FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

Investigating a Color Music Interaction System

in a Collaborative Music Performance

DIPLOMARBEIT

zur Erlangung des akademischen Grades

Diplom-Ingenieur

im Rahmen des Studiums

Wirtschaftsinformatik

eingereicht von

Thomas Eigner
Matrikelnummer 0525583

an der Fakultät für Informatik

der Technischen Universität Wien

Betreuung: Univ.Prof. Geraldine Fitzpatrick, Ph.D.

Mitwirkung: Dipl.-Ing. Oliver Hödl

Wien, 1. Oktober 2015

Thomas Eigner	Geraldine Fitzpatrick

FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

Investigating a Color Music Interaction System

in a Collaborative Music Performance

DIPLOMA THESIS

submitted in partial fulfillment of the requirements for the degree of

Diplom-Ingenieur

in

Business Informatics

by

Thomas Eigner
Registration Number 0525583

to the Faculty of Informatics

at the Vienna University of Technology

Advisor: Univ.Prof. Geraldine Fitzpatrick, Ph.D.

Assistance: Dipl.-Ing. Oliver Hödl

Vienna, 1st October, 2015

Thomas Eigner — Geraldine Fitzpatrick

Erklärung zur Verfassung der Arbeit

Thomas Eigner
Steinergasse 36/16/12, 1230 Wien

Hiermit erkläre ich, dass ich diese Arbeit selbständig verfasst habe, dass ich die verwendeten Quellen und Hilfsmittel vollständig angegeben habe und dass ich die Stellen der Arbeit – einschließlich Tabellen, Karten und Abbildungen –, die anderen Werken oder dem Internet im Wortlaut oder dem Sinn nach entnommen sind, auf jeden Fall unter Angabe der Quelle als Entlehnung kenntlich gemacht habe.

Wien, 1. Oktober 2015

Thomas Eigner

Danksagung

Mein großer Dank geht an Dipl.- Ing. Oliver Hödl (Diplomarbeitsassistent) für seine begeisternde Heranführung an das Thema, seine überzeugende Art mich für die Materie zu begeistern und natürlich seine unterstützende Hand während des gesamten Arbeitsprozesses.

Ebenfalls ein großes Dankeschön möchte ich an meine Diplomarbeitsbetreuerin Univ.Prof. Geraldine Fitzpatrick, Ph.D. richten, welche mir die Möglichkeit eingeräumt hat, die Arbeit an ihrem Institut zu verfassen und mich immer mit ihrem umfassenden Wissen unterstützt und den notwendigen Informationen versorgt hat.

Zu guter Letzt gilt ein ganz großes Dankeschön meinen Freunden und meiner Familie, die während der Zeit immer unterstützend für mich da waren. Ganz besonders möchte ich mich dabei bei meinem Vater und meiner Schwester bedanken. Sie haben mir ihre wertvolle Zeit geschenkt, um mir geduldig und motivierend bei meiner Diplomarbeit zur Seite zu stehen.

Acknowledgements

I wish to express my sincere gratitude to Mag. Oliver Hödl (co-supervisor) for introducing me to this exciting topic, encouraging me for taking this Thesis topic at his institute and guiding me courageous through the Thesis process.

I sincerely thank Univ. Prof. Geraldine Fitzpatrick, Ph.D. (supervisor) for her useful and anxious inputs to her best knowledge and for giving me the opportunity for writing my Master Thesis on the Institute "Human-Computer Interaction Group".

I acknowledge with thanks the kind of loving support, which I have received from my family and friends all the time. Especially I want to express my deep and sincere gratitude to my father and my sister, who offered me their valuable time and helped me encouraging and patient with my work.

Kurzfassung

Musik spielt in unserem Leben eine bedeutende Rolle und kann mittlerweile in vielen verschiedenen Varianten produziert werden.

Mit dem neuen technischen und digitalen Zeitalter entwickelten sich neue Wege der Mensch-Computer Interaktion, um digitale und interaktive Musik zu schaffen. Es gibt mittlerweile eine Vielzahl an Computer-und Softwaresystemen, die den Zugang zum kollaborativen Musikmachen unterstützen.

Das Ziel dieser Arbeit war ein Farb-Musik-Interaktionssystem zu entwickeln und adaptieren, das in einer kollaborativen Musik Performance zwischen einem Musiker an einem traditionellen Instrument und anderen musikalischen bzw. nicht musikalischen Teilnehmern mit herkömmlichen farbigen Objekten als Instrumenten zum Einsatz kommt. Genauer gesagt sollte ein passendes System-Setting für die kollaborative Musikinteraktion gefunden werden. Zusätzlich sollte der Einfluss des Systems und auftretende Verhaltensweisen der Teilnehmer mit den farbigen Objekten analysiert werden.

Der Studienablauf beinhaltete eine Testphase des Systems und der Farb-Interaktionsobjekte, sowie eine iterative Systemadaption mit einer darauf folgenden Interaktions- und Verhaltensanalyse.

Neben anderen Details brachte die Arbeit Ergebnisse über die unterschiedliche Anwendung der Farb-Interaktionsobjekte und verschiedene Verhaltensmuster während der Musikinteraktion. Ein weiterer Faktor waren die Auswirkungen des Systems und der Objekte auf die Teilnehmer und umgekehrt. Es gehen Vorschläge aus der Arbeit hervor, welche Farb-Objekt-System Einstellungen relevant sein können und was bei der Anwendung dieses Systems für eine kollaborative Musik Performance beachtet werden muss.

Abstract

Music plays a big role in our everyday social life and there are various ways of producing it. The technical era brought up many new possibilities of Human-Computer-Interaction for creating digital interactive music. There are lots of computer and software tools for generating sounds and designing systems for collaborative music-making.

The aims of this study were to adapt and install a *color-music interaction system* for a collaborative music performance with a musician on a conventional music instrument and different attending musical trained and non-musically trained persons with *colored everyday objects*. A specific goal was to find out a useful tool-system setting for the collaborative music performance. After this, the impact of the system and occurring behavior of the participants with the colored objects were analyzed.

The whole study process involved a testing phase of the system and the colored interaction objects, an iterative system adaptation, and a more detailed interaction behavior analysis.

Among other things the results show some usage differences between the participants with color interaction objects and according to this some different collaborative behaviors were recognized. A considered factor was the implication of the system with the color objects on the behavior of the attending people through the collaborative music performance and vice versa. Recommendations will be made which tool-system setting can be useful and what has to be minded for adapting and using a color music interaction system in a collaborative music performance.

Contents

CHAPTER 1

Introduction

Many people make or consume music anywhere at any time. It has the power to touch us in different emotional ways and has a big social-psychological impact on us. The power of music brings us together in several ways (live music events, home-music-listening, *collaborative music-making*, jamming, parties, etc.). The musical diversity is inexhaustible and brings up new styles and creations every day.

Driven by the computer technology progress new possibilities for music experiences occur and offer new ways of music creation and collaboration. In the mobile phone and Internet era, there are nearly unlimited opportunities for new distribution systems to hear, make and share music. The technical evolution brought up new chances for non-musicians to collaborate with musicians and take part in music creation. Human-Computer interaction techniques also offer new varieties of digital interactive music-making (*digital collaborative music interaction systems*). Out of literature sources some *digital music interaction systems* have been found out that are somehow stronger related to the topic of the work and listed in following loose categories (cf. chapter 2.2):

- Interactive and tangible tabletop systems: Describes sound creation through tabletops (e.g. with physically attached control objects) (e.g."ReacTable" , cf. chapter 2.2.1).
- Mobile music systems: Describes interactive music-making with mobile phones or mobile devices (e.g. "echobo" cf. 2.2.2, 2.1").
- Interactive Color and Motion-Sound-Detection Systems: Interactive music-making over motion/color detection, where movement recognition over a computer and a

camera creates sound.

  - Color- and Motion-Sound-Detection Systems developed with *MaxMSP* [1] (e.g. "Lazy Guy", "EAMIR" cf. chapter 2.2.3)
  - Other Motion-Sound-Detection Systems (e.g.: "Theremin", cf. figure 2.2)
- Other interactive Participation Techniques and systems (exist but not examined) (cf. chapter 2.2.4)

The focus of this work will be laid on the investigation of a "Color and Motion-Sound-Detection System". For the sake of completeness the other bullet list topics give a short overview to related fields of the thesis and their theoretical background will be mentioned in *"State of the Art"* (cf. chapter 2). A mutual fact of the quoted categories may be the appearance and possibility of "digital interactive and collaborative music-making and jamming". The relevance of *collaboration* ("Jamming") in music as a social, connective and experimental factor as well as the aspects and possibilities of digital music participation are mentioned repeatedly in literature (cf. chapter 2.1, 2.2.5).

The use of *color* as a good differentiator between objects and its recognizability for tracking systems are based on the work of Vincent Manzo [Manzo, 2014, Manzo, 2011] and findings of other authors [Pradalier and Jud,]. Also, color plays a big role in music-visual representation and the influences of music and color intensify each other in audio-visual settings [Jewanski and Sidler, 2006, Haverkamp, 2009, Hantrakul and Kaczmarek, 2014].

Vincent Manzo did research in the field of color music interaction systems with MaxMSP [Manzo, 2014, Manzo and Kuhn, 2015], amongst them a color detection system called "Lazy Guy" [2], which works with laser generated colors to produce sounds on a computer. For another related project ("EAMIR"), Manzo uses the same systematic technique to let non-musical people get in touch with learning and experiencing the creation of music [Manzo, 2011].
In a similar non-collaborative installation, Kranidiotis uses color tubes to produce and manipulate sounds [Kranidiotis, 2014]. **Motivation** Based on this knowledge, there could be an opportunity to get random colored objects of everyday life into play to create music and sounds. With the aid of color detection and mapping systems (Manzo 2011, 2014) it is possible to map different sound samples and real instrument sounds to such objects. This possibility can offer easy access to music playing without the need of real instruments (cheap and easy to acquire). A new way for collaborative music-making with a CMIS can be opened up that offers versatile access to music playing with different

[1] Music production, developing and creation software `https://cycling74.com/products/max/`
[2] (`http://www.vjmanzo.com/clients/vincemanzo/software.htm`

CSCO. To draw a bow to the classical form of playing music, this system will be used in a collaborative music with a musician on a classical instrument. In this setting, the classical musician could take the supportive part and guide musically through the performance with his musical knowledge. Additional impulse and motivation for choosing this topic came out of literature research. Also, some evidence based facts and justifications were perceived:

- The importance of **music collaboration** and **participation** for human societies in history and now (cf. chapter 2.1.1).
- A close relation between **color** and **music** in a psychological and technical sense (cf. chapters 2.1.2, 2.2.3).
- **MaxMSP** as a suitable computer software environment for developing and adaptation of **color-motion detection systems** (cf. chapter 2.2.3).
- Usability of digital music systems for **collaborative music-making** (cf. chapter 2.2.5).
- Easy way to music-making for non-musicians, children and people who are less inclined to experience music for themselves by means of **digital music systems and instruments** like enjoying and learning music. ([Manzo, 2014]).

Aim With these challenges, the aim of the research was to find a useful system- and color-object setting for performing interactive collaborative music. A *CMIS* and CSCOs should help to let any participants (e.g. musicians, non-musicians) take part in a collaborative music performance with a supporting musician on a classical instrument. Common colored objects of everyday life that are suitable for sound creation with the system could be used as CSCOs. It has to be considered that these objects must have the right requirements to suit the technical guidances and the use of the CMIS (the right color, form and size for object recognition over webcam and good handling and controlling properties). In several free music performances, the music-collaborative suitability should be tested. The participants' behaviors and their feedback should help to draw conclusions about the implementation solution and the performance. With recorded data of the sessions, the study could probably supply input for further works in system and collaboration music interaction design for *CMIS* with *CSCOs*.

The above leads to following **research questions**:

- **RQ1**: Which setting requirements for the *CMIS* with *CSCOs* are needed and recommended for collaborative music-making between participants and a musician on a classic instrument?

- **RQ1a**: Which interplay requirements have to be minded during the definition and implementation of the *CMIS* with the *CSCOs*?

- **RQ2**: Which different interaction behaviors and expressions are occurring during the music performance and which impressions do the participants have?
  - **RQ2a**: What are the distinctive differences between musicians and non-musicians?
  - **RQ2b**: In specific which mutual or collaborative behaviors appear between the participants and the piano player?
  - RQ2c: Which impact do the CSCOs have on the interaction whether someone is a musician or not?
  - **RQ2d**: Which impressions do the participants have about the interplay of the *CMIS* with *CSCOs* and the piano player?

CHAPTER 2

State of the Art, Theoretical Background, and Related Work

2.1 Historical and Psychological Background

2.1.1 Music Participation and Collaboration

Referring to Turino (2008) anthropologists found out, that people always participated in music, dance and festivals to express their cultural practices for their collective identities. Through *music collaboration* (dancing and singing together) people experience the feeling of oneness and togetherness. Several ancient groups of people all over the world (e.g. Peru, Zimbabwe, Cajun, and Louisiana) were socialized with participating and collaborating in their own music. In his work Turino (2008) says that the special form of music participation and interaction is the open form of individual contributions in a specific moment[Turino, 2008, p.37].

Participatory music differs from presentational music in the following attributes [Turino, 2008]:

- Short, open, redundantly repeated forms, highly repetitive
- “Feathered” beginnings and endings
- Intensive variation with less individual virtuosity
- Constancy of rhythm/meter/groove

When observing a live music performance, an audience member is inundated with a wealth of aural, visual, spatial and movement stimuli [Broughton and Stevens, 2009].

Lamont found three positive effects of live music experience [Lamont, 2009]:

- Firstly, music has potential to fulfill the pursuit of pleasure, because it stimulates the brain regions for reward/motivation, emotion, and arousal. Many listeners, music lovers and concert attendees feel something as enjoyment in listening to music.
- Music has also a big influence on engagement and the sense of community. Some attributes that are affected are physical reactions, perception, cognition, feeling/emotion, existential/transcendental elements, and personal/social elements.
- Many people also have the feeling of a bigger "meaning" in music. They identify themselves with a music genre or belong to a particular music culture.

Improvisational Interaction and the Theory of "Jamming" Together

In the case of music improvisation, there is a new level of excitement and engagement happening. The dynamic of shared sound creation offers a way of error-free interactive music experience between the audience and the artist. There are no more limitations and boundaries and a new level of song interpretation. This aspect can give the crowd members a fearless, positive and exciting feeling of responsibility and prominence. In a collective purpose, there are more possibilities that new song creations can occur through every individual input and creativity. The unpredictable behavior of this system makes the collaborative performance more versatile and exciting [Borgo, 2006].

As Strogatz (2004) stated:

> "'For reasons we don't yet understand, the tendency to synchronize is one of the most pervasive drives in the universe, extending from atoms to animals, from people to planets [Strogatz and Goldenfeld, 2004]."'

Improvisation was and is a big factor in jazz music, where many musical influence factors and creativity take place. The canonical example of an improvising group was mentioned in the jazz ensemble [Macdonald and Wilson, 2006]. All the way from a small group of music players to a big band improvisation takes a big part in playing jazz music [Berliner, 1994]. But it is also a factor in many other music styles like jam-influenced rock and non-musical performances of theater groups [Tuedio, 2006, Sawyer and DeZutter, 2009]. The approach to improvised music playing and jamming is very versatile. The attending participates can be very skillful or less experienced and there is a high standard of music experience and training required for improvisational group music-making at a high level.

The form of improvisational music can be constrained in an open form, pre-scripted or unscripted or contain both elements. The jamming musician is trying to fit several patterns or sounds of the other musicians around. He has to play, listen, act and react and tries to find the balance between improvised playing and the need to fit musically to other musicians.
Given that, every musician brings his/her own skill-set of playing experience and access to the jamming session, the creative output is very versatile and not a singular vision of any individual, but the sum of every individual contribution.

> *In collaborative improvisation, a creative product emerges that could not even in theory be created by an individual [Sawyer, 2007].*

Musicians describe the term of improvising together with the synonym "dialogue" or "conversation" [Monson, 1996]. Important for them were to "say something" or express something meaningful through their music. Another term, which was mentioned in the context of "jamming" and playing together, is the word "Grooving" [Doffman, 2009].
It also describes a specific beat or rhythmic element, the practice of playing and also refers to peak moments in a performance [Hallam et al.,].
This jamming experience varies in the musicians' opinion and feeling. One time they feel "in the groove" and the other time they may be flat. If the "jamming" or "Grooving" works, it can create a feeling of satisfaction and connection with others that not many activities can do [Mazzola, 2008].
For many musicians, the sensation of "being in the groove" is very difficult to explain and spreads among many different musical traditions [Lamont, 2009].

Also, a thing called “flow” [] is being mentioned to explain a “peak experience” in jamming and instrumental music-making [Csikszentmihalyi, 1990, Bouwer et al., 2013, Swift et al., 2011, Holland, 2013].

2.1.2 Color and Music

Theoretical Background

In his work Dr. Haverkamp (2002) talks about the strong connection between acoustic and visual perception. He appoints the theory of these two strongly coupled senses to cognitive psychological sources. The result of research was really the mentioned link between the hearing and seeing sense in perceptual psychology [Haverkamp, 2002, Schönhammer, 2013].
Dr. Haverkamp also brought up the term of “Synesthesia”, which is a neurological phenomenon in which stimulation of one sensory or cognitive pathway leads automatic, involuntary experiences in a second sensory or cognitive pathway. So the additional aspect of visual impulses like colors in music can lead to an increased hearing experience and sensation. It can also be called “Chromesthesia” which is a special form of “Synesthesia” in the association of color and sound. This phenomenon and Synesthesia in art (“Visual music”) is mentioned in several books and papers. [Brougher and Zilczer, 2005, Wipperfürth, 2011].
Another work of Dr. Haverkamp (2009) describes the use of the effect of “Synesthesia” in design development for multiple senses, where he also described some projects with color and sound (Music Theater, Musical improvisation), which can be related to an earlier chapter of Interactive Music Participation with technical device [Haverkamp, 2009].

Historical Background

Also in old literature the importance of the combination of color with music was mentioned. The famous philosopher Aristoteles was driven to invent a colored scale which was ordered to musical intervals and consonants. Based on this idea in the early 18th century Sir Isaac Newton (1643 - 1727) was dropping sunlight through a prism in a dark room. The resulting color spectrum of light was projected on a flat surface, where he measured the color areas. He assigned the results to the seven notes of the musical scale. Later in the 18th century L. B. Castel reinvented the system where every color fit a chromatically tone based on Isaac Newton’s invention. The color-music relation and system was re-interpreted many times through history. [Dobretzberger, 2014, Haverkamp, 2002].

2.2 Digital Music Interaction and Participation Systems

Through the last years, there have been many projects including interactive music game design, music installations and interactive audience participation in different music contexts with different technical tools.

2.2.1 Interactive Tangible Tabletop Systems

This section mentions *interactive* and *collaborative music making* with *tangible tabletop devices*.

Related to Xambo (2013) the well known *"ReacTable"* is described and tested in performances [Xambó et al., 2013]. The usage as a *collaborative experimental music instrument* is explained in 2.2.5.

Jorda (2007) used the *"ReacTable"* to explore the synergy between tabletop devices and live music performances [Jordà et al., 2007].

Xambo (2011) also explored the use of a multi-touch tabletop system that supports *collaborative* workflows and democratic principles [Xambó et al., 2011a].

The JamTable is a tabletop device which was tested in a collaboration between novice and experienced musicians [Esteves et al., 2013].

2.2.2 Interactive Social- and Mobile Music- Making

A big field of interactive audience participation is based on social computing, the web, and mobile devices.

(a) echobo

(b) mopho

Figure 2.1: Mobile Music-Making

[Oh and Wang, 2011] explains some audience-participation techniques based on social mobile computing and gives input for collaborative music performances.
This work can be compared to the research of McAllister et. al (2004), in which wireless Personal Digital Assistants (PDAs) were used for an interactive music performance

[McAllister et al., 2004]. Using the “web” as a platform for live interactive music was described by Young (2001) [Young, 2001].

A concrete mobile music performance concept was demonstrated by Lee and Freeman (2013). It combines mobility, interactivity, social interaction and mobile composition and follows the trend to Mobile Phone Orchestra. This mobile music instrument, called “echobo” was also mentioned in another paper were different other mobile music instruments and systems like “moPho” were mentioned [Faculty et al., 2012, Lee and Freeman, 2013].
In a similar work Hindle (2013) designed, created and tested a multi-user performance-system based on mobile devices and a web server [Hindle, 2013].
Corresponding to that Weitzner (2012) developed a framework for mobile music-making [Weitzner, 2012].
For mobile phones as a platform for interactive music performances Essl and Rohs (2009) gave a brief look over design spaces and a mapping framework. It is defined in which way the position, velocity and acceleration of the phone take influence on other attributes and musical output [Essl and Rohs, 2009].
Another paper shows dynamic social interaction and group behavior in the context of collective mobile music-making [Tahiroglu, 2009].

2.2.3 Interactive Color- and Motion-Sound Detection Systems

Gesture controlled electronic instruments

In the book *"New Digital Musical Instruments: Control and Interaction Beyond the Keyboard"* Lazzarini (2008) used and explained Digital Music Instruments (DMIs) in form of comparison to existing classic, acoustic instruments. It shows that the new technical era offers a great variety of DMIs and how the mapping and acquisition of musical gestures influence the development of gestural controllers and systems [Lazzarini, 2008].

A well-known gesture controlled instrument is called *Theremin*. It produces sound based on the position of the player’s hands. One hand controls the oscillator frequency and the other hand controls the amplitude of the electrical signal between the metal antennas:

Figure 2.2: Theremin[1]

Interactive Color-Music Systems

“Color Tubes” is an interactive installation created by Yiannos Kranidiotis (2014) and presented at the ICMC (International Computer Music Association) 2014 in Athens. The idea is that the watcher and visitor of the tool can create music and sound trough colored tubes. The music creation is depending on several parameters like the color combination of the tube and the position or the speed of the bi-color tube-cylinder [Kranidiotis, 2014]. In this context, the papers of Macedo (2010) and Collopy (2009) show the correspondence between color and sound [Macedo, 2010, Collopy, 2009].

Interactive Color-Music Systems in MaxMSP

In a case study with children with ASD, a motion-sound interaction system was tested for a therapeutic purpose [Manzo, 2014].

Besides other interactive music systems in *MaxMSP* [2] Manzo designed a “color-music motion tracking system” called *Lazy Guy*[3]. This system works with different laser generated colors to produce various sounds on a computer through a webcam

Manzo’s approaches should also give young novice or non-musicians and children the opportunity for easy music learning, making and understanding through digital music interaction systems ("EAMIR"). [Manzo, 2011, Manzo and Kuhn, 2015].

[1] Source:https://commons.wikimedia.org/wiki/File:Barbara_Buchholz_playing_TVox.jpg

[2] Music production, developing and creation software: https://cycling74.com/products/max/

[3] http://www.vjmanzo.com/clients/vincemanzo/software.htm

2.2.4 Other Interactive Participation Techniques and Systems

Dimensionality, appropriation, style and constraint in Digital Musical Instrument Design is described in [Zappi and Mcpherson, 2014] [Gurevich et al., 2010] In a case study ten musicians are tested to play with an easy-use one button wooden instrument for their exposure in a live setting and private sessions (interaction with the instrument, the style of behavior, the impression of the instrument, rehearsal experience,..).

In several works key techniques and concepts for interactive audience participation were mentioned [Benford, 2010, Maynes-Aminzade et al., 2002].

From the basic theoretical point of view, the key concepts of theatrical and musical performances and the potential support of *"Computer Supported Cooperative Work"* were shown in another work [Benford, 2010].

More detailed Maynes-Aminzade et al. (2002) illustrates practical the interaction technique of audiences body movement to control graphs on a screen [Maynes-Aminzade et al., 2002]. In a theoretical way, Hsu and Soenick (2009) shows methodologies, frameworks, questionnaires to evaluate HCI (Human-computer interaction) music systems [Hsu and Sosnick, 2009]. Kaiser et al. (2010) investigate the possibility of improved interaction between an artist and the audience in the context of the dance club culture through a collaborative visual creation [Kaiser et al., 2010].
Also, the work of Bryan (2011) takes place in the DJ scene. He illustrates the interactive music performance between two turntables and a DJ desk and shows in an example the possibility of “Air scratching” with the mobile phone without a physically attached record [Bryan and Wang, 2011].

Xambo et al. (2011) evaluate the problems of collaborative music interaction and relates to the knowledge of design patterns in real-time music activities [Xambó et al., 2011b]. The paper of describes the use of physiological indicators of emotion as a means for performer and audience to interact with a computer music composition. Through kinematic and physiological sensors, the gestures of the performer and the emotions were recorded and interpreted during the music performance [Knapp, 2011].

[Deweppe et al., 2009] Collaboration and teamwork in an interactive music game was experimented and evaluated by Deweppe et al. (2009). Smith and Garnett (2012) define an expert system that works on human-computer interaction through music [Smith and Garnett, 2012].

Interactivity, collaboration, and teamwork seem important to draw the bow to the other literature and to the context of the Master Thesis.

Hansen and Andersen (2012) developed a little interactive music interaction game with *MaxMSP* on two tablets to play fluency. The experiment was documented and evaluated in an experimental study with participants that cooperate with each other and mutual actions were evaluated. Hansen (2011) also evaluated such a system in a different context of novice collaboration in solo accompaniment improvisation [Hansen and Andersen, 2012, Hansen et al., 2011].

2.2.5 Interactive Digital Music Collaboration, Improvisation and "Jamming"

The "Viscoteque app", an easy-use music application for mobile phones, was designed for real-time music interaction. In several case studies, the participants were brought together for jamming sessions to explore the effect of the digital music instrument and the experience of collaborative improvisational interactive music-making [Holland, 2013, Swift et al., 2011].

[Xambó et al., 2013] In a big project called "Let's Jam the Reactable" peer learning during musical improvisation with a tabletop tangible interface explored the behaviors of many music participants with a tangible tabletop instrument. In several sessions investigations and explorations about human-computer interaction were made:

- Interface characteristics: How does the digital instrument influences human behavior over time?
- Musical improvisation: How does the digital instrument improvisation brings new challenges?
- Social factors: the nature of collaboration and group learning

Another work (Weinberg, 2009) describes the collaboration and jamming between human and robotic musicians. The virtual marimba player analyzes the audio input and melodic information of the human player and responds by its own playing [Weinberg et al., 2009].

The paper of Tahiroglu (2009) presents the plan of action for researching and investigating social interaction in a group improvisation and reflecting the results in its implementation.

> *"The design of an interactive performance system enables audience participation in an improvisational mobile music performance. The goal of*

> *the study is to understand more about social behavior in collective mobile music-making through audience participants' gestures in the moment of playing."*[Tahiroglu, 2009]

In the context of digital music collaboration and improvised music making the work of Hansen (2012) shows the concept and design for novice collaboration in solo and accompaniment improvisation. The evaluation was based on analyzing the produced sound during the sessions and an additional video analyzes [Hansen and Andersen, 2012].

Also, the experience of an interactive participation of audience with a real musician in a live performance was conducted and evaluated [Mazzanti et al.,].

CHAPTER 3

Methodological Approach and Methods

3.1 Defining Overall Study Process

The usage of the CMIS with CSCOs will be investigated in a collaborative music performance. Therefore, several interaction sessions have to be carried out with a real musician on a classical instrument and varying participants. The aim is to test the system during these performances on functionality and to get feedback of the attending persons on their experience. An important factor is the combination of system, usability and behavior test. Also, some apparently collaborative moments (e.g. mutual - together) between the musician and the participants will be considered for finding conclusions to the thesis research questions. The participants should instantly use the CMIS with particular CSCOs in the music performance without training. This can help to get a feeling if the system is easy to use and offers easy access to music making.

3.1.1 Components of a Study Session Setup

These components are relevant for the implementation and execution of the performance and the recording of the session for later analysis.

1. *Participant* – musician or non-musician uses CSCO (2) with CMIS (5-6) and collaborates with piano player (4) in a music performance

2. *CSCOs* – (everyday, common) colored sound controlling objects for the participant to interact with and to control the sound
3. *Piano* – sends midi data to computer (6)
4. *Piano player* – accompany participant in his/her music interaction with music improvisation on the piano
5. *Webcam(CMIS)* – collects movement and color data of CSCO and sends it to the laptop
6. *Laptop(CMIS)* – collects and processes interaction data (webcam, MIDI data) and produces according sounds
7. *2 Sound boxes* – output of sound

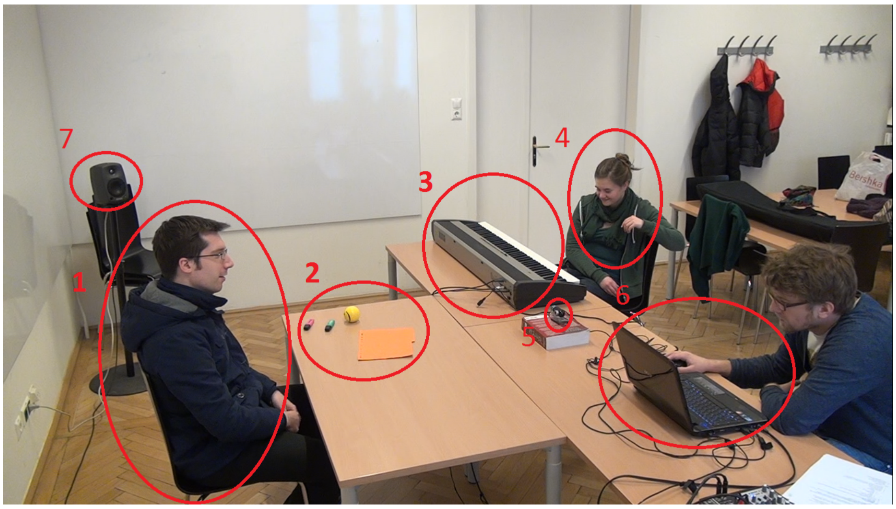


Figure 3.1: Study Session Setup

3.2 Process Operations and Components

The whole study process will be carried out in several repetitions with intermediate adjustments until the configuration is suitable to bring usable results (pilot studies and one main study).

Process operation phases

- Defining prototype for CMIS (cf. chapter 3.4.1)
  This process step is needed to find and implement a software solution patch.
- Defining set of CSCOs in usability tests with CMIS (cf. chapter 3.4.2)
  Testing the suitability, application and handling of several common colored sound

controlling objects with the CMIS.

- Recruiting Piano player (cf. chapter 3.4.4)
- Iterative study process (cf. chapter 3.4.5):
  - Recruiting participants for several performance sessions
  - Defining sound setting for the performances
  - For each session with the participants:
    - carry out the music session (with introductions and explanations)
    - questionnaire for the participant
  - if necessary adapt and re-implement design in iterative stages
- Evaluation of questionnaires
- Evaluation of video data
- Analysis of interaction behavior

Component List

This list should be read like an inventory list of the used elements during the iterative study process. Settings for the following deployed components were observed and possibly adapted:

- Hardware
  - *Piano* - Music instrument the classical musician used during the interaction.
  - *Camera* - Records performance for later video analysis and evaluation.
  - *Sound boxes* - Output of collaborative performed sound
  - *CSCO list* - Common colored sound controlling objects can be used by participants as instrumental objects with different sounds in interplay with the CMIS. Sounds are created through movement of the objects in front of the webcam, which are processed in a software on a computer.
- Software
  - *Sound Mapping* - Sound attribution of CSCOs adjusted through CMIS (computer with MaxMSP and webcam).
  - *MIDI record* - Records sound input of the performance for a possible music analysis in MaxMSP.
  - *Screen Recorder* - Computer software program records participants play on webcam for later video and behavior analysis.
  - *Drumsound list* - Drumsound selection for participants' choice in MaxMSP as background beat for the music performance. Important for a better musical feeling and support for the participants playing rhythm.

- Other matters
  - *Questionnaires* - Questions for later analysis of participants feedback.
  - *Instructions/Performance* - Information for the participants about the content and process of the interaction. Includes also a specific length (duration) of the music performance between the participant and the piano player.

This list is also a map for the requirements and items, which were needed for the right setting and environment for the music interaction study. According to this adjustments are to find in the particular study design setting (cf. chapters 3.4.5.1, 3.4.5.2, 3.4.5.4). Furthermore, the corrections and adaptations can show the way of finding the right setting and emphasize more important components.

3.3 Software for Implementation and Evaluation

Depending on different methods and process stages different software programs were taken for assistance:

- System prototype implementation: MaxMSP [Manzo and Kuhn, 2015]

object for the implementation of the CMIS prototype. Contains important features for the communication with the CSCSo and processing of the sounds.

- Video data analysis: *Kinovea* [1], *Observer XT* [2], MS Excel [3]

The Kinovea software provides features for time framing and clocking of video data. MS Excel serves as a table calculation program to manage the different data sets from the performances in table form.

- Behavior analysis: Observer XT

With the "Observer XT" software, interaction behaviors of the participants during the music performance can be coded and evaluated. It helps to find similarities or differences between the participants' interactions.

- Questionnaire analysis: *QDA data miner*[4]

This qualitative data analysis software object supports the evaluation of the questionnaire and provides useful methods to sum up answer sets and filter by keywords and content.

[1] http://www.kinovea.org/
[2] http://www.noldus.com/office/de/observer-xt-an
[3] https://products.office.com/de-de/excel
[4] http://provalisresearch.com/products/qualitative-data-analysis-software/

3.4 Implementation

3.4.1 Defining Prototype for the CMIS

The goal was to develop or find a system, which combines color recognition and interpretation (color and movement from video inputs over a webcam) to develop and create sound through the input data (“Sound mapping”[Françoise, 2013]) on a computer. Based on similar works and attempts an appropriate approach would be an interactive system, which could be implemented, installed and used easily for interaction studies (Compare with *"EAMIR" "Lazy Guy"*[Manzo, 2011, Manzo, 2014].

The participants should be able to interact easily with the system in practice without huge technical knowledge and effort (cf. chapter 3.4.3). Besides from a usability requirement, this intention can give both non-musical and musical people easy access to music making.

According to literature *MaxMSP*[5] combines suitable characteristics and options (sound processing through video input) for developing a CMIS. During the testing phase some other systems like "Kinect for windows" [6] and tracking ideas of the "‘computer vision lab"’ [7] were dropped cause of complexity, effort and cost reasons.

Lastly, MaxMSP was chosen as an implementation software and a developing platform for the CMIS prototype.

3.4.1.1 Implementation and Usage of Prototype in MaxMSP

The following steps had to be worked out to get an operative prototype for the CMIS:

1. Getting to know MaxMSP functions and tutorials about "Color tracking"
2. Implementation and Customization of CMIS prototype core elements with the help of MaxMSP tutorials and forum entries
    - **Color Object Tracking**: Defining of a traceable color object over a webcam by clicking on the according color on an Interaction Window in MaxMSP. The object will be allocated to the system with its color so that it can be tracked down in its movement and position on the webcam screen (interaction window area)(cf. figure A.2). Every attached colored object can be allocated to a separate tracker window (cf. figure A.1). This function was very important for defining the right CSCOs (Color Sound Objects) for the studies

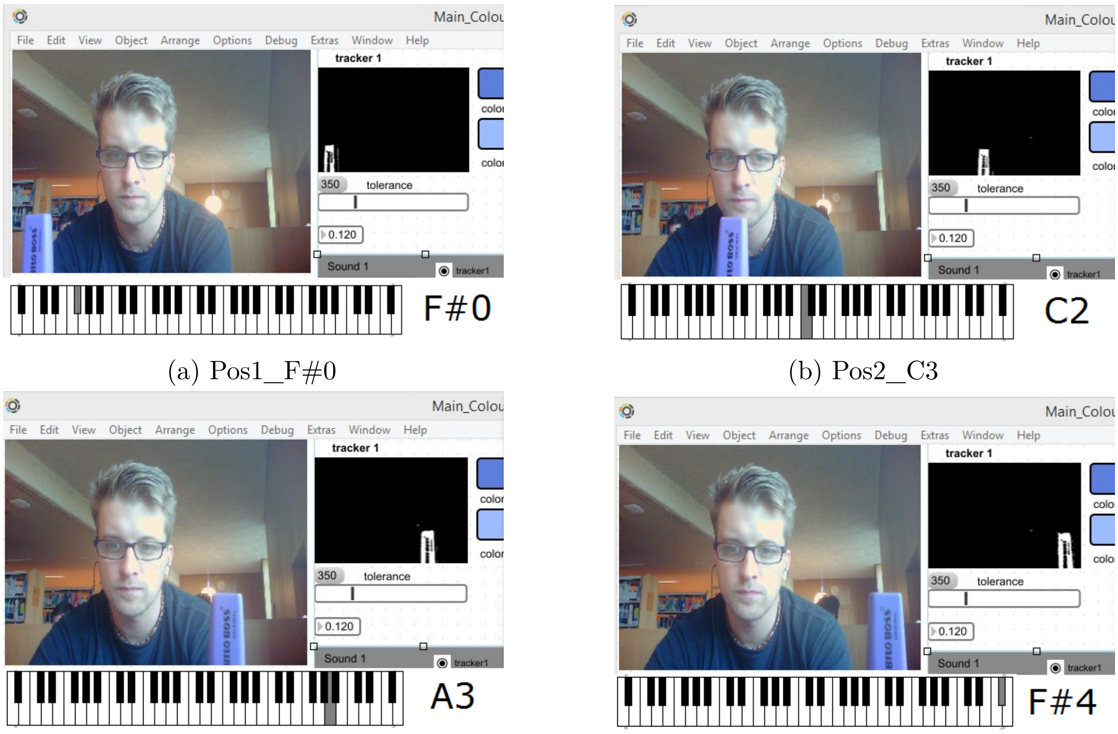
[5] `https://cycling74.com/products/max/`
[6] `https://www.microsoft.com/en-us/kinectforwindows/`
[7] `https://www.caa.tuwien.ac.at/cvl/`

(cf. chapter 3.4.2). At the beginning of every study, the colored objects were allocated by its color and communicated with the system. For the recognition, the object must have a clear and nearly shining color.

- **Sound Mapping**: Pre-defined or loaded sound files can be attached to every CSCO in MaxMSP. Therefore, every CSCO has its own separate "color-to-sound-window" ("Tracker Window") where the sounds can be mapped individual and independent to a particular CSCO in individual sound control patches ("Sub-Windows").
- **Midi Sampler**: (cf. chapters A.1.5 and A.1.6) This section was responsible for the exact correlation of the sound files and Midi Sounds to the particular CSCO and its movement on the webcam. Therefore, some accurate adjustments of note changes can be made. According to the recognized interaction field of the participants, in MaxMSP the movement had to be separated in several sections, which then were related to different notes. For example about one-meter interaction space from left to right (vertical or x-Axis of webcam range), ten notes are defined in ten different sections. Which means every note has the same hitting range of about ten centimeters. In figure 3.2 we can see an example for a scope to 19 consistent note steps and which note will be played according to the position of the color sound controlling object (marker). Depending on the size, the color of the object and the distance to the camera the notes are easier or more difficult to hit.
  Among others, this software part was changed and adapted during the iterative study process.
- **Midi Record**: This function records the different played notes and sounds into a Midi File for a possible further music analysis (cf. chapter A.1.7).

3. **Loading sound packages/Midi Files for Sound Mapping:** external sound samples or internal midi sounds for individual sound mapping to each one of the CSCOs.
4. **Customizing of Tracker Sound Control** (sound settings): fine tuning of notes and sounds (e.g.volume, pitch, effects, length of note)
5. **Initializing Drumbeats:** load external drum beat samples into MaxMSP. Selectable as background beat for the music interaction by the participants.

A more detailed description about the prototype functions can be found in the Appendix Section A.1.



(a) Pos1_F#0 (b) Pos2_C3

(c) Pos3_A3 (d) Pos4_F#4

Figure 3.2: Object Position to Play Note

3.4.2 Defining Set of CSCO

Through system requirements and the approach of **easy access** to music making with common colored objects (cf. chapter 1 *Aim*) following requirements for pre-selection were made up:

- *Form* - The object should be traceable and the form should match with the system requirements ⟶ Not too big (shouldn't cover too much space of webcam interaction window (*Main Window* cf. figure A.1 in chapter A.1.2). Not too small (should be easy to recognize by the webcam interaction window *Main Window*)
- *Handy* – For controlling and handling matters the object should be easy to hold and easy to move around (e.g. geometrical haptic)
- *Common* – The object should be known well and easy and cheap to acquire (everyday object). So objects can be tested, that somebody may have by hand.
- *Intensive color* – Because of technical requirements the color of the object should be easily recognizable by the system and webcam and should have a high contrast to the environment.

- *Diversity*– The object should have a good recall value and differ by color and perhaps by form. This condition could help participants during the music performance with easier object selection and distinction.

With these pre-conditions, a short list of usable objects was made up for testing which were mainly easy to acquire, very common and someone can have easy by hand. Additionally this can be seen as one part of the answer to research question

- **Interaction test with t-shirts** A system test with colored t-shirts brought an unsatisfying result. The problem was the contrast of color and structure shadows of the material on the object that makes color recognition and tracking very difficult. So it has been concluded that objects with a very unstable surface may are not suitable for the interaction.
- **Interaction test with carton** Through its big and shapeable surface paper is a good object for our purpose and the case study. The behavior and the applicability were also tested forehand with the system.
- **Interaction test with markers** As a very common, well-known and handy writing object some colored markers were tested for usability with the system. The color recognition and handling were satisfying. Because of its shape and form it was useful with the system and can be taken for the study process.
- **Interaction test with ball** In some basic MaxMSP color tracking videos shown on youtube[8] people were using balls as interaction objects. Also, some other videos have shown good object recognition results with balls trough webcams. In some tests the handling of the object seemed satisfying enough to use it for the case studies.
  As an example for every other test figure 3.3 shows how the ball and every other object was tested. With some calibrations of the color (cf. chapter A.3) in MaxMSP, the object should be recognized everywhere in the reach of the webcam in Field 1. Field 2 shows where the object is tracked and only the object should be displayed with the white shadow of his surface. After that, the controlling of the sounds should be tested like it was explained in figure 3.2. It was necessary that every pre-defined note has been able to hit with the object.

A little restriction for the selection of usable CSCOs was that the webcam and the system couldn't separate between fundamental colors and their combinations (e.g.: blue and violet). As a result, some colored objects would disturb each other and the sounds would

[8] `https://www.youtube.com/watch?v=ZveY_8fqh18`

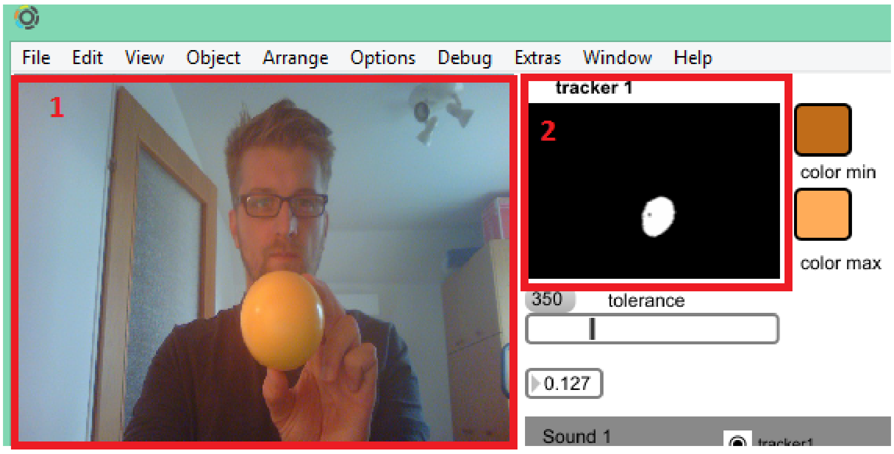


Figure 3.3: Interaction Test with Ball

overlap. This was the reason for excluding similarly colored objects. For example, a light red object is very similar to an orange object or dark blue is very similar to violet and so on. This means that one object may trigger a sound of another object and vice versa.

The selection and defining of the CSCOs brought usable results for following objects:

Figure 3.4: Picture of CSCOs

Yellow Ball
Pink Marker
Green Marker
Orange Carton

Table 3.1: CSCOs List

As mentioned the choice of color was partly restricted by system conditions. Based on that, some tests showed good results and no color overlaps among yellow, pink, green and orange. The correlation between colors and objects was freely chosen and weren't relevant for the further study objectives.

Two objects of the same kind (pink marker, green marker) were taken for the study to test if different colors are important for selecting a CSCO.

3.4.3 Defining Study Design

To up the collaboration environment some necessary points have to be considered in the development of the case study.

- *Musical variety* – the participants can follow their own style and are able to choose between different instruments *(interaction objects)* with different sound mappings. They should have the freedom to choose their own drumbeat to find their own rhythm and beat (slower-faster) [Xambó et al., 2013]
- *Freedom/No boundaries* – The expression and use of the interaction objects should be free. There is also the possibility to hold them in different ways and combine them as favored.
- *Easy* – The interaction should be easy to learn and understand by given first hand instructions about the setting and system configuration. The setting should help the participants to understand the musical features fast and to let them express free musical in the system constraints.
- *Support/Assistance* - *The piano player* should be the collaborative counterpart in the interaction. Through his musical knowledge, the musician can support the interaction and give the participant some sort of feeling for music. The piano can act as a helping hand for creating musical *rhythm and flow*.

The free and improvisational approach of the music performance is relevant to create a "jamming" environment and for testing the different behaviors. Maybe it is also easier for the participants to use the system and test the usability if there are no boundaries and a very free use for the CMIS with the CSCSOs. This easy access should then help to get useful data for the discussion and conclusion of the research questions. During the iterative study process, “test” participants should attend in the collaborative performance to give feedback about the system, setting and the interaction.

To reach this goal the study runs through 3 stages:

- **Pilot Study**
- **Pilot Study 2.0**
- **Main Study**

3.4.4 Recruiting of Participants and Piano Player

For the classical musician part, a piano player (female, 25-years-old, music therapist, 15 years of piano playing experience) is recruited and will accompany in every study performance. With her music therapeutically background the piano player is familiar with improvised, collaborative music performances. As the musical pendant during the interaction, she is able to guide and lead through the performance and help to create a musical flow and sound base. There are no insights that other music instruments wouldn't be possible for the same purpose.

Some participants are recruited out of the field of music studies (therapy, theory) and also some hobby-musicians and non-musicians are participating. Altogether 18 participants (nine male/nine female, between 21 and 61 years) are participating one by one at the iterative studies. Participants are considered as **musicians** if they stand close in contact with music in their studies/work or have been playing instruments for many years. **Non-musicians** have no significant musical knowledge and are not in touch with music in their work, studies and are not playing any instrument.

The participants work together with the piano player and will give feedback about the CMIS, CSCOs, and the interaction.

During the collaboration, the classical musician can help to create a musical flow or jamming feeling (cf. chapter 2.1.1), an easier learning of the system for the participants to feel more connected to the music and may also suggest the impression of connectivity for *making music together* in a social sense (cf. chapter 2.1.1).

3.4.5 Implementation of Studies

For a better understanding of changes during the iterative study processes, the setup components and elements get clear identification names and are stressed out again in the next chapters. Additionally the study instructions, their process, and changes will be described:

3.4.5.1 Pilot Study

The pilot study was carried out in three performance sessions with three different participants with the following setting:

Pilot Study	
Piano	Korg 2e MIDI piano
Camera	1x
Sound boxes	2x
CSCOs	CSCO_list1 (cf. 3.1)
Sound mapping (CMIS)	Midi_Sampler1 (cf.A.1.5)
Midi record	No
Screen Recorder	No
Drumbeats	Drumsound_list1 (cf. 3.4)
Instructions/Process of music interaction	Performance_list1 (cf. 3.4.5.1)
Participants	3 (cf. 3.5)
Questionnaire	Questionnaire1 (cf. A.23)

Table 3.2: Pilot Study Components

The structure and setup are very similar to other studies and can be found on the picture in the appendix (cf. figure A.12).

Sounds Pilot Study object sounds (cf. 3.3): The colored objects were mapped and calibrated to specific electronic, atmospheric sounds to create an abstract and individual piano-electro-sound mood for the experiment. The experimental cinematic – atmospheric sample sound package was purchased from *Bluezone Corporation*[9]. It has to be mentioned,

[9] http://www.bluezone-corporation.com/samples/abyss-deep-atmospheric-sounds-and-soundscap

that other sound packages would have been usable too. This choice was only made by personal preferences to create a little electronic-cinematic atmosphere with no specific scientific relation. The sounds were attached differently to each CSCO and could be controlled by vertical movement (x-axis).

Orange Carton	deep, dark, atmospheric sound with high synthesizer notes
Pink Marker	deep, dark, continuous atmospheric sound
Green Marker	continuous female voice "ah-sound"
Yellow Ball	dark popping trap-dubstep beat, 140bpm

Table 3.3: Sounds Pilot Study

drumbeats (cf. 3.4): The first two drumbeats were purchased and downloaded from prime loops hip hop beat sample package and the last two drumbeats were a content of the Bluezone Corporation sound package[10]. These drumbeats were chosen according to the object sounds with different beat structures. Every participant was able to select one background beat as a supporting rhythm of his choice.

Drum Beat 1	rhythmic hip hop beat, 90bpm
Drum Beat 2	variant hip hop beat, 90bpm
Drum Beat 3	dark trap-dubstep beat, 140bpm
Drum Beat 4	dark popping trap-dubstep beat, 140bpm

Table 3.4: Drumbeats

Participants Pilot Study Table 3.5 shows the attending participants with some useful attributes for differentiation. For a better understanding, every participant gets a participant number (P1-P3). These labels are similar in the following studies.

Instructions and Process of Pilot study Instructions: The participants have been instructed with following key facts about the music interaction:

- The participant is able to *influence the sound and music* with the movement of the *color objects.*

[10] `http://www.soundstosample.com/producer/Bluezone_Corporation/29`

Name	Age	Musician	Gender
P1 - NK	26	no	female
P2 - BF	25	musician (hobby guitarist)	male
P3 - PD	24	musician (music science, saxophone)	male

Table 3.5: Participants Pilot Study

(a) P1 (b) P2 (c) P3

Figure 3.5: Participants Pilot Study

- The webcam recognizes the movement and colors and the computer processes the data to sound.
- Each of the *four color objects* is mapped to one of the *four sound samples*. The music genre of the sound files is a mix of ambient, trap beat, psychedelic, spherical sound.
- The interaction object is free to choose.
- The interaction is *five min long* and starts with the drum beat.
- The *drum sample* (one out of four) is available to choose.
- The interaction can be done sitting or standing.
- The system is very sensitive, which is the reason why the *movement* of the objects should not be too fast and *thoughtful*.

Process: Here is a short gradual description of the music performance process in chronical order. The average time for one pass was about 30 minutes:

1. The participant is signing the letter of agreement.
2. The participant gets instructions about the interaction and the system (cf. chapter 3.4.5.1)
3. The system and technique are getting ready. (MaxMSP, video camera)
4. The participants' chosen drum-sample starts.

5. The piano player and the participant start the interaction and start to play.
6. The "song" or music interaction ends after about five minutes with a fade-out (sound is slowly turned down).
7. The participant is led through a questionnaire and his answers are recorded on tape.

Summary Pilot Study The pilot study gives a first impression about the setting behavior and interplay. From the technical point of view the test of the CMIS, and CSCOs have brought a satisfying result for the next pilot study. Some setup components had to be adjusted and prepared for another study (cf. 3.6). A small evaluation and summary of the questionnaire (cf. chapter A.2) brought some conclusions about the interplay of CSCOs and the CMIS and especially the answers to the questionnaire supplied input for the final results of this work (cf. chapter 4.2.3). So the circumstances have routed to another pilot study (cf chapter A.3) for eliminating some of the occurring problems in the process and to reach a satisfying study setting for the performance and the evaluation.

Additional information to this study are in the appendix (cf. chapter A.2). Table 3.6

Hardware	**Software**	**Other matters**
Video camera position: the camera was not prepared and positioned correctly $\rightarrow$ the participants disappeared behind the back of the instructor. *Second video camera position?*: for a front view of the piano player and side view of the participant	*CamStudio*: Screen recorder software – The files were damaged, so no participant was recorded on the computer screen	The participants need more time for the interaction and to get to know the system better. The music interaction time should possibly be between 6 or 7 min.

Table 3.6: Pilot Study Issues

lists the occurring problems of the Pilot Study, which should have been solved in another study.

3.4.5.2 Pilot Study 2.0

Based on the findings of the first pilot study following modifications were made as corrections of the pilot study and adapted for later analysis:

Hardware	Software	Other matters
Second overhead video camera: gives a side view of participant and front view of the piano player for later video analysis.	*CamStudio Screen Recorder*: record of the music interaction on the computer screen for video and behavior analysis. *Implementation of MIDI Data record*: MaxMSP software adaptation to record played MIDI data of the participant (interaction objects) and piano player for a possible later music analysis.	More detailed *Introduction* and *Explanation* of the system and the performance for better knowledge and learning.

Table 3.7: Pilot Study Solved Issues

The pilot study 2.0 was carried out in five performance sessions with five different participants with the setting of table 3.8:

Sounds Pilot Study 2.0 object sounds (cf. 3.3): The sound files and mappings were left unchanged to the pilot study.
drumbeats (cf.table 3.4): The freely selectable drumbeats were left unchanged to the pilot study.

Participants Pilot Study 2.0 Are listed in table 3.9.

Instructions and process of Pilot Study 2.0 Instructions: The basic facts and instructions were mentioned earlier in the pilot study (see Chapter 3.4.5.1). Some small changes were made and some instruction points were stressed out more specific to give a more detailed explanation of the performance:

- The interaction time was changed to **six minutes**.

Pilot Study 2.0	
Piano	Korg 2e MIDI piano
Camera	2x
Sound boxes	2x
CSCOs	CSCO_list1 3.1
Sound mapping	Midi_Sampler1 A.1.5
Midi record	Midi_Record1A.1.7
Screen Recorder	Yes
Drumbeats	Drumsound_list1 3.4
Performance/Instruction of music interaction	Performance_list2 3.4.5.2
Participants	5 3.9
Questionnaire	Questionnaire2

Table 3.8: Pilot Study 2.0 Components

- In the instruction of the music interaction following **points were emphasized**:
  - The participant can test the objects and sounds and see what happens. There is no target or specific goal to reach and the participant can feel free to play how and whatever he/she wants.
  - The piano player has an assisting part and plays his own music in an experimental way and has also no boundaries and limitations. Perhaps he will synchronize and interact with the sound and/or movement of the participant and vice versa.

Name	Age	Musician	Gender
S2_P1 - AE	65	no	female
S2_P2 - BF	28	no	male
S2_P3 - DG	22	no	female
S2_P4 - CT	29	no	male
S2_P5 - KE	61	no	male

Table 3.9: Participants Pilot Study 2.0

  - There is no outcome specified and the music interaction experiment will show what happens.

Process: The basic concept is very similar to the pilot study process (see Chapter 3.4.5.1).

1. The participant is signing the letter of agreement.
2. The participant gets instructions about the interaction and the system (3.4.5.2)
3. The system and technic are getting ready. (computer with MaxMSP, video camera)
    - Starting CamStudio (screen recorder)
    - Starting Quickrecord (MIDI recorder in MaxMSP)
4. The piano player is getting ready.
5. The participants' chosen drum-sample starts.
6. The piano player and the participant start the interaction and start to play.
    - The MIDI output of the participants' and piano players' play is recorded in MaxMSP.
7. The "song" or music interaction ends after about **6 min** with a fade-out (sound is slowly turned down).
8. The participant is led through a questionnaire and his answers will be recorded on tape.
9. The piano player is led through a questionnaire and his answers will be recorded on tape.

Summary Pilot Study 2.0 With some modifications and new implementations (cf. figure 3.7) the second study was conducted . The main changes have been a **second video camera**, a **screen recorder** for evaluation matters and a **midi recorder** for recording the CSCO play in MaxMSP. The data of small video analysis (CSOS handling) (cf. chapter A.3.1) and the questionnaire answers should help to give feedback about the participants' use of the CMIS with the CSCOs and the functionality of the system in the collaborative music performance . The outcome of this study induced to the final improvement steps to the main study. Also, the summary of the questionnaires provides some data for final results and conclusions.

Additional information about this study can be found find in the appendix (cf.chaper A.3).

Hardware	**Software**	**Other matters**
MIDI E-piano: There were some major MIDI latency problems, so that the piano player couldn't play on point. The piano player felt very uncomfortable and distracted by this issue.	*Sound mapping*: It was difficult to hit different notes for the participants.	*Sound files*: The participants were more and more distracted by the unnatural sound samples of the interaction object. They had problems to hear the change of the notes. Two participants mentioned, that they didn't know exactly what to do and more detailed information about the interaction.

Table 3.10: Pilot Study 2.0 Issues

3.4.5.3 Interim Report of Pilot Study and Pilot Study 2.0

The feedback of the participants and experiences of the performances showed a little disturbed impression of the sounds and therefore complications with the handling. For some participants, the unnatural sound had been obstructive for a better performance and collaboration. It was also audible that there has been a disturbing dull sound when the participants left the interaction area (*Interaction Window* A.1) with their CSCOs.

Another conclusion is that the participants would have needed more time or training to warm up with the CMIS and the CSCOs.

The first problem can be solved with a new implementation and recreation of the CMIS sound mapping (A.1*Midi Sampler (Main Study)*) in MaxMSP. Additionally better instructions and a little object-system testing phase (cf. chapter 3.4.5.4) should offer an easier access to the system for the performance. The latency issues can be solved with another piano which has a separate audio output. With these solutions and other corrections a new study was conducted.

3.4.5.4 Main Study

The input from the two last studies were tried to solve with following corrections:

Hardware	Software	Other matters
MIDI sound latency problem: The piano players' e-keyboard was changed to a stage piano. The piano itself is producing the sound and outputting on the piano sound boxes. For sending MIDI data to the computer an additional MIDI cable was installed and attached to a computer and stage piano. *Camera view*: The camera was positioned more centered to get a better front look of the participant and his interaction.	*New prototype implementation*: A new implementation of the mapping and the sound structure of the interaction objects was realized (see *objects and Sound* 3.4.5.4) A.1A.8).	*Interaction*: The participants get a little more interaction time and a short testing phase. The instruction content is more detailed and adapted to the new system settings.

Table 3.11: Pilot Study 2.0 Solved Issues

The main study was carried out in ten performance sessions with ten different participants with the setting in table 3.12.

Sounds of Main Study object sounds (cf.table 3.13): Because of the participants' experiences and feedbacks to the pilot study and pilot study 2.0 the sound mapping was recreated to more common MIDI sounds (cf. A.1.6). In contrast to the former studies the participants could control natural sounds and are able to control the volume of the sounds with vertical movement (y-axis). Because of the assisting part the piano player could choose MIDI sounds ("sound mappings") for the CSCOs. The sounds were selected from the list of General MIDI sounds (cf.figure A.13)
Drumbeats: The drumbeats were left unchanged to the last studies (cf. table (3.4).

Participants of Main Study Are listed in table 3.14.

Instructions and Process of Main Study Instructions: The participants got a small briefing and instructions about the functions and the interaction:

- The participant is able to influence the sound with the color and the movement of the interaction objects and is invited to interact and collaborate musically with the piano player who accompanies on the piano.

Main Study	
Piano	KORG SP300 Stage Piano
Camera	2x
Sound boxes	2x
CSCOs	CSCO_list1 (cf.tab 3.1)
Sound mapping	Midi_Sampler2 (cf.ch A.1.6)
Midi record	Midi_Record1 A.1.7
Screen Recorder	Yes
Drumbeats	Drumsound_list1 3.4
Performance/Instruction of music interaction	Performance_list3 (cf. ch.3.4.5.4)
Participants	10 3.14
Questionnaire	Questionnaire2

Table 3.12: Main Study Components

Orange Carton	Atmosphere + Bowed
Pink Marker	Flute
Green Marker	Distortion guitar
Yellow Ball	Pizzicato Strings

Table 3.13: Sounds Main Study

- The webcam captures the movement and colors and sends the transformed data to the PC, which processes the sound.
  - Each color is an instrument.
  - four colors, four tones (orange carton, pink marker, green marker, yellow ball)
  - **X-axis** – is relevant for the different **key** (scale)
  - **Y-axis** – is relevant for **volume** of the tones
- The interaction objects are freely selectable (orange carton, pink/green marker or yellow ball)
  - Colored surface is different → handling different → Cartoon has small key jumps

Name	Age	Musician	Gender
A1	24	no	female
A2	32	no	female
C3	23	yes	female
C4	26	no	female
F5	30	no	male
I6	25	yes	female
K7	29	no	male
M8	25	yes	male
O9	24	yes	male
V10	24	yes	female

Table 3.14: Participants Main Study

- The system is very sensitive. Small disturbing noises should be ignored.
- A small **test run** of **two min** to get used to the system and the sounds. Sounds and movement can be tested out.
- Afterward starts the real music interaction with the piano player for about 6 min.
- Drum Samples (one out of four) freely selectable

Process:

1. The participant is signing the letter of agreement.
2. The participant gets instructions about the interaction and the system.
3. The participant is able to test out the objects, sounds and movements in a **two min test run**
4. The system and technique are getting ready. (computer with MaxMSP, video camera)
   - Starting CamStudio (screen recorder)
   - Starting Quickrecord (MIDI recorder in MaxMSP)
5. The piano player is getting ready.
6. The participants' chosen drum-sample starts.
7. The piano player and the participant start the interaction and start to play.
   - The MIDI output of the participants and piano players play is recorded

8. The “song” or music interaction ends after about **six min.** with a fade-out (sound is slowly turned down).
9. The participant is led through a questionnaire and his answers will be recorded on tape.
10. The piano player is led through a questionnaire and his answers will be recorded on tape.

Summary of Main Study With a re-implementation step of the CMIS and the CSCO **(Midi Sampler2)** and some other modifications (cf. table 3.11) the final main study was carried out. In this last practical phase, the system setting (cf. table 3.12)was tested and proved to be compatible and suitable for a collaborative music performance. The new sound mapping technique was more usable than the preceding one and it looked like the CMIS controlling was a little bit easier. Therefore, the participants’ behaviors and impressions were evaluated in more detail (cf. chapter 3.5.2) than in the previous studies as the interaction data was has been found more useful.

3.4.6 Study Adjustments and Implementation Steps

These tables give a quick summarizing overview of main study setting modifications. Necessary changes and unchanged elements give a compact info on which corrections were needed.

	Pilot Study	**Pilot Study 2.0**	**Main Study**
*P*iano	X	Unchanged	Changed
*C*amera	X	Changed	Unchanged/Adjusted
*S*ound boxes	X	Unchanged	Unchanged
CSCO	X	Unchanged	Unchanged
*S*ound mapping (CMIS)	X	Unchanged	Adjusted
*M*idi record	-	X	Adjusted
*S*creen Recorder	-	X	Unchanged
*D*rumbeats	X	Unchanged	Unchanged
*P*erformance/Instruction of music interaction	X	Adjusted	Adjusted
*Q*uestionnaire	X	Adjusted	Unchanged

Table 3.15: Study Adjustments

Pilot Study	**Pilot Study 2.0**	**Main Study**
Midi Sampler	Midi Sampler	Midi Sampler 2.0
	Midi Record	Midi Record

Table 3.16: Main Software Implementation Steps

For the first two studies (Pilot Study, Pilot Study 2.0) a sound-mapping solution was chosen (cf. chapter A.1.5) in which external Soundfiles for the controlling of the CMIS by CSCOs in MaxMSP (cf. ch.3.4.5.1) were used. Because of technical problems, tests, and feedback of the participants (cf.chapter 3.4.5.3, table 3.10) a new sound-mapping method (cf. figure A.8) was implemented and applied for the Main Study. It processes and uses internal Midi Sounds and is easier and more precise to handle. Another modification was the use of a *Midi Record*A.1.7 solution in the Pilot Study 2.0 and Main Study. This improvement helped to record the participants music experience for further analysis.

The functionality of the prototype is described more detailed in the appendix (cf. chapter A.1).

3.5 Evaluation Methods

Throughout the study process following methodological approaches were chosen:

Input Data	Analyse	Analyse Method	Study
videos	qualitative	per hand	pilot study 2.0
videos	qualitative/quantitative	with software	main study
questionnaires	qualitative	with software	pilot study pilot study 2.0 main study

Table 3.17: Study Methods

The software, which was used throughout the study process, is listed earlier in chapter 3.3.

The evaluation of the pilot studies was based on the feedback of the participants to the questionnaires to find answers about their experience during the music performance. Conclusions were made which adaptations and implementations were useful for the system and lead to the further study. In addition with the video analysis of the pilot study 2.0 these data were also helpful to find answers for the research questions of this thesis.

For the main study evaluation a video analysis combined with a software supported behavior study was conducted, which assisted in finding answers on how the participants experienced the interaction. With the help of the questionnaire analysis more detailed information about the participants' impressions were acquired.

Therefore, the evaluation process was split into three parts (*Interaction object analysis, interaction behavior analysis, and questionnaire analysis*). By grouping the participants' experiences in different categories (*Interaction objects, system handling, and collaboration*) results according to the research questions were found out.

3.5.1 Interaction Object Analysis (quantitative)

The first evaluation step was to measure the duration (play time/object in use) of every *interaction object* throughout every of the ten interactions. The CSCO handling was used as an indicator for the different interaction and participation styles and behavior diversities. This also helped to draw conclusions about the CMIS and CSCO interplay and their usability. A small video analysis program called *kinovea* [11] was used and the results of the analysis were written in an external excel table.

Also, the most important facts about the participators and interactions were written into the table (e.g.: Age, Gender, Piano player feedback, etc...). Further statistics and calculations were made with excel statistic solutions (pivot tables) and according diagrams.

3.5.2 Behavior- and Interaction Analysis (qualitative)

This evaluation method was used only for the main study to evaluate the participants interaction behavior with the final CMIS and CSCO setting. Based on Internet research and investigations about "behavior analysis" and human interaction evaluation a software company called *Noldus*[12] came to mind. Their software object called *Observer XT*[13] provides coding principles, methods, schema as evaluation and visualization processes for behavior studies and, therefore, offers suitable features for the collaborative color interaction study.

With the limited software version, the maximum number of participants for the analysis were five, so the evaluation was split into two groups *(musicians, non-musicians)*.

3.5.2.1 Behavior Analysis with Observer XT

Based on a predefined Coding Scheme (Coding Scheme (cf. figure 3.6) with coded behavior events followed by a data profile (cf. figure 3.7), which filters desired values, the results were evaluated in the analysis section of the behavior analysis software program ObserverXT with integrated objects (pre-defined filters, table sorts, and calculations).

[11] http://www.kinovea.org/
[12] http://www.noldus.com/
[13] http://www.noldus.com/human-behavior-research/products/the-observer-xt

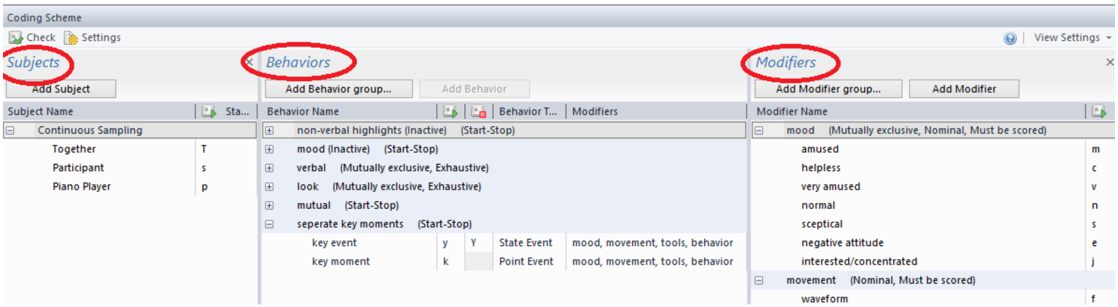


Figure 3.6: Observer XT - Coding Scheme Section

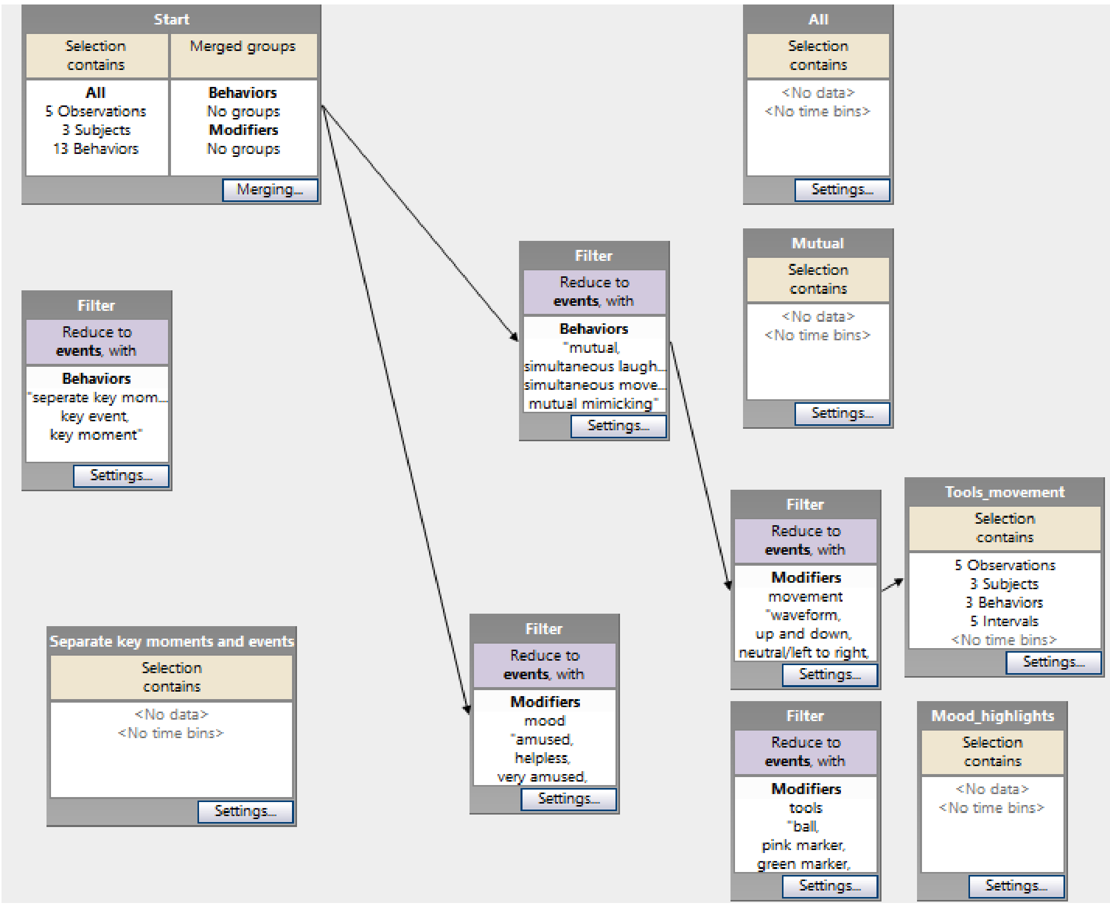


Figure 3.7: Observer XT - Data Profile

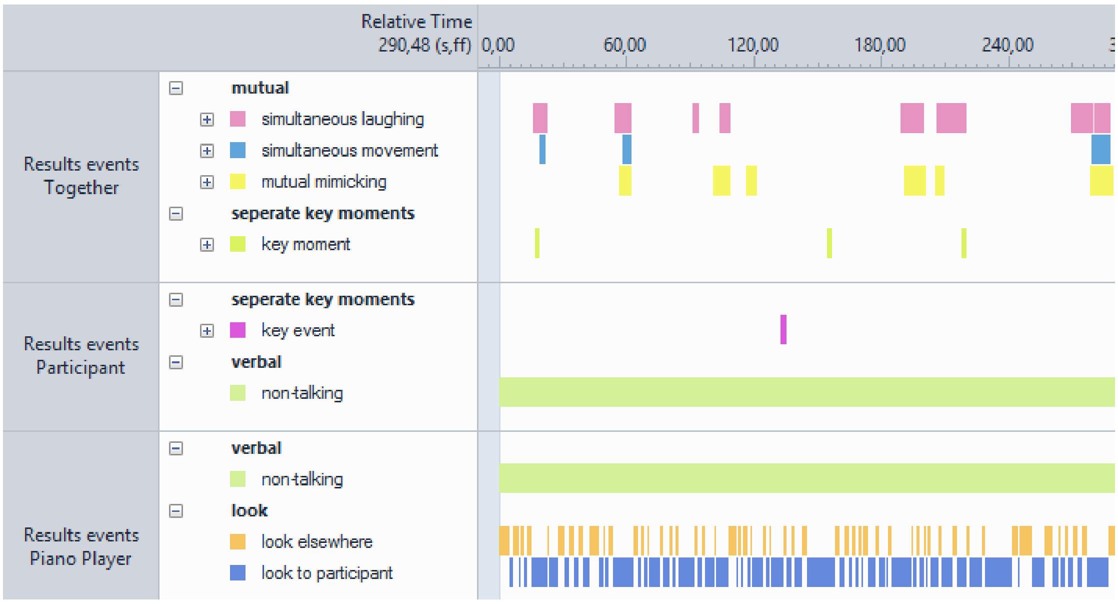


Figure 3.8: Observer XT - Timeline- Participant C3

Following highlighted time and event based **behaviors** and interaction attributes for the participants were found and had been set:

- Verbal
  - Talking
  - Non-talking
- Mutual (collaborative and non-verbal communicative aspects between piano player and participant)
  - Mutual mimicking - play of piano player copied and synchronized by participant)
  - Simultaneous moving - body movement or CSCO play similar to piano play (same note and direction changes on instrument)
  - Simultaneous laughing
- Separate key moments (participant related highlights)
  - Key event - extraordinary, progressive behavior
  - Key moment - extraordinary, punctual behavior

Following **modifiers** were made up during video analysis, had been set and can be related to according behaviors of the participants:

- mood - amused, helpless, very amused, normal, skeptical, negative attitude, interested/concentrated

- movement - waveform, up and down, no movement, shake head in disbelieve, neutral/left to right, head popping, shaking (objects), swinging (objects), tipping (objects), drumming
- behavior - wild posture, wild gesture
- movement - ball, pink marker, paper

Behaviors and modifiers that were made up during the video analysis of the interactions and had been coded can be connected individual in Observer XT.

Based on a work of Hansen (2011) these actions and attributes have been tried to set into the context of digital collaborative music interaction, where similar mutual, interpersonal effects were recorded and evaluated [Hansen et al., 2011].

Not all of these values have been necessary for the evaluation and conclusion of the CSCO and CMIS (e.g. piano player values) but were coded for the completeness of the behavior analysis.

The data profile GUI (cf. figure 3.7) is a pre-selection and connection schema of the coding elements for filtering the preferred evaluation results. In the example below all the *"mutual"* events were filtered by the modifier *"movement"*.

The visualization GUI (cf. figure 3.8)shows all the appearing events on a timeline. On the picture above the visualization of *participant* C3 with exceptionally piano player attributes is imaged. For the evaluation process of the main study, the attributes and behaviors of the piano player can be neglected.

CHAPTER 4

Main Study and Pilot Study Results

4.1 Interim Results of Pilot Study and Pilot Study 2.0

The two pilot studies were a useful test for the system and the preparation of the main study. The data and questionnaires helped to solve some technical issues and to get information to for the right sound arrangement, interaction setting and process, which should also help to find answers to the research question *RQ1* (cf. chapter 1).

The interaction tools were tested and fitted to the circumstances and were used differently and alternating by the participants. Also every tool was at least recognized by the system and was usable for Sound creation. No changes were required for the CSCO list (cf. figure3.1).

4.2 Evaluation Results

It has to be minded that the interaction object and behavior analysis was only implemented with the ten participants of the main study (cf. table 3.4.5.4). For the questionnaire analysis also the data from the other two studies was considered. These following results should underline the answers to the questionnaire

4.2.1 Evaluation of the Interaction Object Analysis (Main Study)

These results give feedback about the favor use and controlling time of the CSCOs. The evaluation diagram 4.1a shows that every tool was used a convenient percentage (minimum 17%) of the time. The participants favored the **ball** as the most used interaction object (**CSCO**) for the interaction. In **combination** the **ball + pink marker** were used the most and one participant also tried a connection of three tools (ball + green marker + pink marker) (cf.figure 4.1b).

The figure shows the average tool combinations of every participant per minimum is shown in figure 4.2. The content describes how often the participant changed the CSCO ("Sound object"). *3,79 changes/min* were counted as an average value for all participants. A propensity to **constant tool changes** and the favor for **alternation** can be concluded in this case. This characteristic may be followed by more different CSCO for example.

4.2.2 Evaluation of the Behavior- and Interaction Analysis (Main Study)

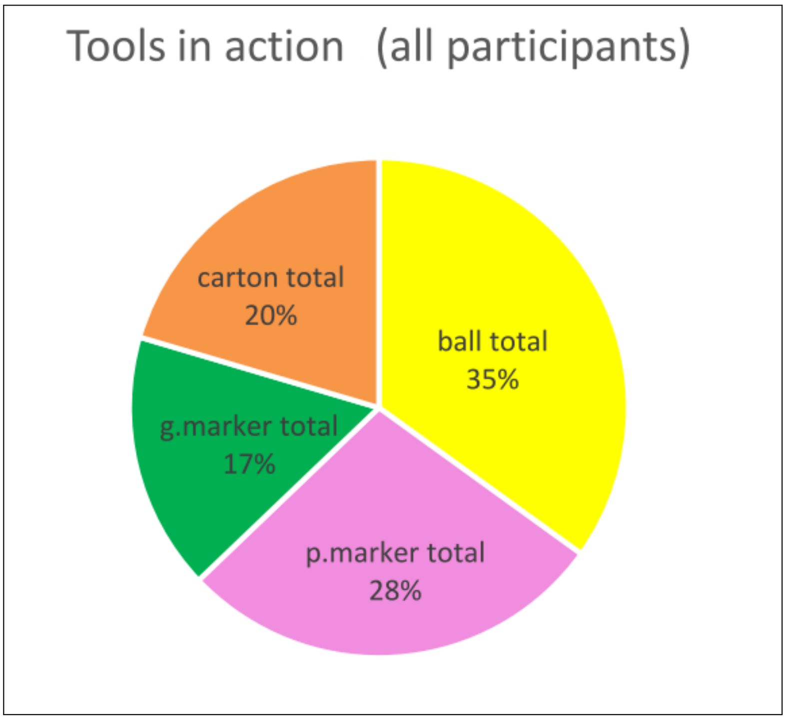
Behaviors and interactions which were recognized during video analysis were coded with the Observer XT and are listed in the Appendix chapter 3.5.2.1 The results of the behavior analysis were evaluated more detailed than needed. With the background of the research questions, the focus lies on the distribution of general appearing behaviors so that conclusions can be made about the system and the performance.

Mutual total highlights

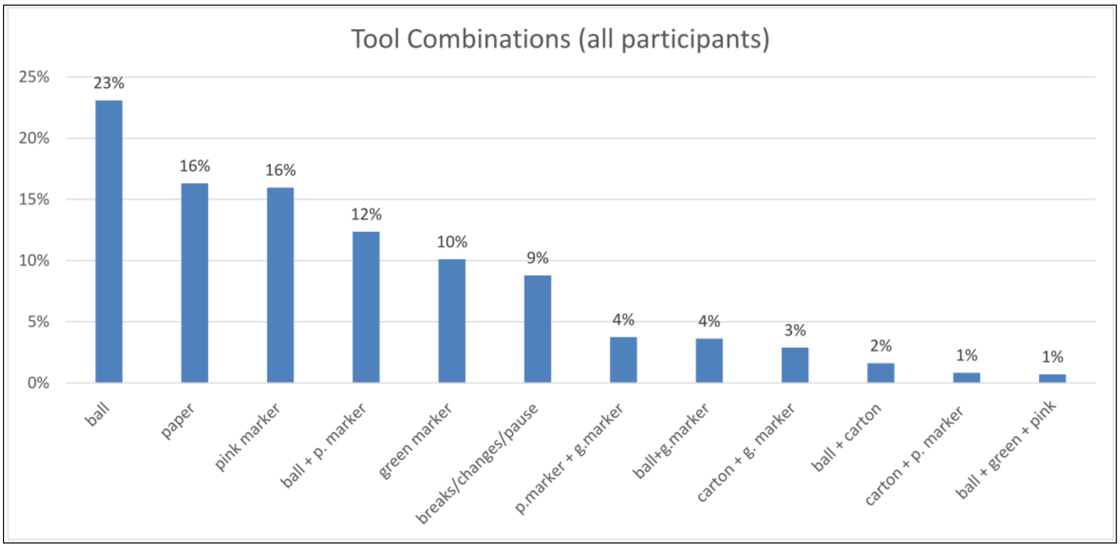
"Mutual" denotes expressions and gestures that occur collaborative (together) between the piano player and the participant in various ways. Figures 4.6a and 4.6b show the occurring mutual, collaborative and connective interpersonal effects of CMIS and CSCO between participants and piano player during the music performances. *Simultaneous movement*, *mutual mimicking* and *simultaneous laughing* were recognized and may indicate connective behavior (laughing) and the intention for collaboration (moving, mimicking).

Mutual tool combinations

The frequency scale of the interaction tools in collaborative or mutual highlights with the piano player are shown in figure A.16). We can see mutual moments with every of the interaction tools (yellow ball, orange carton, green marker and pink marker). The



(a) Tools in action



(b) Object Combinations (all participants)

Figure 4.1: Object Usage Analysis (Main Study)

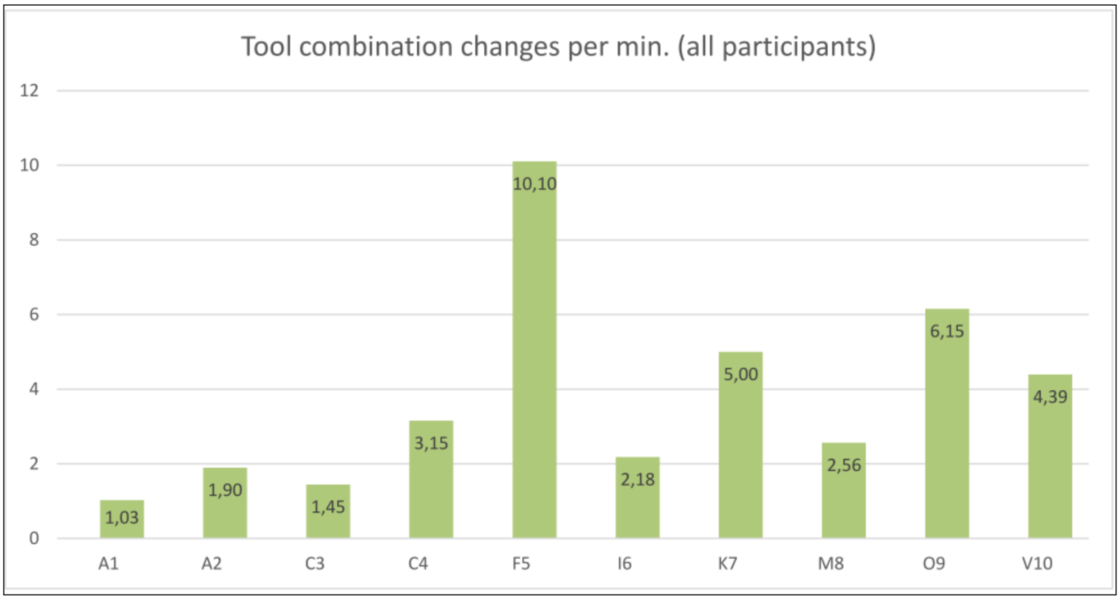


Figure 4.2: Object Combination Changes (Main Study)

highest values in mutual mimicking were recognizable in the following order: ball, carton, the green marker. The pink marker was used the least.

Mutual tool movement

The appearance of different movement styles of the interaction objects in combination with mutual (collaborative) interactions are described in the diagrams (cf. figures A.18 and A.19). These figures allow to argue how practical the tools are. and show the high diversity interaction style and form of using the interaction tools. The **paper** and the **ball** had the most different movement activities, which may show their versatile controlling and application possibility. Every participant had at least one mutual moment with every CSCO.

Verbal highlights and separate key moments

Talking activities and key moments or key events which define individual interaction highlights and some exceptionally participant moments are shown in figure 4.1. It gives an impression about behaviors which describe the performance or interaction with the CMIS and CSCO through extraordinary behaviors and verbal key moments. This table also provides a view about the participants' impressions and experiences during the music performance. These impressions underline some questionnaire answers about their

Musician	tool combination changes/min
No	21,18
Yes	16,74
Sum	**37,91**

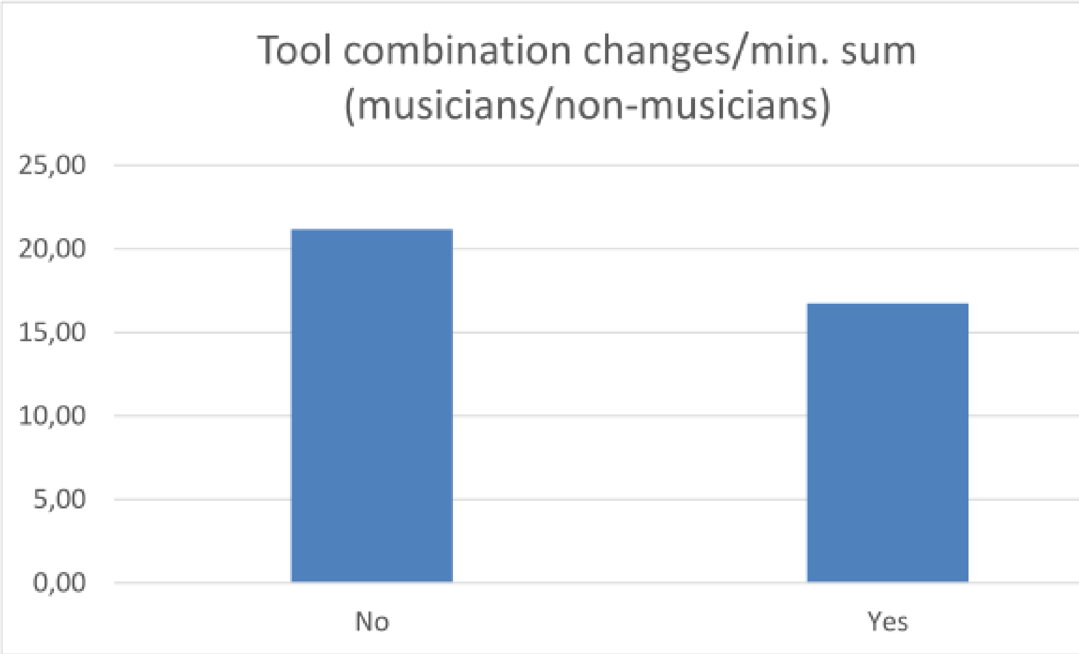


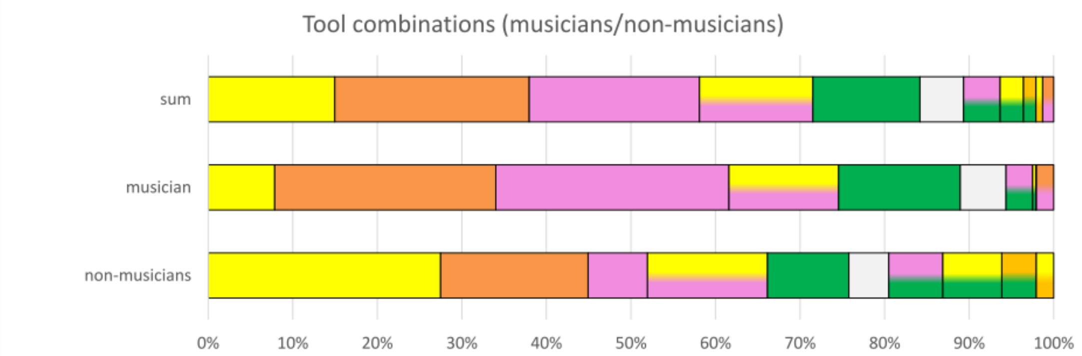
Figure 4.3: Object Combination Changes Comparison (Main Study)

feelings during the performance and will be discussed more general in the discussion chapter.

Mood change highlights

Good indicators for different occurring behaviors were recognizable mood changes (laughing, smiling, skeptical and disturbed looks) (cf. figure A.22).

The measured mood changes allowed to discover relatively easy, if a participant was amused (facial expression) or skeptical (head shaking in disbelief) during the interactions. The figures give an impression about the excitement, commitment and objective feelings of the participants during the interaction with the CMIS and the CSCOs. High values in "amused" and "very amused" are noticeable, which indicates a positive experience during the performance . On the other side, the high "skeptical" bulks show that there was a



	non-musicians	musician	sum
ball	11%	5%	16%
paper	7%	18%	25%
pink marker	3%	19%	22%
ball + p. marker	6%	9%	15%
green marker	4%	10%	14%
breaks/changes/pause	2%	4%	6%
p.marker + g.marker	3%	2%	5%
ball+g.marker	3%	0%	3%
carton + g. marker	2%	0%	2%
ball + carton	1%	0%	1%
carton + p. marker	0%	1%	1%
ball + green + pink	0%	0%	0%

Figure 4.4: Object Usage Comparison (Main Study)

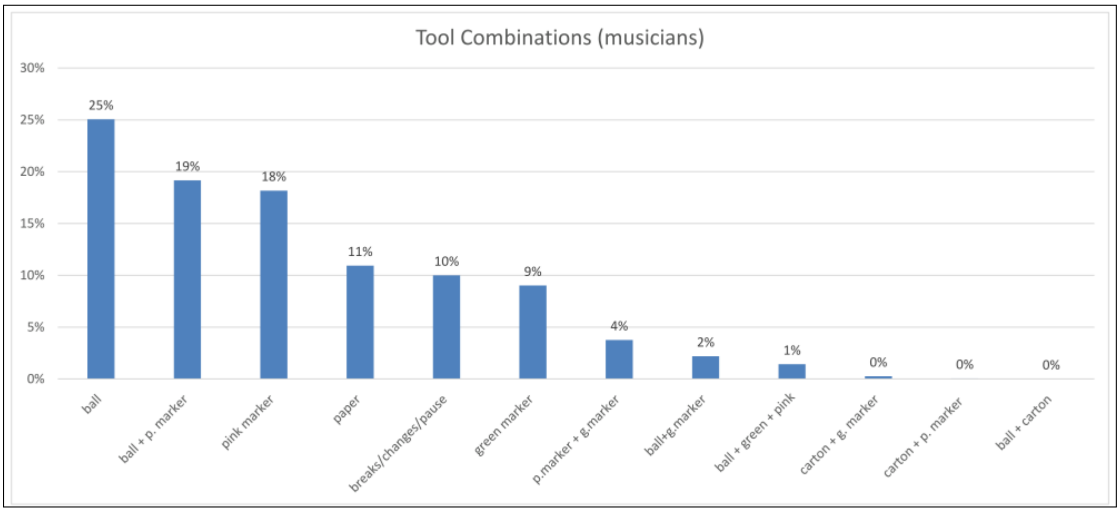
reserved contact to the system and the music interaction.

Differentiation between musicians/non-musicians

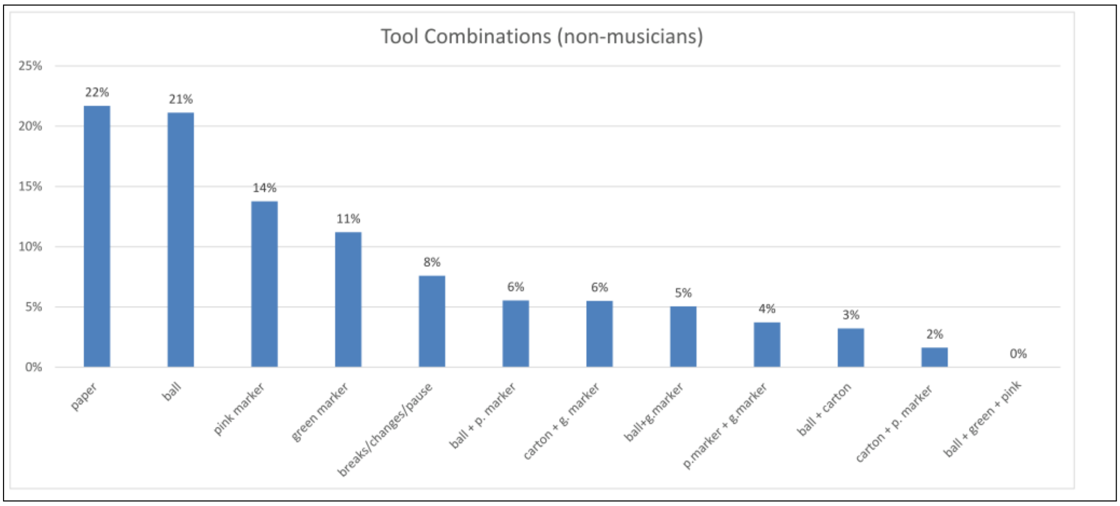
With these differentiation data for the more specific research questions (cf. chapter 1, *RQ2a, RQ2c, RQ2d*) should be acquired.

Based on the **usage of the CSCOs** figure 4.4 shows the preference for the yellow ball of the non-musicians, whereas musicians used the pink marker the most. The orange carton was much affected by both groups and on both sides the top three most used tools had been the ball, the carton, and the pink marker. Noticeable was the high use of the pink marker+yellow ball combination of the non-musician side and a wider spread in usage of the colored objects (cf.figures 4.5). Together with the use of more combination changes (cf.figure 4.3) of these participants this may indicate a more experimental and versatile approach of this participant group.

According to mutual highlights (cf.figure 4.6) musicians had higher values in every category. The distribution of the occurring mutual behaviors is very similar in both

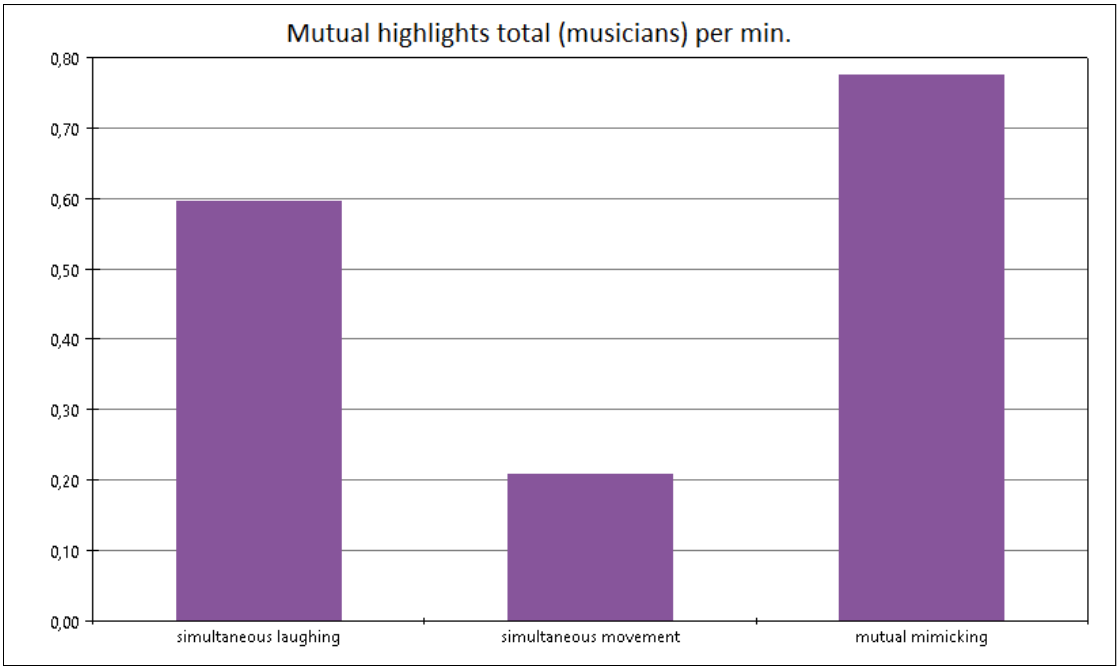


(a) Object Combination Changes Musicians (Main Study)

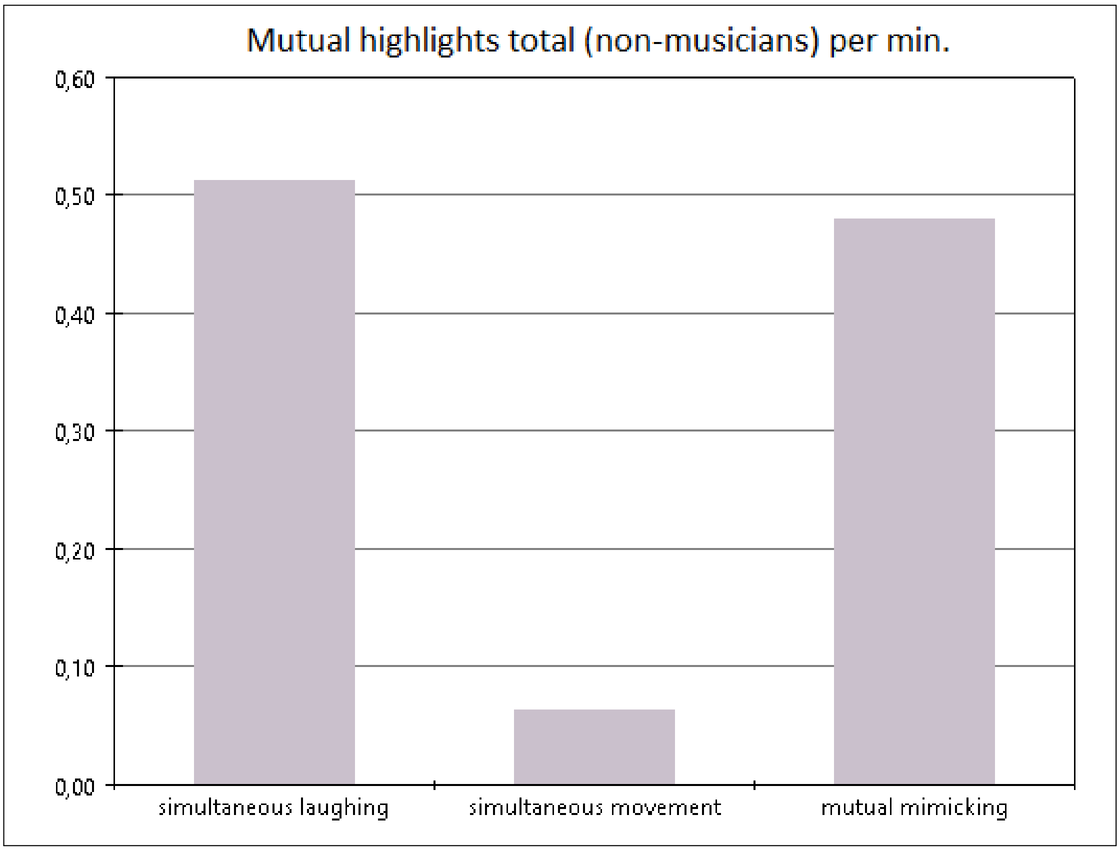


(b) Object Combination Changes Non-Musicians (Main Study)

Figure 4.5: Object Combinations (Main Study)

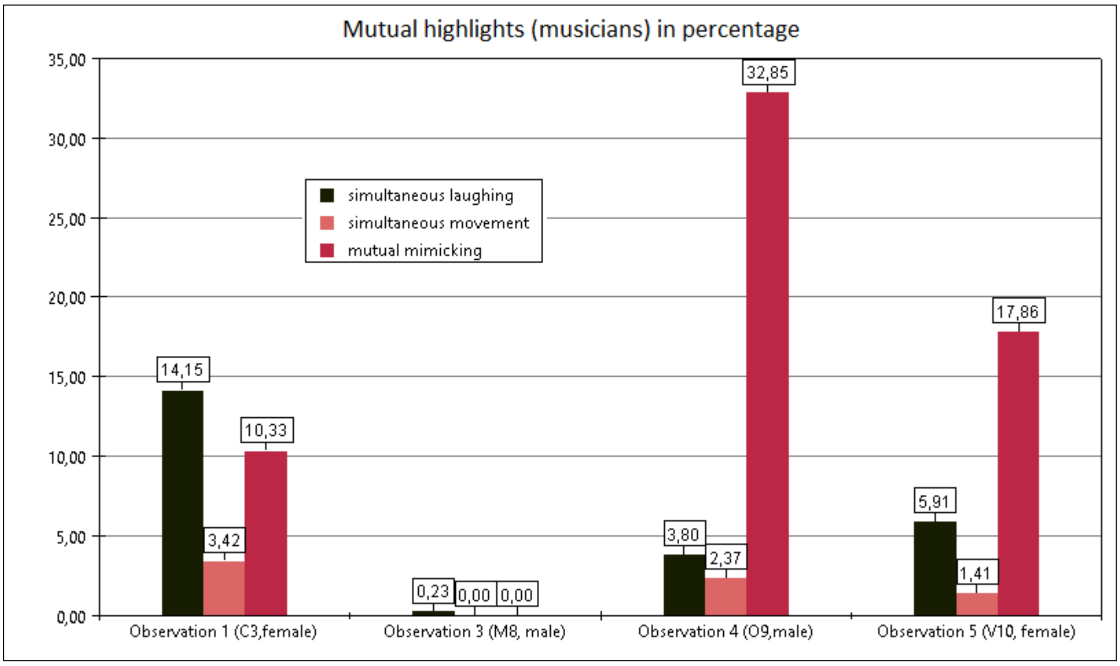


(a) Total Mutual Highlights (Musicians)

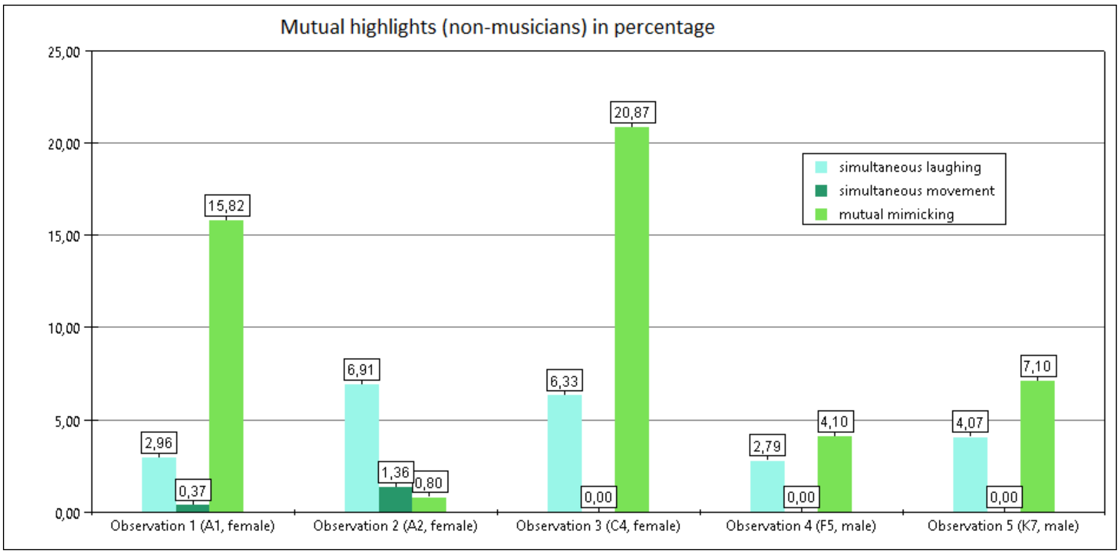


(b) Total Mutual Highlights (Non-Musicians)

Figure 4.6: Total Mutual Highlights Comparison



(a) Musicians



(b) Non-musicians

Figure 4.7: Total Mutual Highlights Individual (Main Study)

Name	Time in sec.	Behavior	Modifier	Comment
A1(non-musician)	26,92	talking	ball, skeptical	"‘I don’t hear what i am"’
A2(non-musician)	24,92	key event	interested (concentrated), no movement, green marker	waiting and listening for the piano player rhythm
	89,75	talking	pink marker, amused	approved, "‘good"’ "‘fine"’ or "‘nice"’, nodding
F5 (non-musician)	89,75	talking	pink marker, amused	approved, "‘good"’ "‘fine"’ or "‘nice"’, nodding
	10,56	talking	ball, interested/concentrated	Question to piano player about sound
	37,98	talking	green marker, interested concentrated	Comment about green marker "‘the noise is interesting that it makes"’
	306,88	key event	amused, bouncing, ball	Ball bouncing
	368,44	key moment	pink marker, wild movement	Start wild movement to finish

Table 4.1: Verbal Highlights and Separate Key Moments

groups.

In table 4.1 we can see that only non-musicians were talking during the performance. Also, there were some key moments, where the participants used the tools exceptional or gestured and behaved unorthodoxly.

If we split mutual highlights into individual sections of participants, we can get an impression how different the collaborative behaviors had been between the participant groups. A negative aberration was the performance of one musician who wasn’t even playing mutual at all and is missing in the figure 4.7. Also, musician M8 was very spare with mutual actions. On the other hand, most total highlights were measured in the musician group with participant O9. Non-musicians had more activities, but also three of them had no simultaneous mimicking values.

4.2.3 Evaluation of the Questionnaires (Pilot Study, Pilot Study 2.0 and Main Study)

The participants had been asked about their experiences and impressions during the interaction and also in detail about the **interaction tools**, **system** and the **collabora-**

tion (cf. Chapter 4.2.3). The answers should help to draw conclusions to the Research Questions (cf.1 *RQ2*) and together with the behavior analysis underline the experiences and impressions of the participants.

Positive points

It was rather motivating for the participants to take part in the interaction and performance. Most of them were very surprised and excited of the creative idea of sound interaction with interaction tools and a piano player. They didn't know that something like this exists or is possible and highlighted this as a positive feeling and experience. They haven't done something like this before and this experiment was their first. The musical approach with tools and the interaction with the piano player was also a positive aspect:

> *"It was an exciting idea and it was fun. And it is a really playful approach for creating music very easily. And it is good to give non-musical people an easy access and approach to music. It was the most direct approach I've ever seen to make music only with your hands and without playing instruments."*(MZ, musician)

> *"It was nice to get together and you have to adapt and adjust your play to the other one and find a mutual ending"* (NK, non-musician)

> *"It was nice to get together and you have to adapt and adjust your play to the other one and find a mutual ending."*(NK, non-musician)

> *"When I felt that there was an interaction and I was able to understand how the piano player reacts to my play."* (F6, non-musician)

> *"The idea was very cool and that it was the first time for me that I can make such sounds with normal objects. It was very funny."'* (V10, musician)

Negative points

Many negative opinions were given on the delay of the system in sound recognition and producing. Most of the time, it was very difficult to hit individual tones and the participants couldn't manage to find a precise and exact way to play. It was challenging for them to synchronize with the piano player.

> *"It was difficult because of the processing of the movement to the creation of the sound and how to create some variation and how and when the system reacts."* (M8, musician)

> *"It was difficult to hear the notes and to play them exactly. Sometimes I wanted to play one note and the system played four notes. You don't have it so much in your hands what you want to play."* (C4, non-musician)

Improvement suggestions

More tools, sounds, instruments and an easier and more precise system handling, were recommended as improvement points for the interaction setting by the participants.

> *"The handling could be better so that the signal doesn't interrupt."* (A1, non-musician)

> *"More precise. It is good to know how wide the interaction range is and the precision that you can't move out of the field."* (F6, non-musician)

> *"For the interaction it is possible to add some other instruments like drums or someone who plays the guitar. The more people the more interactive it will get."* (I6, musician)

Other comments and statements

There were many impressions of the music interaction for the participants that were very interesting and came to their mind. Some keywords are pointed out and describe the participants' experience:

"Unusual", "funny", "cheerful", "playfully", "challenging", "creative", "interesting" "exciting", "chaotic", "concentrating" "influenceable" ,..

Some other very interesting comments were made between the questions or after the interview:

> *"Yes, I think it is exciting because some instruments are expensive like a violin or difficult for transportation or you didn't have them at hand all the time. With such tools or items, it is easier to create something. It is fascinating that you can create sound with such things."* (I6, musician)

Statement about the use of this kind of music interaction system and similar approaches:

> *"I mean for example in a therapeutic field for people with limited motoric functions."* (BF, non-musician)

> *"My experience is that disorientated and confused people react very positive to music. Therapeutically way. "*(AE, non-musician)

> *"I know a music teacher from Hungary who invents an orchestra for people with disabilities. She was developing instruments or rearranged them for the needs and possibilities of the band members"*(V10, musician)

CHAPTER 5

Conclusion, Discussion and Further Work

5.1 Conclusion and Discussion

Based on the inputs of the implementation process and the results of the evaluation, following answers to the research questions were found:

RQ1 and RQ1a: *Which setting requirements for the CMIS with CSCOs are needed and recommended for collaborative music making between participants and a musician on a classic instrument?*
Which interplay requirements have to be minded during the definition and implementation of the CMIS with the CSCOs?

In general, the iterative steps of the three studies were important to *solve different hardware and software issues.* A different sound mapping solution was implemented for the main study which helped to get a *better object-system interaction play* through general midi sounds and a little bit *more precise mapping technique* (*Sound mapping Main Study* cf. chapters 3.4.5.4, A.1.6). The second reason for the adaptation was that some participants were disturbed by the unnatural, non-classical, electronic sounds, which were used in the first two studies. Another issue that was solved during the iterative process was the MIDI sound delay of the piano players' keyboard. After solving these problems with a new mapping solution and more common CSCO sounds (guitar, synthesizer,etc.), the interaction became more fluid and playful. The duration time was redefined because the participants weren't able to get the know the system well and, therefore, more time would be recommended for practice and play. The iterative process gave a good insight on how to approve and adapt the study design, the questionnaire, and the introduction. The system handling and controlling problems could be solved in further experiments with the system setting.

To the best knowledge of the thesis and its conclusions a **useful setting** for the CMIS with the CSCO was figured out (cf. table 3.12) and in addition with the evaluation results following **recommendations** for the components can be made:

- **CSCOs - Colored Sound Controlling Objects**
  - Best selection: ball, paper
  - Selection recommendations: baton, "rubik cube" with different colored surface, a broader set of objects A consistent and closed form (ball) would be recommended as a good object property for system recognition (cf. chapter 3.4.2).
- **CMIS - Color Music Interaction System**
  - Sound Mapping - Midi Sampler_2 (cf. section A.1.6)
  - Midi Record - Supports sound and movement analysis (e.g.: music analysis, playing pattern analysis)
  - Sound recommendations - natural, common and familiar sounds (e.g.: MIDI sounds - guitar, synthesizer,..)
  - Interplay with CSCOs: Color-to-Sound recognition needs to be more precise $\Rightarrow$ hitting right notes, better camera, more precise system, darker room
- **Performance/Interaction/Collaboration**
  - Training - participants need more time to practice
  - Duration - $>$ 6min

During the defining phase of the CSCOs it was a challenge to find colors that are very diverse and are not overlapping each other and don't have the same spectral color. It was very difficult to get more than 4 colors into play, but suggestions for the color selection had been made (cf. chapter 3.4.2).

Information to CSCOs (Color Sound Controlling Objects)

Handling, Movement:
The *ball* turned out to be the best usable object for the participants. There were many diverse variations of handling (rolling, swinging, waving and bouncing) by using this

object. Together with the *carton*, which was also very interesting and variable in handling for the participants (swinging, “hide other instruments behind it”, wiggle), it appeared that it was *best recognizable* by the system.

Color relevance:
Only for two participants (female 22, female 56) the color and the look of the interaction object were relevant for choosing it. They liked the “positive” bright color and the smiley logo of the ball. Therefore, the color was more system relevant then a reason for choosing an object.

Suggestions:
Other suggestions for objects that would have been desirable as “instruments” were a conductors’ baton and geometric figures like a square, a dice or a pyramid. Also, it would have been interesting to use a Rubik cube[1]. Because of its geometric surface and different colors on every side it may be used as an interaction object for many sounds ("sound mapping"). It can be turned to the side of the desired color to play the according instrument.

RQ2: Which different interaction behaviors and expressions are occurring during the music performance and which impressions do the participants have?

In general, the recognized occurring behaviors and expressions were coded in chapter 3.5.2.1. The item lists with behaviors and modifiers give an overview to answer this question. Especially mutual moments, mood changes, different object handling and movements had been interesting to watch (cf. chapter 4.2.2). Very noticeable were mutual behaviors of the participants with the piano player (cf. research question RQ2b).

RQ2a: What are the distinctive differences between musicians and non-musicians?

Through the easy access to music making and collaborating with the CSCO non-musicians were able to experience a performance very similar to musicians. The system offered non-musicians the possibility for easy music creation and a new way of music experience. The system and setup could be improved for experienced musicians with better musical accuracy and performance. This could explain why two musicians had the least mutual highlights (cf. fig. 4.7). Therefore, it may be difficult to employ this system for professional music making by real musicians. A good example for the difference was the performance of an experienced musician (M8, male). He showed a negative attitude

[1] `https://eu.rubiks.com/`

because the system was not practicable to meet his requirement as a drummer for timing and playing the notes in the rhythm he wanted to play. The skeptical attitude of some participants (cf. figure A.22) indicated the difficulty of playing and sounding the way some persons wanted to. In addition with the answers of the questionnaires, it turned out, that music therapists hardly had difficulties with the performance. This is also illustrated in the comparison of the different collaborative moments. It seems that musicians either had high mutual moments or very less. On the other side, the collaborative behavior of non-musicians had been more balanced.

RQ2b: *In specific which mutual or collaborative behaviors appear between the participants and the piano player?*

The Observer XT evaluation shows that these specific mutual behaviors were recognized in the order of their appearances:

- Mutual mimicking
- Simultaneous laughing
- Simultaneous movement

It is interesting that nearly every participant (8/10) in a way tried to interact with the piano player. This behavior can be related to literature were the phenomenon of "synchronizing" was described in the context of collaborative music making (cf. chapter 2.1.1)[Hansen and Andersen, 2012]).

RQ2c: *Which impact do the CSCOs have on the interaction whether someone is a musician or not?*

For this purpose the results of the interaction object analysis are relevant (cf. chapter 4.2.1. Regarding the usage of the objects, it seems that non-musicians have taken a more free and experimental approach and a broader variety of combinations. Musicians had higher demands on their musical output and appeared more concentrated and cautious in the usage of the objects (cf. fig 4.4). We can see the preference for the yellow ball of the non-musicians, whereas musicians used the pink marker the most.

RQ2d : *Which impressions do the participants have about the interplay of the CMIS with CSCOs and the piano player?*

Most of the participants had been very excited by the interaction and had much fun with it. They were very surprised how easy it was to play and create music. Especially *non-musical people* and music therapists could take pleasure out of it. Overall the positive feedback on the system was in the majority. Therefor some indications about the commitment and excitement can be found in the behavior analysis like sympathetic mood changes and participatory mutual highlights between the participants and the piano player (cf. figures A.22, 4.6a, 4.6b).

The piano player had an important role for the participants, because of his sound leading and accompanying of the interaction. In some comments and answers to the questionnaire the participants mentioned a short flow experience, the excitement of finding together and the attempt to find a similar rhythm and ending (cf. chapter 4.2.3).The piano player was also someone to hold on musically and was the social-musical collaboration aspect during the interaction.

Most participants told that they have taken the following sequence of playing:

1. Trying out the system and objects → how does it work?
2. Trying to create a familiar and good sounding melody or rhythm
3. Trying to interact with the piano player

Additionally the questionnaire feedback showed interested and open minded answers to the performance. For this study, it can be an indicator for the acceptance (suitability) of the CMIS with the CSCOs in collaborative music performance.

On the negative side, the participants had sometimes problems to hit the right notes they wanted to play. This was a little problem throughout the study but had been improved a little bit during the iterative processes. It was very difficult for them to hit only one note and so they often struck many notes at once. Tis was probably a problem of the camera, the video processing combined with recognizing the position in real time and to identify the right color the whole time (different brightness ranges on different positions and different light reflections). It may be good to use very dark rooms, brighter colors for the interaction objects and more interaction space for hitting one particular note (better camera position) to improve this deficit. Maybe another improvement for the system and the interaction would be point marks to define the interaction area. A possibility could be the use of glue strips on particular areas, to define and set the participants' reach of play.

As another recognition, there would have been more output for the participants if they would have had more time for learning, experience and training for getting to know the color music interaction system.

Based on the few participants these results are not representable for a quantitative, scientific study. It is assumed, that the results and conclusions could apply to a higher number of persons. The evidence for this assumption could be proofed in possible follow-up projects.

With the knowledge of the iterative studies and the performance sessions, new improvement and application possibilities were revealed (system, objects and music performance) which can be adapted in possible further studies and investigations.

5.2 Further Work

Color Sound Controlling Objects (CSCOs): The color music interaction system can be modified with additional objects (e.g. dice, cube, baton) and according sounds. Different sound mapping methods with more and/or different notes between the objects can be tested.

Music interaction setting variations: There are different possibilities how the interaction performance can be recreated or advanced: The use of more systems with CSCOs and participants playing simultaneously on separate CMIS can acquire new input on the system or the collaborative performance. Another interesting point is to expand the "jamming" part, where participants only have one instrument (CSCO) and play or improvise among themselves like in a big Jazz ensemble.

Music analysis: With the output of the Midi data more detailed and exact measures can be made about the object movement and the musical expressions and variations. For this, the sound output can help to find answers to following possible further questions: Are there any similarities between the participants? Are there patterns, adjustments, repetitions and imitations among the participants?

Music Therapy: In the thesis literature review and later on with the answers of the questionnaire some connections and the use of the system for this matter where mentioned and recommended. Because of the easy and playful access to music making, the CMIS could be very usable for children or people with different disabilities. That is why it would be an opportunity to test the color music interaction system in music therapy.

APPENDIX A

Appendix

A.1 Prototype Functions

Based on several libraries, programming objects (internal and external) can be chosen in MaxMSP for multimedia programming. The structure of the methods and objects are visualized in graphs which are nested in different "patches" (programming levels). The execution and determination in MaxMSP are based on the connected objects in the visualized graph. This structure is very uncommon in programming languages but gives easy learning approach and clear overview of the implementation process. (source Wikipedia[1])

Through patches (code fragments) of forums entries[2] and tutorial help files[3] [4] some main functions were pre-implemented and used in the implementation phase.

The following points and chapters will show and explain some main functions (e.g. mapping of the colors and movements to sounds) of the prototype.

[1] https://en.wikipedia.org/wiki/Max_(software)
[2] https://cycling74.com/forums/topic/color-tracking-with-a-webcam-in-jitter/
[3] https://docs.cycling74.com/max5/tutorials/jit-tut/jitterchapter25.html
[4] https://docs.cycling74.com/max5/tutorials/jit-tut/jitterchapter25.html

A.1.1 Main Window

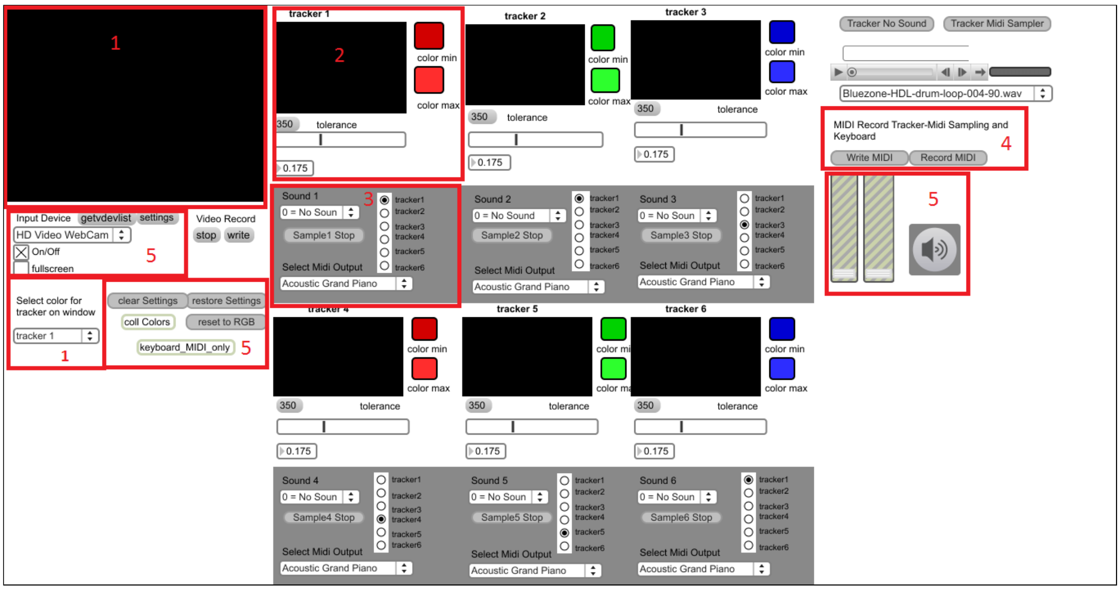


Figure A.1: MaxMSP Main Window

1. *Interaction Window* – Shows the webcam video input (colors and coordinates), the window for color selection (mouse click on a colored object), according tracker 1-4 (Color-Sound Interpreter)
2. *Tracker Windows* (Patch for color tracker A.1.3) – Displays position of specific color (white area on black background) (cf. A.3)
3. *Tracker Sound Control* (Patch for sound control) – Sound and Sample Selection for particular tracker (1-6)
4. *Midi Record* – Buttons for piano record (Patch for Midi keyboard) and Midi Sampler record (cf.A.1.5A.1.6
5. *Sound and Color Settings* – Drum Sample Selection, tracker selection, color settings,

A.1.2 Color Tracker Window

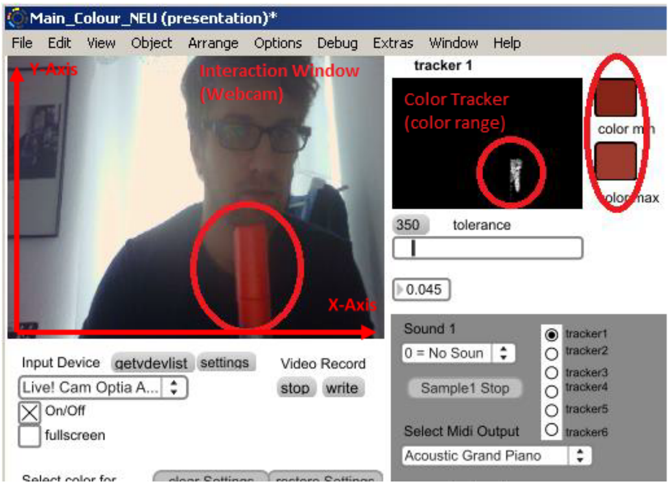


Figure A.2: MaxMSP Tracked Colored Object

The defined color object (by clicking on it color in the interaction window) will be recognized and attached to one Tracker (here Tracker 1). If this object appears in the webcam area (range of window), the object will be tracked down by its coordinates and the system follows its movement (X-Y-Axis).

A.1.3 Patch for Color Tracker

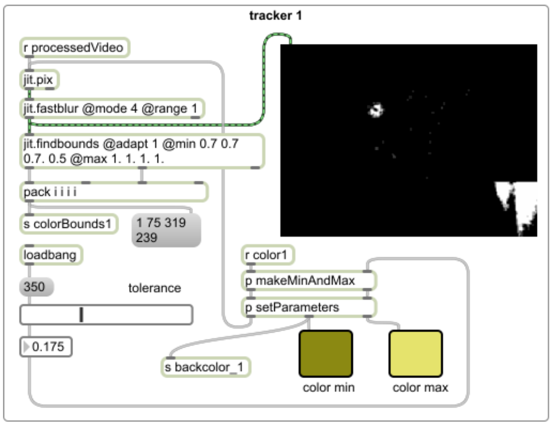


Figure A.3: MaxMSP Tracker Patch

This is the sub-patch for every *color-tracker window*. The particular color object is recognized by the specified color range in the boxes. The color range for identifying an object by its color can be changed by the tolerance controller. The most important object here is `jit.findbounds` [5]. It scans a matrix (window) for colors in range (min, max) and gives back a list of the leftmost outlet and the maximum point as a list of the second outlet.

A.1.4 Patch for Sound Control

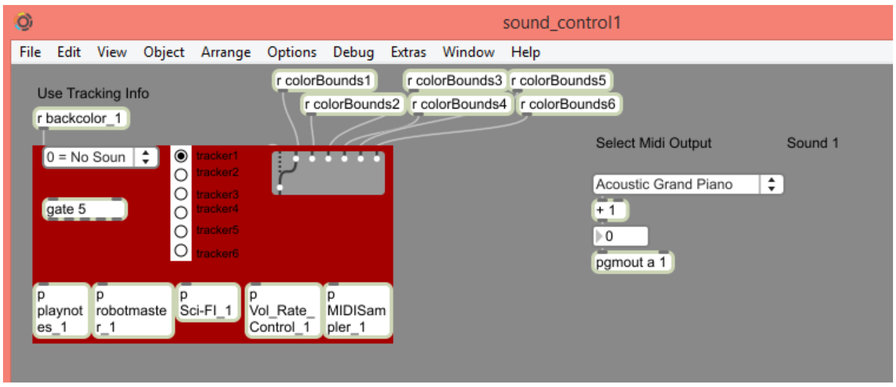


Figure A.4: MaxMSP Patch Sound Control

In this part of the patch (cf. Figure A.4), the sound output for every one of the tracker color inputs can be selected (Tracker 1 – Tracker 4). In this case the sub-patches (*p*

[5] `https://docs.cycling74.com/max5/refpages/jit-ref/jit.findbounds.html`

MidiSampler and p playnotes) will be chosen. In "'Select Midi Input"' one of many MIDI Sound Samples for the MIDI player (*p playnotes*) can be selected.

The *Interaction Window* is the part where the play or interaction is recognized. Depending on the recognition of the colored objects and their movement (cf. figure A.2) the system reacts and creates the sounds.

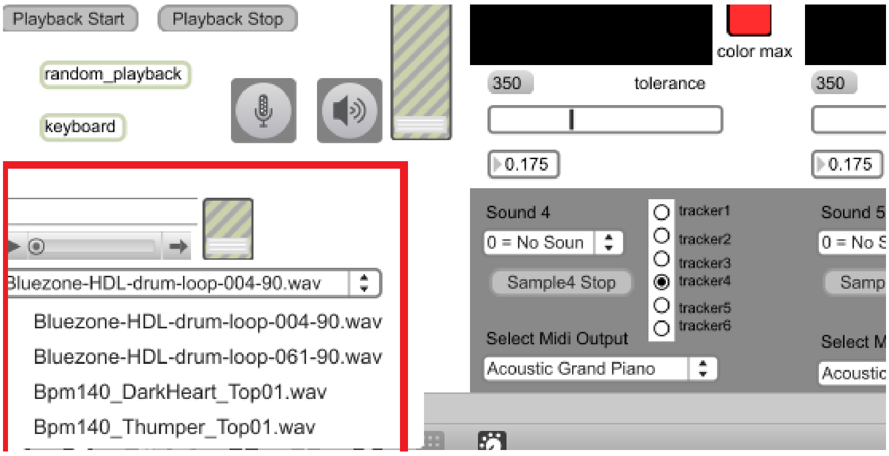


Figure A.5: MaxMSP Drum Sample Menu

Figure A.5 shows the drop down menu for choosing a drum sample.

A.1.5 Patch for Midi Sampler (Pilot Study, Pilot Study 2.0)

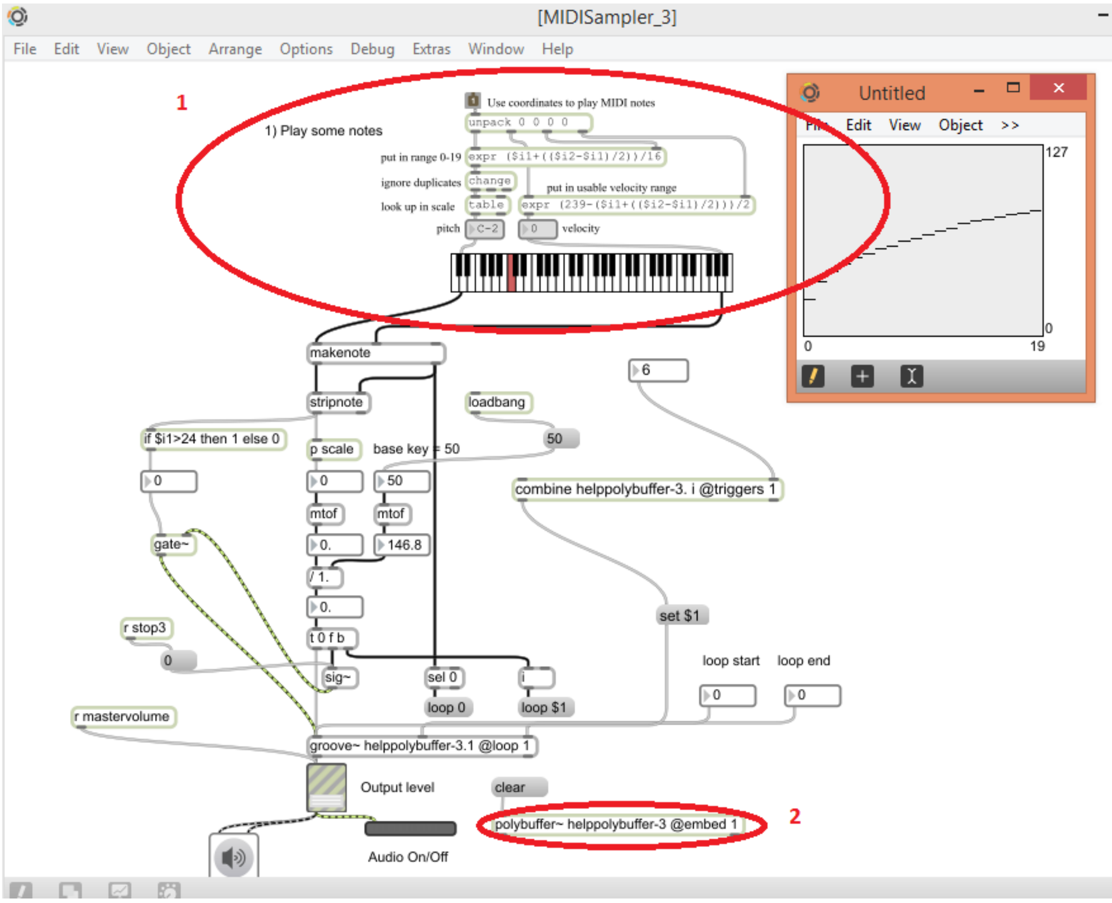


Figure A.6: MaxMSP Midi Sampler (Pilot Study, Pilot Study 2.0)

1. Maps input data to sound (coordinates/movement of tracked colored object (cf. figure A.2)

This Sound Patch and "sound mapping" method was to transform small sound samples in sound frequencies, which then can be changed in their key. The upper part of the patch (A.6 ("Play some notes") uses the **x-coordinate** of the tracked color (cf. A.2) and maps them to a specified table. The calculation object `expr` puts data in a useful range from 1-19. This was also described in the tutorial "*Midi Sampler*" [6]

Then with the object `table` a small mapping curve which maps the input data 1-19

[6] https://docs.cycling74.com/max5/tutorials/jit-tut/jitterchapter25.htmlhttps://cycling74.com/wiki/index.php?title=MSP_MIDI_Tutorial_3:_MIDI_Sampler

(values from movement and coordinates of the object on webcam) to the midi number range from 1 to 127 can defined and created. An exponential mapping curve of the sounds was the best solution after testing some sound samples for preparing the Pilot Study (cf. chapter 3.4.3.

Later on in the patch the object `mtof`[7] converts the base key from MIDI to a frequency, which is then used as a divisor for the input notes. The played notes or note changes are sent as a ratio to the `groove` object which is responsible for the playback of the created sound. For the input sample cue a helper object called `helppolybuffer`[8] is responsible for the accumulation and preparation of specific sound files (cf. chapter 3.4.5.1.

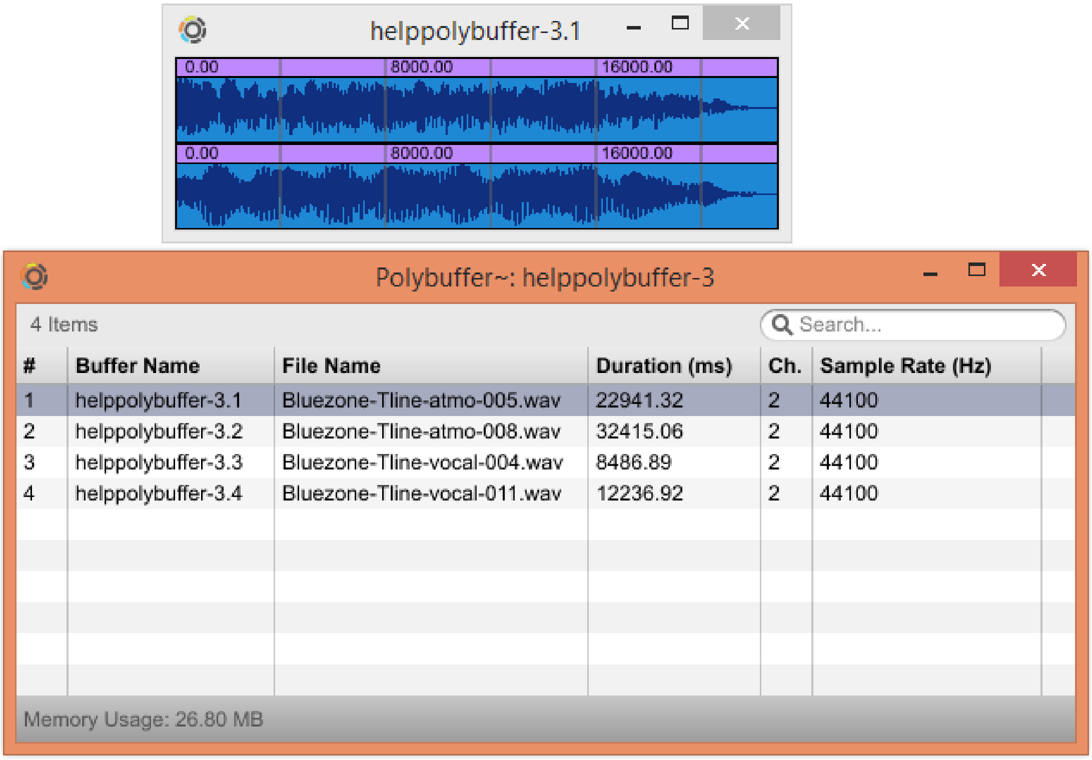


Figure A.7: MaxMSP helppolybuffer

[7] https://docs.cycling74.com/max5/refpages/max-ref/mtof.html
[8] https://docs.cycling74.com/max6/dynamic/c74_docs.html#polybuffer~

A.1.6 Patch for Midi Sampler 2 (Main Study)

This patch was implemented and used for the Main Study(cf. Chapter A.4). It uses similar objects to the *Midi Sampler Patch* (cf. Figure A.6. Instead of converting the input MIDI notes to frequencies, they were used instantly for MIDI sound output files. Furthermore, the **y-coordinate** was employed in addition for the **velocity** of the played notes as a second output characteristic. The steps in the table object are defined more steady and constant, which should fit best for the purpose.

Note scaling table The table object was needed to scale the possible **127 midi notes** to a smaller amount and range for a better use of the prototype with the colored sound objects. Because of limitations of the webcam input and the recognition of the object movement (x-y-coordinates) the best result was to map the table to **19 different notes**. It means that every colored object which is mapped to a midi sound can play 19 different notes according to its position on the x-axis. (cf. figure A.2)

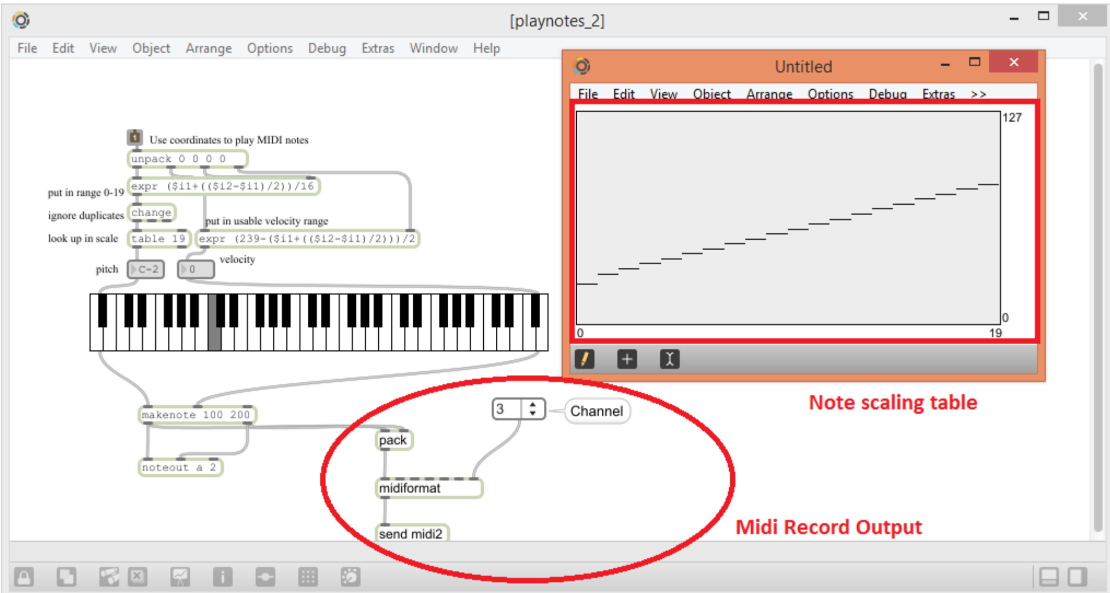


Figure A.8: MaxMSP MidiSampler2 (Main Study)

In this example following settings were used:

- X-Axis - Notes (0-19)
- Y-Axis - Velocity (Volume) of Midi Sounds (0 - 127 = 0 - 100%)

A.1.7 Midi Record (Pilot Study 2.0, Main Study)

Additionally a MIDI recorder should be used in the main study to record the participant input and the piano input. It supports both future music analysis and conclusions about the movements/positions of the colored object. Therefore, every individual colored object Midi Sampler has a separate number for the midi channel in the same Midi Data list. The piano output was recorded in a separate list with the same format.

```
358992 148 30 37;
359158 148 24 37;
359240 148 30 0;
359407 148 24 0;
361658 148 30 49;
361723 148 33 37;
```

Figure A.9: MaxMSP Midi Output List

The MIDI numbers from left to right are as followed:

- System time - Counting starts with first play (note) of CSCO/first hit of piano
- Channel - Number allocated to each CSCO (1-4) as identifier (144-147)/ 144 for piano
- Key(Pitch) - Note played by CSCO (x-axis value) /Note played by piano
- Velocity - Volume played by CSCO (y-axis value) /Velocity of hit note on piano

A.1.8 Patch for MIDI Keyboard (Piano Player)

This patch was implemented for the use and fine tuning of the MIDI piano of the piano player. Afterwards, it was also used for recording the played notes in a MIDI file for a possible later music analysis (cf. Section *Midi Record*A.1.7).

A.2 Information to Pilot Study

The first case study took place in the library of the Human-Computer Interaction Group of the Technical University Vienna in Argentinierstrasse 8, 2. Stock.

The picture A.11 below shows the study setting. At first the calibration of the color tools according to the sounds took place on the gray table. An important step was to find and calculate the right color range for every color interaction tool in MaxMSP.

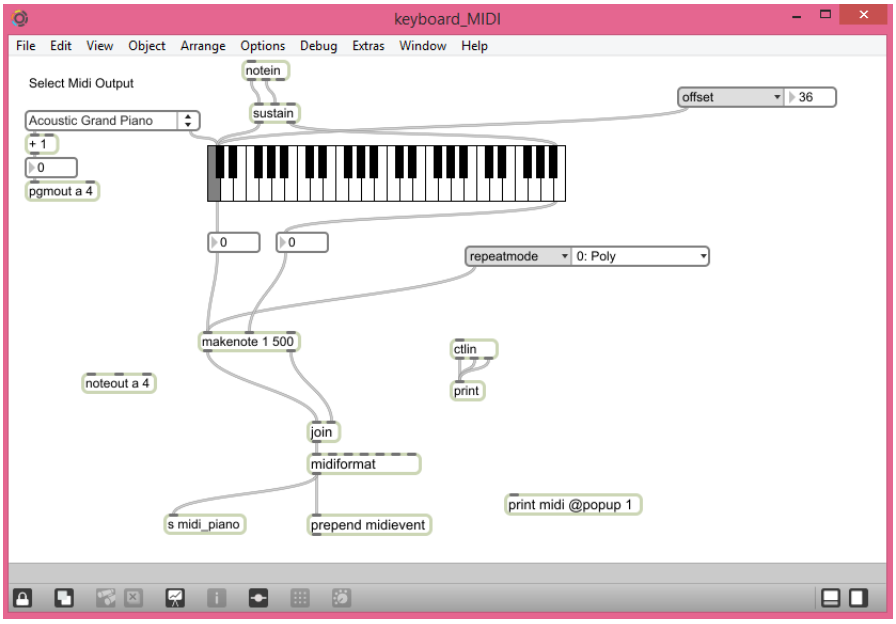


Figure A.10: MaxMSP Midi Keyboard

Figure A.11: Setting Pilot Study

A.2.1 Questionnaire summary

Interaction tools and music handling

The ball was for all of the three participants a nice tool. This tool was handy and had a good sound with good capacity and volume – accord function (P2). One (NK) had the *green marker as favorite*. One (P3) had the *pink marker*, *cause of the bass line*. P2 was concentrating on the x-axis and P3 on the y-Axis. P3: green was not so good, not important, forgotten it quickly, tries to manage orange and yellow ball.
P3: Paper was not recognizable from tone pitch. The ball and pink marker were best to recognize and to use. A *baton* and *magic* stick would be fun, too.

Positive/negative points

P1: Finding together with piano player sound. Groove in. Find same ending with the piano player. Concentration factor – good point. Complete new, so nothing negative.
P2: Interesting idea. Very exciting and most direct approach for sound creation and music making without an instrument. *"It is an easy approach to music for people who have nothing to do with it."* The system could be more precisely with half-tones → difficult to find right range of tones. *"Wanted to find right bass line to work"*
P3: More color tones would be nice. Should be more precise.

A.2.2 Notes and Conclusions

The interaction was a good test for hardware, software and interaction requirements.
Because of the occurred problems and issues, the data couldn't be relevant for a detailed qualitative study. Also, some of the unwanted technical difficulties lead to wrong study conditions.
The output of the user experiences and answers to the questionnaire gave a brief look on the behavior and feelings during the interaction, which can be compared with the further studies.
The circumstances should route to another pilot study (see Chapter A.3) for eliminating most of the problems in the process, but also have a straight line to retrace the evaluated study outputs with their solutions and conclusions.

A.3 Information to Pilot Study 2.0

Camera view and description of interaction setting

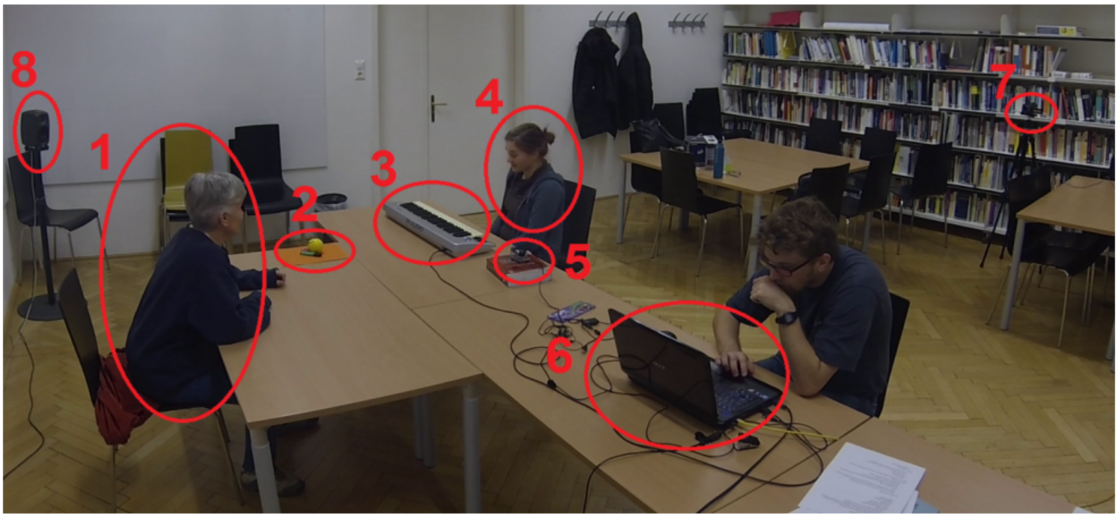


Figure A.12: Top View - Interaction Setting Pilot Study 2.0

1. Participant – uses CSCOs (2) and collaborates with piano player (4)
2. CSCOs – pink marker, green marker, orange paper, yellow ball, sound tools for the interaction
3. Piano – KORG Midi piano, instrument for piano player, sends midi data to computer (6)
4. Piano player – accompany participant in his/her music interaction with music improvisation on the piano (3)
5. Webcam (CMIS) – collects movement and color data of interaction tool and sends it to the laptop
6. Laptop (CMIS) – collects and processes interaction data (webcam, piano, MIDI data) and produces according sounds
7. front video camera (1 out of 2) – records front view of participant
8. sound box (1 out of 2) – output of sound

A.3.1 Performance Summary of Pilot Study 2.0

S2_P1 - AE, female, non-musician, 56 years)	
Overall performance	very skeptical, don't know what to do, no harmonic play, very experimental, random and playful, seems to have fun and didn't listen much to what is happening
Ball	swinging, wiggling, throwing from left to right hand, bouncing on table, rolling on the table and on paper
Pink Marker	swinging, wiggling, stepping on table
Green Marker	swinging, wiggling, stepping on table, throwing in the air
Carton	waving, tilting, rolling ball on paper

Table A.1: S2_P1 Performance

S2_P2 - BF, male, non-musician, 28 years	
Overall performance	trying out interaction field, get knowledge of range (holding tools back and forth and from left to right), very normal and common play, slow, investigative and concentrated
Ball	rolling
Pink Marker	normal
Green Marker	normal
Carton	normal

Table A.2: S2_P2 Performance

S2_P3 - DG, female, non-musician, 22 years	
Overall performance	playing with tools together (rolling ball with markers, turning markers around each other), very playfully, experimental and random
Yellow Ball	rolling, bouncing
Pink Marker	swinging, wiggling, stepping on table, rolling
Green Marker	swinging, wiggling, stepping on table, throwing in the air
Orange Carton	waving, tilting

Table A.3: S2_P3 Performance

S2_P4 - CT, male, non-musician, 29 years	
Overall performance	very normal and common play, slow, concentrated
Yellow Ball	normal
Pink Marker	normal
Green Marker	normal
Orange Carton	normal

Table A.4: S2_P4 Performance

S2_P5 - KE, male, non-musician, 61 years	
Overall performance	playing with tools together (turning markers around each other, hiding other tools behind carton)
Yellow Ball	swinging
Pink Marker	swinging
Green Marker	swinging
Orange Carton	normal

Table A.5: S2_P5 Performance

A.4 Information to Main Study

The study was held in the same location as the last two studies (A.2A.3)

Piano	Chromatic Percussion	Organ	Guitar
0 Acoustic Grand Piano	8 Celesta	16 Hammond Organ	24 Acoustic Guitar (nylon)
1 Bright Acoustic Piano	9 Glockenspiel	17 Percussive Organ	25 Acoustic Guitar (steel)
2 Electric Grand Piano	10 Music box	18 Rock Organ	26 Electric Guitar (jazz)
3 Honky-tonk Piano	11 Vibraphone	19 Church Organ	27 Electric Guitar (clean)
4 Rhodes Piano	12 Marimba	20 Reed Organ	28 Electric Guitar (muted)
5 Chorused Piano	13 Xylophone	21 Accordion	29 Overdriven Guitar
6 Harpsichord	14 Tubular Bells	22 Harmonica	30 Distortion Guitar
7 Clavinet	15 Dulcimer	23 Tango Accordion	31 Guitar Harmonics
Bass	**Strings**	**Ensemble**	**Brass**
32 Acoustic Bass	40 Violin	48 String Ensemble 1	56 Trumpet
33 Electric Bass (finger)	41 Viola	49 String Ensemble 2	57 Trombone
34 Electric Bass (pick)	42 Cello	50 SynthStrings 1	58 Tuba
35 Fretless Bass	43 Contrabass	51 SynthStrings 2	59 Muted Trumpet
36 Slap Bass 1	44 Tremolo Strings	52 Choir Aahs	60 French Horn
37 Slap Bass 2	45 Pizzicato Strings	53 Voice Oohs	61 Brass Section
38 Synth Bass 1	46 Orchestral Harp	54 Synth Voice	62 Synth Brass 1
39 Synth Bass 2	47 Timpani	55 Orchestra Hit	63 Synth Brass 2
Reed	**Pipe**	**Synth Lead**	**Synth Pad**
64 Soprano Sax	72 Piccolo	80 Lead 1 (square)	88 Pad 1 (new age)
65 Alto Sax	73 Flute	81 Lead 2 (sawtooth)	89 Pad 2 (warm)
66 Tenor Sax	74 Recorder	82 Lead 3 (caliope lead)	90 Pad 3 (polysynth)
67 Baritone Sax	75 Pan Flute	83 Lead 4 (chiff lead)	91 Pad 4 (choir)
68 Oboe	76 Bottle Blow	84 Lead 5 (charang)	92 Pad 5 (bowed)
69 English Horn	77 Shakuhachi	85 Lead 6 (voice)	93 Pad 6 (metallic)
70 Bassoon	78 Whistle	86 Lead 7 (fifths)	94 Pad 7 (halo)
71 Clarinet	79 Ocarina	87 Lead 8 (brass + lead)	95 Pad 8 (sweep)
Synth Effects	**Ethnic**	**Percussive**	**Sound Effects**
96 FX 1 (rain)	104 Sitar	112 Tinkle Bell	120 Guitar Fret Noise
97 FX 2 (soundtrack)	105 Banjo	113 Agogo	121 Breath Noise
98 FX 3 (crystal)	106 Shamisen	114 Steel Drums	122 Seashore
99 FX 4 (atmosphere)	107 Koto	115 Woodblock	123 Bird Tweet
100 FX 5 (brightness)	108 Kalimba	116 Taiko Drum	124 Telephone Ring
101 FX 6 (goblins)	109 Bagpipe	117 Melodic Tom	125 Helicopter
102 FX 7 (echoes)	110 Fiddle	118 Synth Drum	126 Applause
103 FX 8 (sci-fi)	111 Shanai	119 Reverse Cymbal	127 Gunshot

Figure A.13: General Midi List[9]

[9] Source: http://www.itimarconinocera.org/sito/menu/dipartimenti/tecnico_scientifico_informatica/corso_musica_elettronica/17_file/General_Midi.gif

Camera view and Description of Interaction setting - Main Study

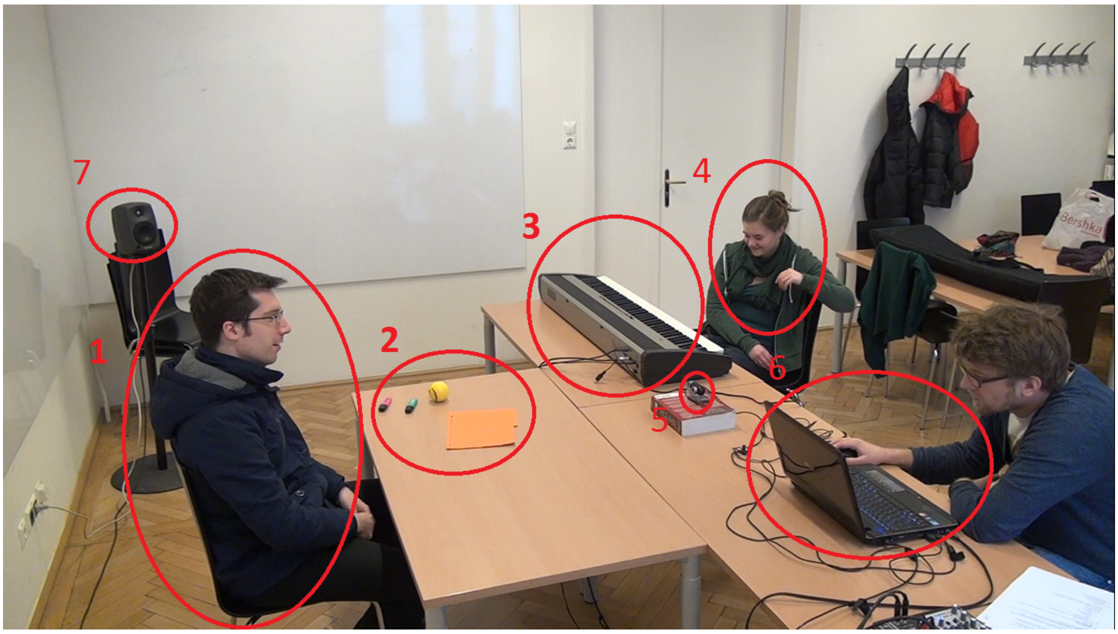
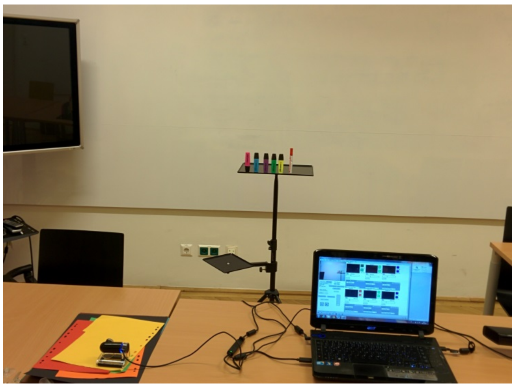


Figure A.14: Setting Main Study

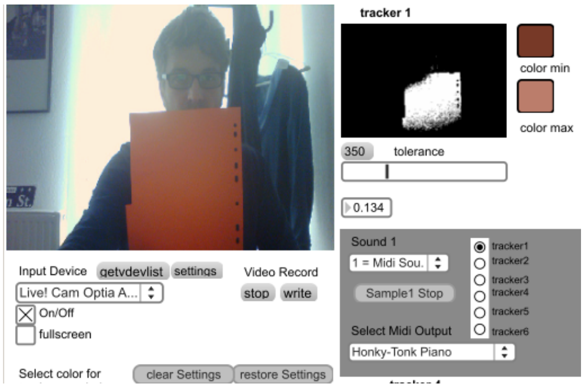
1. *Participant* – uses interaction tools (2) and collaborates with piano player (4)
2. *Interaction tools* – pink marker, green marker, orange paper, yellow ball
3. *Piano* – YAMAHA stage piano, instrument for piano player, sends midi data to computer (6), separate sound output solved MIDI latency problem (Solved issues 3.11)
4. *Piano player* – attends participant in his/her music interaction with music improvisation on the piano
5. *Webcam* – collects movement and color data of interaction tool and sends it to the laptop
6. *Laptop* – collects and processes interaction data (webcam, MIDI data) and produces according sounds
7. *2 sound boxes* – output of sound

A.5 Figures and Tables

A.5.1 CSCO Tests



(a) Color Marker Test



(b) Carton Test (MaxMSP)

(c) T-Shirt Test

A.5.2 Behavior and Object Analysis Diagrams

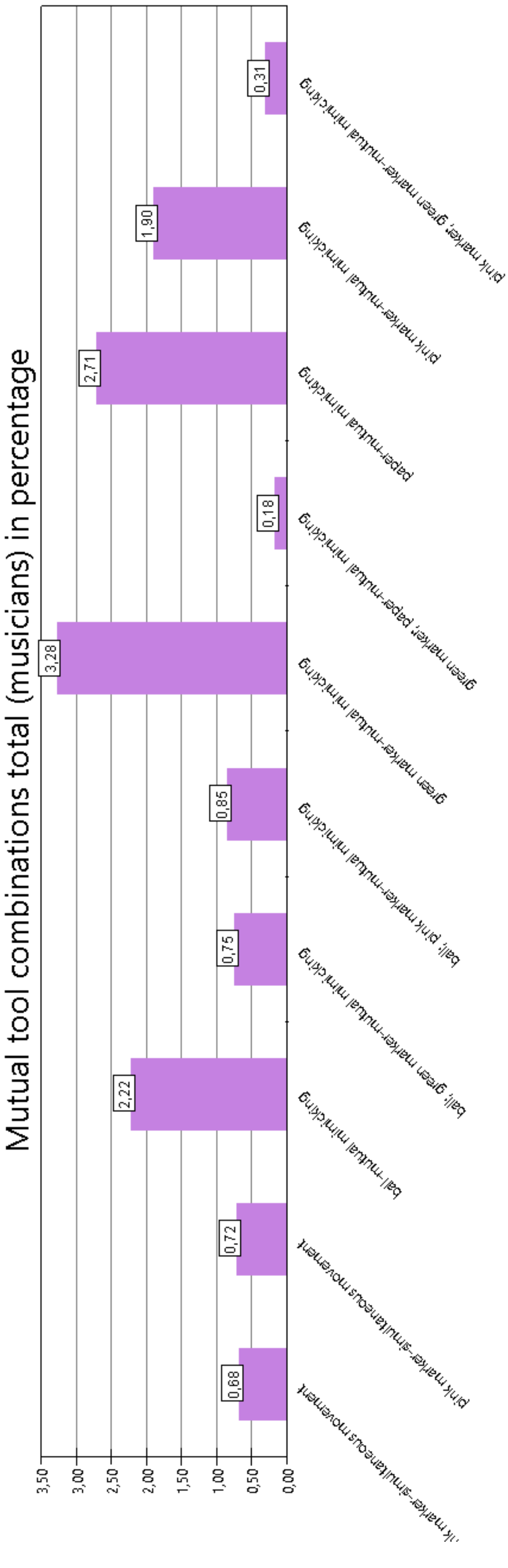


Figure A.16: Mutual Object Combinations (Musicians)

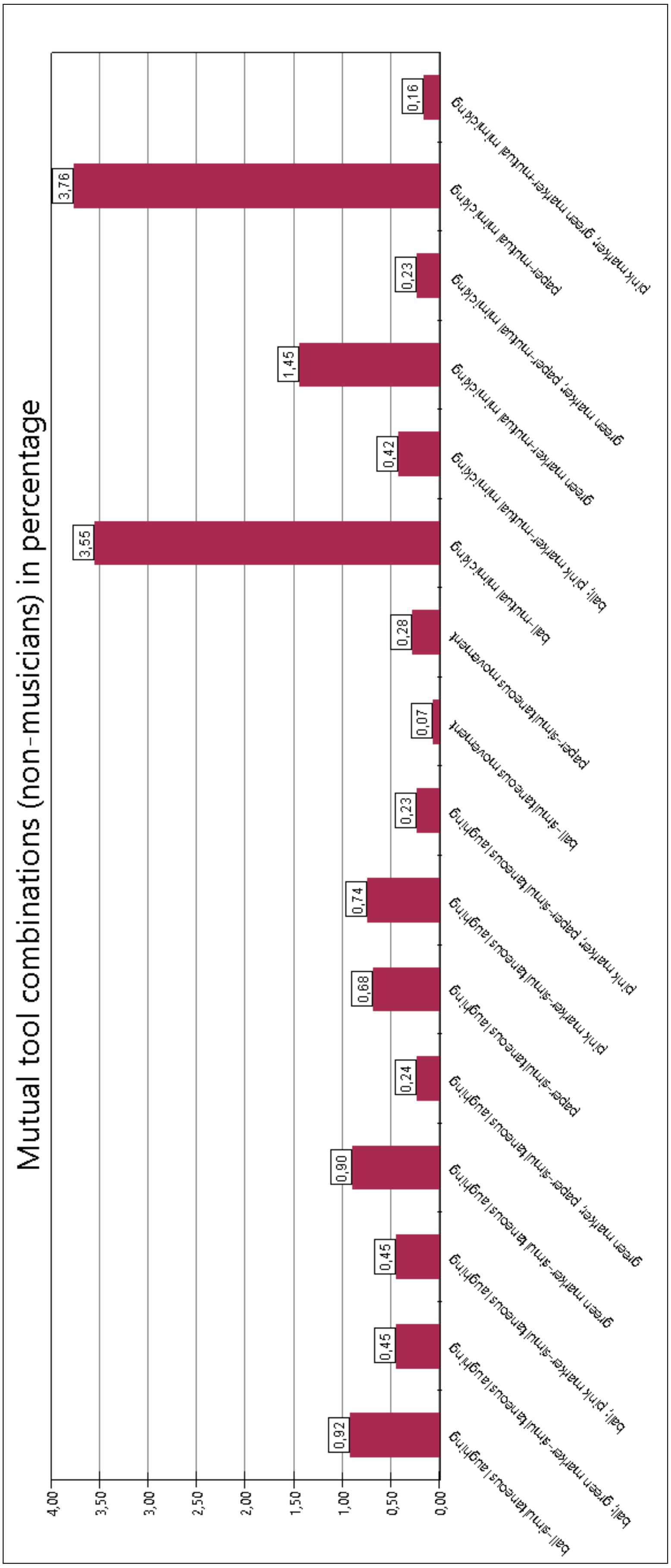


Figure A.17: Mutual Object Combinations (Non-Musicians)

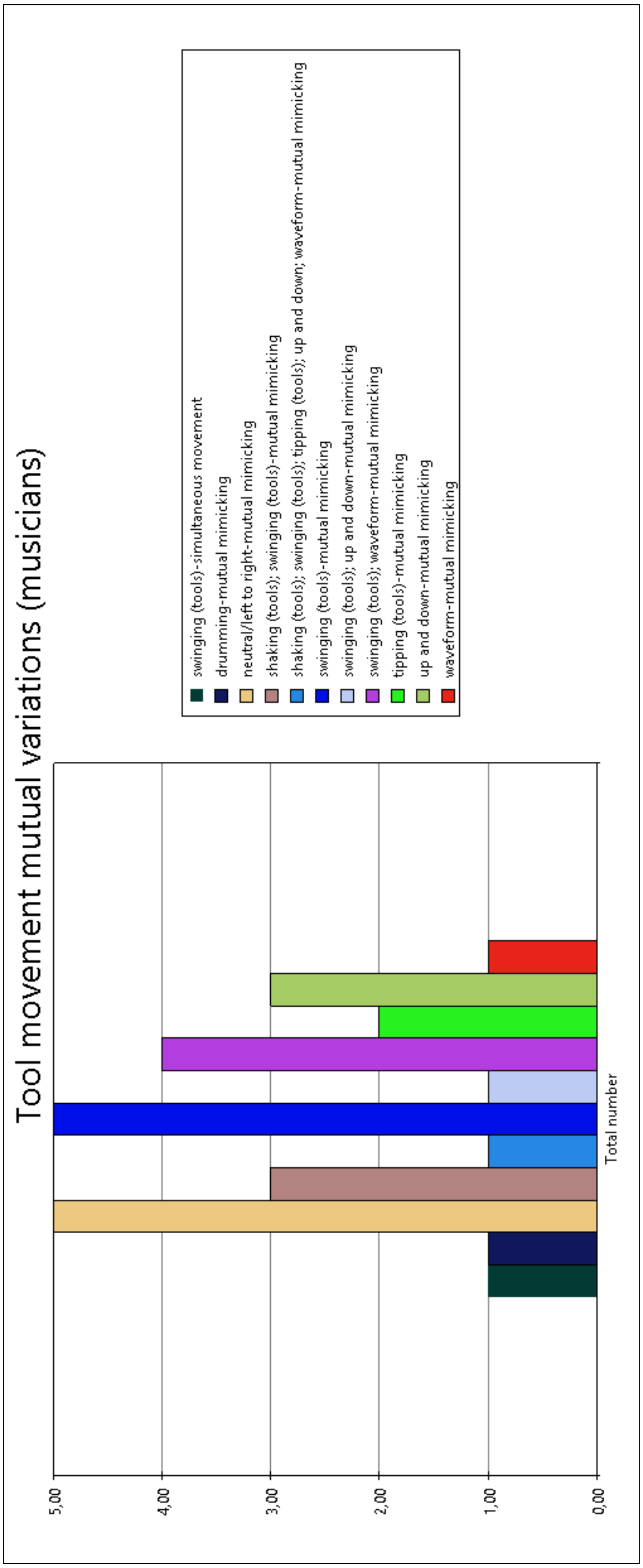


Figure A.18: Mutual Object Movement (Musicians)

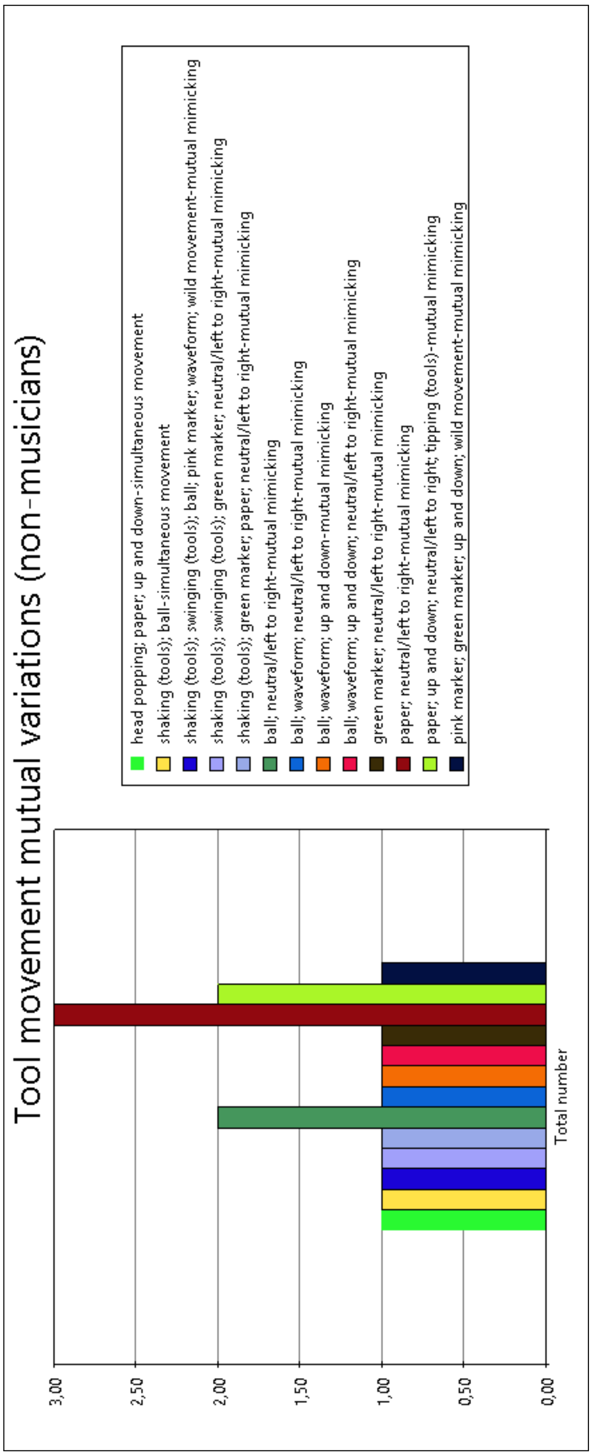


Figure A.19: Mutual Object Movement (Non-Musicians)

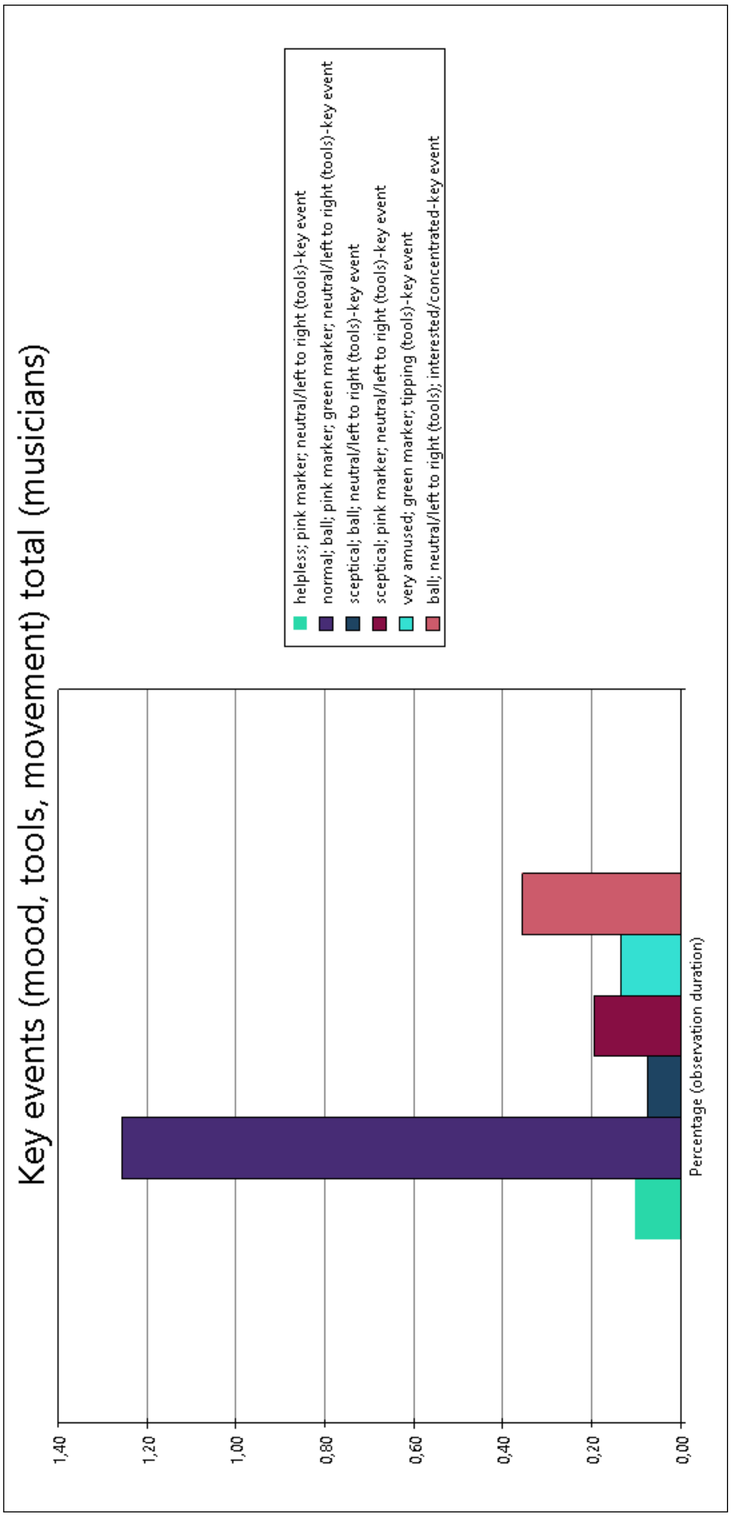


Figure A.20: Key Events (Musicians)

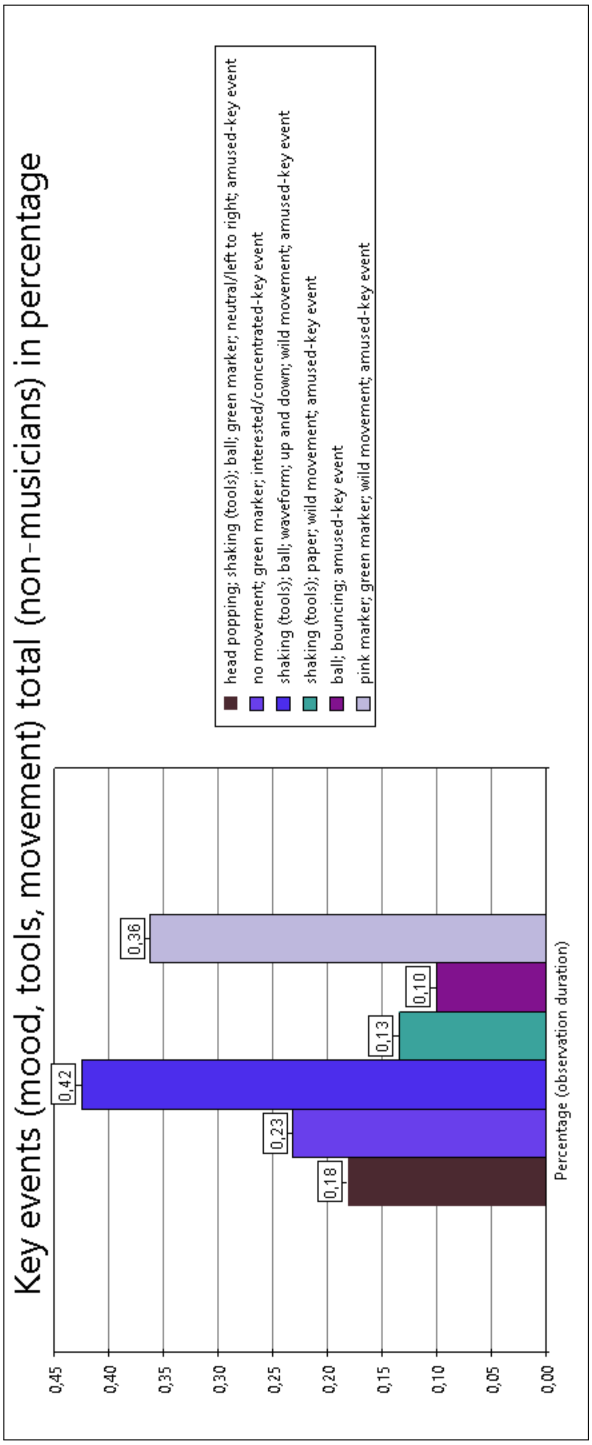
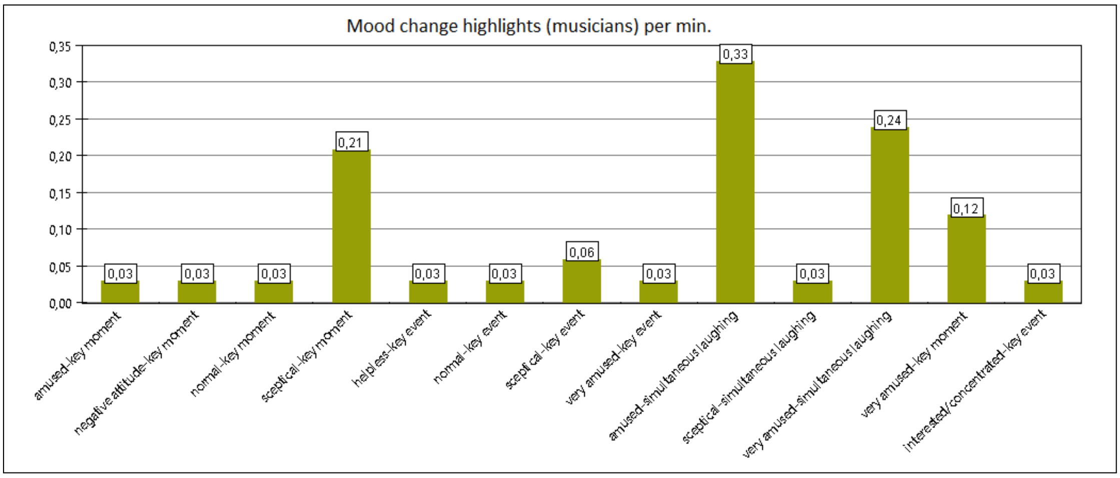
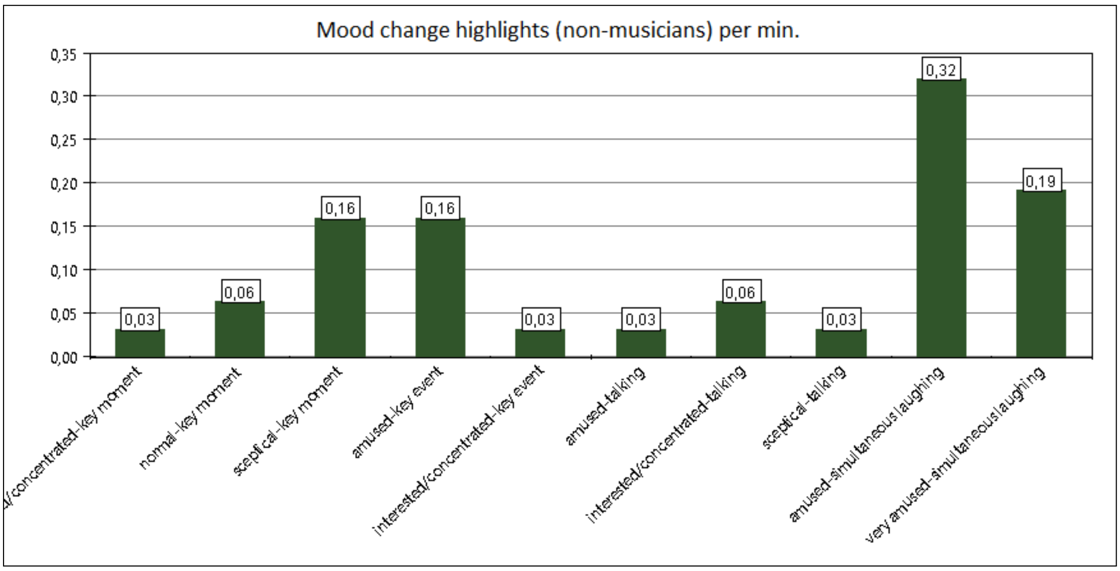


Figure A.21: Key Events (Non-Musicians)



(a) Musicians



(b) Non-musicians

Figure A.22: Mood Change Highlights

A.5.2.1 Questionnaires

Date: 21.11.2014

Interviewer:

Human Computer Interaction Group

In a few words describe how you experienced the music interaction.

Answer:

	Questions	Weak/Poor			Strong/Good	
		1	2	3	4	5
1	**How good was the musical influence of the color interaction acoustical noticeable?**					
	Comment:					
2	**Which interaction tool did you enjoy the most and why? Which was less enjoying?**	ball		marker		paper
	Comment:					
3	**Which tool could also be used for such an interaction?** *Answer:*					
4	**Do you think that this system is usable as an interaction or jam session for an interactive music creation with an musician? Yes/No? Why?** *Comment:*					
5	**Was the drum sound important and supportive for the interaction?** *Comment:*					
6	**What did you enjoy the most?** *Comment:*					
7	**What was not that good? What can be improved?** *Comment:*					
8	**Which intentions, plans, thoughts and strategies did you have during the color interaction?** *Comment:*					
9	**Do you study or work with musical background? What is your connection to music?** *Answer:*					

Thank you for the interview!!!!

Figure A.23: Questionnaire Pilot Study

Date: 18.12.2014

Interviewer:

Human Computer Interaction Group

In a few words describe how you experienced the music interaction. *Answer:*

	Questions
	Interaction with the system
1	**Which interaction tool did you enjoy the most and why? Which was less enjoying?** *Answer:*
2	**Which tool could also be used for such an interaction?** *Answer:*
3	**Which intentions, plans and thoughts did you have during the color interaction?** *Answer:*
4	**Did you have strategies and goals?** *Answer:*
	Interaction with the musician
5	**Do you think that this system is usable as an interaction or jam session for an interactive music creation with an musician? Yes/No? Why?** *Answer:*
6	**Do you think that this interaction system is usable for interactive music making and creation? Yes, why? No, why?** *Answer:*
7	**Did you interact with the piano player?** *Answer:*
7a	**YES: How did you reach that? What have been your intentions?** *Answer:*
7b	**NO: Why not? What was the reason?** *Answer:*
8	**Which influence did the piano player have during the interaction?** *Answer:*
9	**What would be the difference if the piano player is not part of the interaction and you would play alone?** *Answer:*

Date: 18.12.2014

Interviewer:

	General questions
10	**What did you enjoyed the most and what the less?** *Answer:*
11	**How can the music interaction be improved?** *Answer:*
12	**Are you in touch with music in your studies or your work?** *Answer:*
13	**Do you play an instrument? How long?** *Answer:*
14	**How would you describe your music experience or your musical understanding?** *Answer:*
15	**Are you interested in interactive music creation and do you have experience with it?** *Answer:*

Thank you for the interview!!!!!!

Is it possible to contact you for other studies?

Name:

Age:

Phone number (optional):

E-Mail:

WE ASSURE THAT WE WILL KEEP YOUR PRIVATE DATA SECRET AND PUBLISH THEM ONLY IN AN ANONYMOUS WAY.

Figure A.24: Questionnaire Pilot Study 2.0 and Main Study

A.5.2.2 Other Pictures and Tables

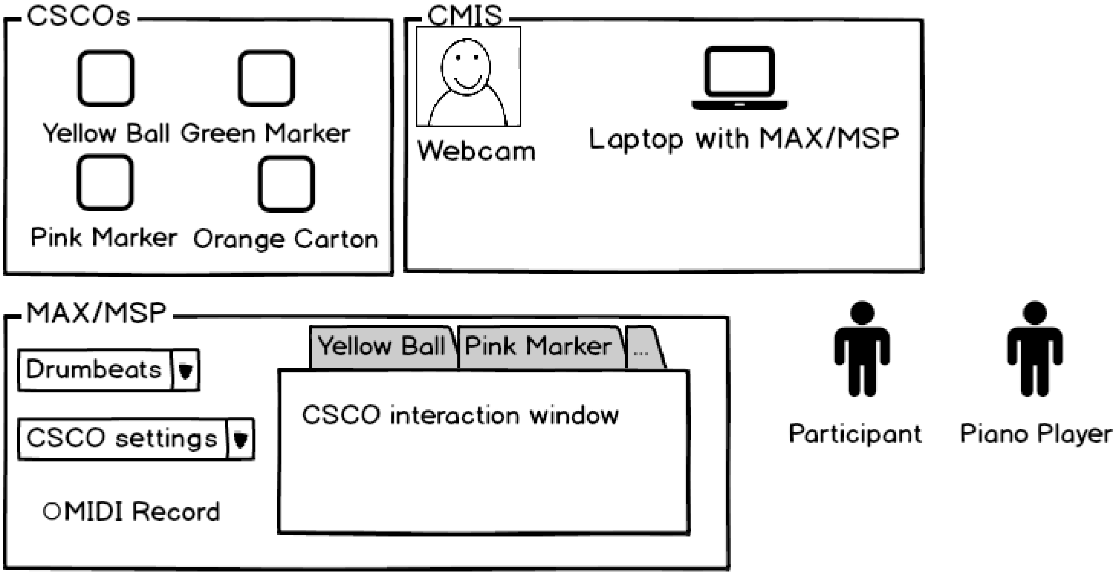


Figure A.25: Setup Components Mockup

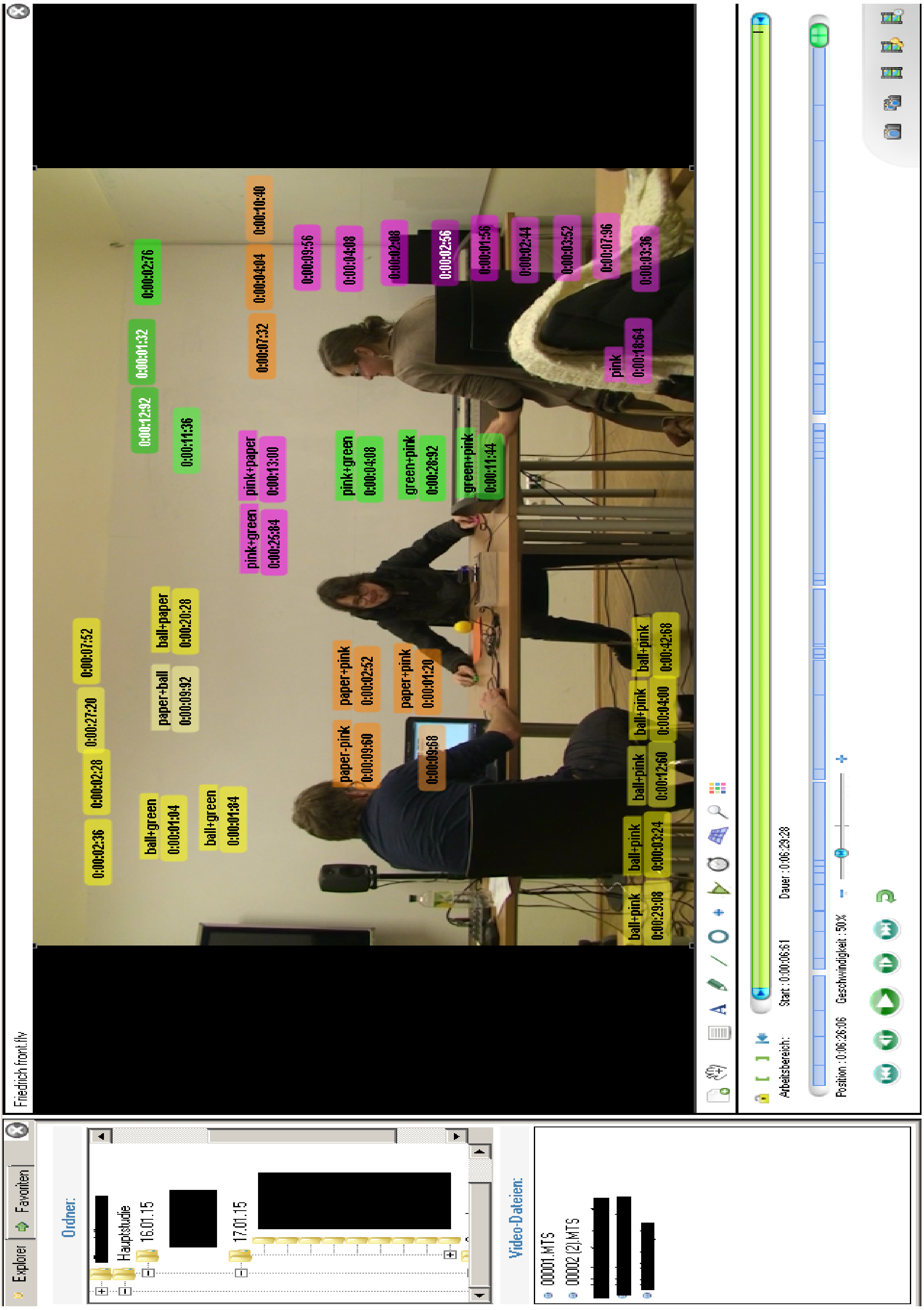


Figure A.26: Kinovea Screenshot

List of Figures

List of Tables

Glossary

CMIS A color music interaction system (CMIS) is a system that recognizes color sound controlling objects (CSCOs) by their color, interpret their movements and processes it to sound.. xv

CSCO A color sound controlling object (CSCO) is a common colored object, which is recognizable by a color music interaction system (CMIS) and can be used to handle and control sound with its movement.. xvi

Acronyms

CMIS Color Music Interaction System. xv, 2–4, 15–19, 24–26, 29, 32, 33, 37–40, 43, 46, 48, 49, 59, 60, 62–64, *Glossary:* CMIS

CSCO Colored Sound Controlling Object. xvi, 3, 4, 15–17, 19–23, 25–27, 29, 31–35, 37–40, 42, 43, 45, 46, 48–50, 59–64, 95, 96, *Glossary:* CSCO

Bibliography

[Benford, 2010] Benford, S. (2010). Performing musical interaction: Lessons from the study of extended theatrical performances. *Computer Music Journal*, 34(4):49–61.

[Berliner, 1994] Berliner, P. (1994). *Thinking in Jazz : The Infinite Art of Improvisation (Chicago Studies in Ethnomusicology Series).* University Of Chicago Press.

[Borgo, 2006] Borgo, D. (2006). Sync or Swarm: Musical Improvisation and the Complex Dynamics of Group Creativity. *LECTURE NOTES IN COMPUTER SCIENCE*, 4060:1.

[Bouwer et al., 2013] Bouwer, A., Holland, S., and Dalgleish, M. (2013). Song walker harmony space: embodied interaction design for complex musical skills. pages 241–258.

[Brougher and Zilczer, 2005] Brougher, K. and Zilczer, J. (2005). *Visual music: Synaesthesia in art and music since 1900.* Museum of Contemporary Art.

[Broughton and Stevens, 2009] Broughton, M. and Stevens, C. (2009). Music, movement and marimba: An investigation of the role of movement and gesture in communicating musical expression to an audience. *Psychology of Music*, 37(2):137–153.

[Bryan and Wang, 2011] Bryan, N. J. and Wang, G. (2011). Two Turntables and a Mobile Phone. In *NIME 2011 Proceedings of the International Conference on New Interfaces for Musical Expression*, number June, pages 179–184.

[Collopy, 2009] Collopy, F. (2009). Rythmic Light.

[Csikszentmihalyi, 1990] Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal performance.*

[Deweppe et al., 2009] Deweppe, A., Leman, M., and Lesaffre, M. (2009). Establishing usability for interactive music applications that use embodied mediation technology.

[Dobretzberger, 2014] Dobretzberger, F. (2014). colormusic.

[Doffman, 2009] Doffman, M. (2009). Making it groove! Entrainment, participation and discrepancy in the'conversation'of a jazz trio. *Language & History*, 52(1):130–147.

[Essl and Rohs, 2009] Essl, G. and Rohs, M. (2009). Interactivity for Mobile Music-Making. *Organised Sound*, 14(02):197.

[Esteves et al., 2013] Esteves, A., Quintal, F., and Oakley, I. (2013). jamTable: Can physical interfaces support the collaboration between novice and experienced musicians? *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 7989 LNCS:99–108.

[Faculty et al., 2012] Faculty, T. A., Lee, S. W., and Fulfillment, I. P. (2012). AUDIENCE PARTICIPATION USING MOBILE PHONES AS MUSICAL INSTRUMENTS COPYRIGHT 2012 BY SANG WON LEE AUDIENCE PARTICIPATION USING MOBILE PHONES AS. (August).

[Françoise, 2013] Françoise, J. (2013). Gesture–sound mapping by demonstration in interactive music systems. *Proceedings of the 21st ACM international conference on Multimedia - MM '13*, pages 1051–1054.

[Gurevich et al., 2010] Gurevich, M., Stapleton, P., and Marquez-borbon, A. (2010). Style and Constraint in Electronic Musical Instruments. *Proceedings of the International Conference on New Interfaces for Musical Expression*, (Nime):106–111.

[Hallam et al.,] Hallam, S., Cross, I., Thaut, M., and Ashley, R. Musical improvisation.

[Hansen and Andersen, 2012] Hansen, A.-M. S. and Andersen, H. J. r. (2012). Novice collaboration in solo and accompaniment improvisation. *Proceedings of the International Conference on Sound and Music Computing 2012*, pages 187–193.

[Hansen et al., 2011] Hansen, A.-M. S., Andersen, H. J. r., and Raudakoski, P. (2011). Play Fluency in Music Improvisation Games for Novices. *Proceedings of the International Conference on New Interfaces for Musical Expression*, (June):220–223.

[Hantrakul and Kaczmarek, 2014] Hantrakul, L. and Kaczmarek, K. (2014). Implementations of the Leap Motion device in sound synthesis and interactive live performance. *Proceedings of the International Workshop on Movement and Computing*, pages 142–145.

[Haverkamp, 2002] Haverkamp, M. (2002). Syn{ä}sthetische Wahrnehmung und Ger{ä}uschdesign. *Fortschritte der Akustik, DAGA.*

[Haverkamp, 2009] Haverkamp, M. (2009). *Synästhetisches Design : Kreative Produktentwicklung für alle Sinne.* Hanser.

[Hindle, 2013] Hindle, A. (2013). SWARMED: Captive Portals, Mobile Devices, and Audience Participation in Multi-User Music Performance. *nime2013.kaist.ac.kr*, pages 4–9.

[Holland, 2013] Holland, S. (2013). *Music and Human-Computer Interaction.* Springer Series on Cultural Computing. Springer London, London.

[Hsu and Sosnick, 2009] Hsu, W. and Sosnick, M. (2009). Evaluating Interactive Music Systems : An HCI Approach. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 25–28.

[Jewanski and Sidler, 2006] Jewanski, J. and Sidler, N. (2006). Farbe-Licht-Musik. *Syn{ä}sthesie und Farblichtmusik. Bern: Peter Lang.*

[Jordà et al., 2007] Jordà, S., Geiger, G., Alonso, M., and Kaltenbrunner, M. (2007). The reacTable : Exploring the Synergy between Live Music Performance and Tabletop Tangible Interfaces. *TEI '07 Proceedings of the 1st International Conference on Tangible and Embedded Interaction*, pages 139–146.

[Kaiser et al., 2010] Kaiser, G., Ekblad, G., and Broling, L. (2010). Audience participation in a dance-club context: Design of a system for collaborative creation of visuals. *Nordes*, (2).

[Knapp, 2011] Knapp, R. B. (2011). *The measurement of performer and audience emotional state as a new means of computer music interaction: a performance case study.* Ann Arbor, MI: MPublishing, University of Michigan Library.

[Kranidiotis, 2014] Kranidiotis, Y. (2014). COLOUR TUBES: AN INTERACTIVE INSTALLATION.

[Lamont, 2009] Lamont, A. (2009). Strong experiences of music in university students. (Escom):250–259.

[Lazzarini, 2008] Lazzarini, V. (2008). Erratum: New Digital Musical Instruments: Control and Interaction Beyond the Keyboard.

[Lee and Freeman, 2013] Lee, S. and Freeman, J. (2013). echobo: A mobile music instrument designed for audience to play. *Ann Arbor*, pages 0–5.

[Macdonald and Wilson, 2006] Macdonald, R. a. R. and Wilson, G. B. (2006). Constructions of jazz: How Jazz musicians present their collaborative musical practice.

[Macedo, 2010] Macedo, A. R. (2010). Visible and Audible Spectrums - a proposal of correspondence. *5ª Conferência Internacional de Arte Digital Artech 2010*.

[Manzo, 2014] Manzo, V. (2014). *INTERACTIVE MUSIC SYSTEMS*. PhD thesis, Worcester Polytechnic Institute.

[Manzo, 2011] Manzo, V. J. (2011). EAMIR.

[Manzo and Kuhn, 2015] Manzo, V. J. and Kuhn, W. (2015). *Interactive Composition: Strategies Using Ableton Live and Max for Live*. Oxford University Press.

[Maynes-Aminzade et al., 2002] Maynes-Aminzade, D., Pausch, R., and Seitz, S. (2002). Techniques for interactive audience participation. *ACM SIGGRAPH 2002 conference abstracts and applications on - SIGGRAPH '02*, (1):257.

[Mazzanti et al.,] Mazzanti, D., Zappi, V., Caldwell, D., and Brogni, A. Augmented Stage for Participatory Performances. *nime2014.org*, pages 29–34.

[Mazzola, 2008] Mazzola, G. (2008). Jazz and the Creative Flow of Collabora-Tive Gesturtes.

[McAllister et al., 2004] McAllister, G., Alcorn, M., and Strain, P. (2004). Interactive performance with wireless PDAs. *Proceedings of the 2004 International Computer ...*.

[Monson, 1996] Monson, I. T. (1996). *Saying something: jazz improvisation and interaction*.

[Oh and Wang, 2011] Oh, J. and Wang, G. (2011). Audience-participation techniques based on social mobile computing. In *Proceedings of the International Computer Music Conference 2011*, volume 2, pages 665–672.

[Pradalier and Jud,] Pradalier, C. and Jud, D. Motion Tracking Systems.

[Sawyer, 2007] Sawyer, R. (2007). *Group genius : the creative power of collaboration*. Basic Books, New York.

[Sawyer and DeZutter, 2009] Sawyer, R. K. and DeZutter, S. (2009). Distributed creativity: How collective creations emerge from collaboration. *Psychology of Aesthetics, Creativity, and the Arts*, 3(2):81–92.

[Schönhammer, 2013] Schönhammer, R. (2013). *Einf{ü}hrung in die Wahrnehmungspsychologie: Sinne, K{ö}rper, Bewegung*, volume 3142. UTB.

[Smith and Garnett, 2012] Smith, B. and Garnett, G. (2012). *Advancing Expert Human-Computer Interaction through Music.*

[Strogatz and Goldenfeld, 2004] Strogatz, S. H. and Goldenfeld, N. (2004). Sync: The Emerging Science of Spontaneous Order. *Phys. Today*, 57:59–60.

[Swift et al., 2011] Swift, B., Gardner, H., and Riddell, A. (2011). A chasing after the wind: experience in computer-supported group musicmaking. *Proc. The 25th BCS Conference on Human-Computer Interaction*, pages 1–6.

[Tahiroglu, 2009] Tahiroglu, K. (2009). Dynamic Social Interaction in a Collective Mobile Music Performance. *2009 International Conference on Computational Science and Engineering*, pages 854–859.

[Tuedio, 2006] Tuedio, J. A. (2006). "AND THEN FLEW ON": IMPROVISATIONAL MOMENTS OF RHIZOMATIC ASSEMBLAGE IN GRATEFUL DEAD MUSICAL EXPERIENCE.

[Turino, 2008] Turino, T. (2008). *Music as social life: The politics of participation.* University of Chicago Press.

[Weinberg et al., 2009] Weinberg, G., Raman, a., and Mallikarjuna, T. (2009). Interactive jamming with Shimon: A social robotic musician. *Human-Robot Interaction (HRI), 2009 4th ACM/IEEE International Conference on*, pages 233–234.

[Weitzner, 2012] Weitzner, N. (2012). massMobile–an audience participation framework. *Proceedings of the ....*

[Wipperfürth, 2011] Wipperfürth, S. (2011). *Syn{ä}sthetische Beziehung zwischen auditiven und visuellen Elementen.* GRIN Verlag.

[Xambó et al., 2013] Xambó, A., Hornecker, E., Marshall, P., Jordà, S., Dobbyn, C., and Laney, R. (2013). Let's jam the Reactable: Peer learning during musical improvisation with a tabletop tangible interface. *ACM Trans. Comput.-Hum. Interact.*, 20(6):34.

[Xambó et al., 2011a] Xambó, A., Laney, R., and Dobbyn, C. (2011a). TOUCHtr4ck: democratic collaborative music. pages 309–312.

[Xambó et al., 2011b] Xambó, A., Laney, R., Dobbyn, C., and Jordà, S. (2011b). Multi-touch interaction principles for collaborative real-time music activities: towards a pattern language. (August).

[Young, 2001] Young, J. P. (2001). Using the Web for Live Interactive Music. In *Proceedings of the International Computer Music Conference ICMC*, pages 302–305.

[Zappi and Mcpherson, 2014] Zappi, V. and Mcpherson, A. P. (2014). Dimensionality and Appropriation in Digital Musical Instrument Design. *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 455–460.