.com/universal-orchestra. 2012.

Van Spall, O. Out of this world: Secret Cinema takes flight. British Film Institute. Available: http://www.bfi.org.uk/news/sightsound/secret-cinema-18. 2012.

Visual.ly Wall Photo. Available: https://www.facebook.com/photo.php?fbid=464546913558172&set=a.259091624103703.74558.211314828881383&type=1. 2012.

Yoon, M. White Noise White Light. Available: http://www.mystudio.us/projects/3. 2012.

Wang, L. B. Y., Lee, H.K., Dempster, A.G. and Rizos, C. Method for Yielding a Database of Location Fingerprints in WLAN, Communications, IEE Proceedings, Vol. 152, Issue 5, October 2005, pp. 580-586.Li, B., Wang, Y., Lee, H.K., Dempster, A.G. & Rizos, C.

"Method for Yielding a Database of Location Fingerprints in WLAN", Communications, IEE Proceedings, Vol. 152, Issue 5, October 2005, pp. 580-586

Wang, G., Oh, J. Salazar S., and Hamilton, R. World Stage: A Crowdsourcing Paradigm for Social / Mobile Music. International Computer Music Conference. 2011.

Weitzner, N., Freeman, J., Garrett, S., and Chen, Y. L. massMobile: an Audience Participation Framework. In Proceedings of the New Interfaces for Musical Expression Conference (NIME 2012), Ann Arbor, Michigan.

Weinberg, G., Interconnected Musical Networks: Toward a Theoretical Framework. Computer Music Journal. No .29. pp 23-29. 2005.

Wilkie, F. Mapping the Terrain: a Survey of Site-Specific Performance in Britain. New Theatre Quarterly. 18 (2). 140-160. 2002.

Winkler, T. Audience participation and response in movement-sensing installations. In Proceedings of the International Computer Music Conference, December 2000.

Worthen, W. B. "The written troubles of the brain": *Sleep No More* and the Space of Character. Theatre Journal 64.1 (2012): 79-97. Project MUSE. Web. 19 Aug. 2012. <http://muse.jhu.edu/>.

Wright, M. and A. Freed. 1997. "Open Sound Control: A New Protocol for Communicating with Sound Synthesizers." In Proceedings of the International Computer Music Conference. International Computer Music Association, pp. 101-104.

Zukin, S. et al. From Coney Island to Las Vegas in the urban imaginary: discursive practices of growth and decline, Urban Affairs Review, 33(5), pp. 627–654. 1998.