The Vocal Chorder – Empowering Opera Singers with a Large Interactive Instrument

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ABSTRACT
With *The Vocal Chorder*, a large interactive instrument to create accompaniment, opera singers can get more power over the performance. The device allows performers to interactively accompany themselves through pushing, leaning on and bending steel wires. The design was guided by the unique needs of the solo-singer, explored through autobiographical design and material explorations, some on stage, and later tested by other singers. We discuss how designing for opera and for the stage requires extraordinary durability and how opera performances can change with a bodily-oriented instrument such as The Vocal Chorder. Through a designerly exploration, we arrived at a device that offered (1) a tool for singers to take control over the rhythmical pace and overall artistic and aesthetic outcome of their performances, (2) an enriched sense of embodiment between their voice and the overall performance; and (3) a means to empower opera singers on stage.

Author Keywords
Opera; Autobiographical design; Interactive instruments; embodiment; empowerment; appropriation

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Human Factors; Design

INTRODUCTION
We aim to describe a designerly exploration (following the terminology of Zimmerman and colleagues [38]) leading to the creation of a novel, interactive instrument for the opera – the Vocal Chorder. As opera is a highly physical art form, taking quite some space on stage, we built a large artifact that would allow singers to accompany their own voices through bodily interaction**.** The device is designed to endure the demands that are typical for the stage: reliability, repeatability and stamina. Whereas opera originally constituted an innovative cultural movement where singers fully participated in the artistic processes, contemporary opera productions have become increasingly hierarchical and singers' influence on the creative process is becoming more and more limited – both off and on stage. This is what we set out to address with our device.

CHI 2014, April 26 - May 01 2014, Toronto, ON, Canada

Designing for Empowerment
By designing for empowerment through putting the control of the accompaniment in the hands of the singer, we, in a sense, link our research to early operatic practices. As design for the opera is a novel domain for interaction design, we will provide a brief background to opera and discuss some of the particular challenges of this design space. We will focus on describing how opera started out as an exploratory art form and how our designerly explorations in that sense reconnect to the early developments of opera.

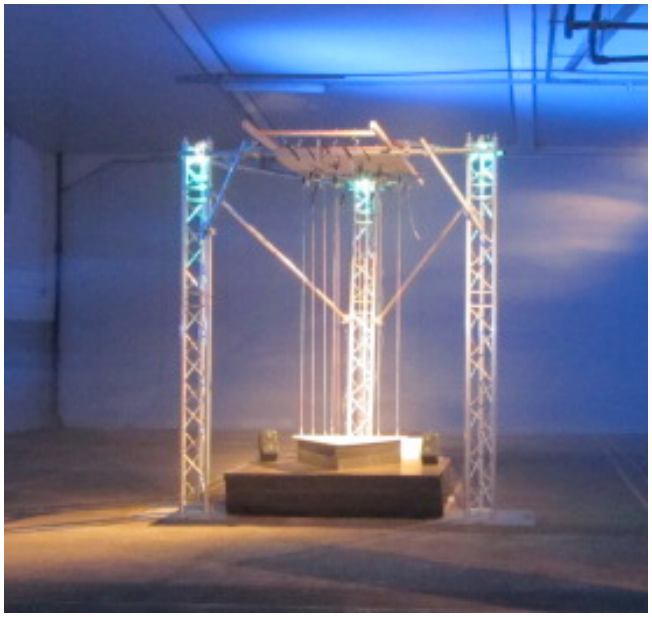

Figure 1. The Vocal Chorder

Given this background, we will then move on to describe some of the designerly explorations, lasting over several years, that resulted in this particular instrument. We will focus on four cases of interactions and performances we engaged in. In particular, the first author of this paper, who is an opera singer and composer, used himself as both sub-

ject and object of our design inquiry – a method referred to as autobiographical design [27]. Our work with The Vocal Chorder is therefore an example of research *through* art and design, as opposed to research *for* or *into* art and design, as differentiated by Frayling [8]. Our findings add on to a historical context of searching new expressions through exploring the art form opera with new works and technologies. We end by discussing how our insights are relevant beyond developing the operatic art proper, in particular for other on-stage settings.

RELOCATING CONTROL IN PERFORMANCES

We are not the first to explore the topic of empowerment in on-stage performance. There are several examples where the audience can partake directly in the performance through various interactive technologies. For example, in the humanaquarium musicians were placed in a large interactive glass box in public places and people walking by could change their performance through touching the glass box [30]. There are also numerous examples of how to use movement sensors to allow audiences to influence both music and imagery, see e.g. [13, 17, 29]. On stage, digital interactivity in different forms have been introduced to put artists, musicians and singers, in charge of the overall aesthetic form of their performance, see e.g. [1, 11, 35]

More specifically, in the opera context, there has been many fertile encounters between electroacoustic music and vocal performances both on and off the stage since the birth of Elektronische musik [4] and Musique Concrète [25] in the 1940s and 50s. Through the appearance of computerized interactive musical instruments, around 1990 and onwards, we got works like Machover and Paradiso's *Brain Opera* that explored opera on-line [18], Waiswisz's interactive interface *The Hands* for controlling sounds through gestures [34], and Manoury's *K...* [20], where interactive technologies aim to liberate the singers on stage. Composers such as Stockhausen, Nono, Berio, Ligeti, Cage, Wishart, Adams and Saariaho have incorporated electronic processing of voices in their operas and vocal music[1]. Research institutes where vocal music and various forms of interactivity has been developed in particular are STEIM in the Netherlands [13, 17, 34, 35], IRCAM in France [1, 20, 29], and Opera for the Future Lab at MIT in the US [11, 18]. An interactive gesture controller was created by Park and colleagues [19], allowing singers to generate additional vibrato and other vocal effects through embedded sensors. In the opera *Death and the powers* [11] various real-time interactive technologies were deployed to create a "disembodied performance" in order to portray a dystopic scenario. In the opera *The Crystal Cabinet* [33], singers and dancers functioned as joysticks. Entering "The Charged Room", they scratched their sounds through altering their positions, letting the resulting sounds feed back into the performance, thereby creating new movements and new sounds. Moreover, the research around *The Throat III* [5, 6, 31] revolves around embodiment of singers' voices in relation to an interactive hand-held instrument for vocal manipulation. With The Throat III, the control of the performance resides in a glove put on the singer's right hand. It modifies the singer's voice to artistically portray and embody the disformed voice of *The Elephant Man.*

Long-term changes in power hierarchies in opera

But apart from our own work on *The Throat III*, to our knowledge, none of these projects have aimed to create interactive instruments that can both empower opera singers at the same time as they improve and extend on the aesthetic and experiential qualities of the whole performance.

There is an incongruity between the aura around famous opera-singers, "divas", supposedly mastering the end-result of their performances and the reality where the contemporary opera singer have little influence over the essential creative process. It has been argued that the opera-world of today is "the age of the producer" and that sequentially the ages of the poet, the singer, the composer, and the conductor have passed by [14]. According to this viewpoint, singers' influence decreased already at the end of the 18th century when composers' influence increased. They, in turn, lost power in favor of the conductors during early 20th century. Finally, the producers (agents, casting directors, and others) of opera today excel the main authority over artistic decisions. Accordingly, this ongoing change in power hierarchies continuously changes the conditions for the singers.

OPERA AND INNOVATION

Opera was born at the end of the 16th century when a group of artists, the Camerata Florentina, were searching for new expressivity that would help them re-create what they understood as the antique drama [23]. In this double procedure of both looking backward to a presumably forlorn art and at the same time envisioning something new, the art form we now refer to as opera was born. In early opera, the solo-singer was commonly accompanied by only one instrument – a harp or a lute – creating a rhythmical and harmonic grounding on top of which the singer performed the vocal lines with a large amount of improvisation. Singers developed virtuosity both in a technical sense, and in an aesthetic sense, adding flavor and personality to the performance within the boundaries that composers and authors had set in the score. In the very early days, there seems to have been less demarcation between creating and performing opera. It has been reported that Jacopo Peri, composer of the very first opera *Daphne* in 1597, accompanied himself on the lute whilst singing [2, 22]. This practice then became less and less common throughout the history.

[1] E.g. Karl-Heinz Stockhausen: *Gesang der Jünglinge* 1956 and *Stimmung* (1968); Luigi Nono: *A floresta é jovem e cheja de vida* (1966); Luciano Berio: *Coro* (1976); György Ligeti: *Le Grand Macabre* (1977); John Cage: *Roaratorio* (1979), Trevor Wishart: *Anticredos* (1980), John Adams *Nixon in China* (1987), and Kaija Saariaho: *From the grammar of dreams* (2002).

However, the innovative and creative search for new expressions continued in opera. For example, as a result of the focus on vocal performance, the particular singing technique evolved which constitutes what we today understand as operatic singing, *Bel Canto* [2, 22, 28]. In short it means that a singer through years of study acquires loudness, a homogenous sound in all registers and stamina to withstand a whole performance. On top of that the performer integrates singing with acting and drama.

Orchestral Instruments Changing Singer Conditions

At the end of the 19th century the romantic orchestra had reached its full power, often numbering over 100 persons, each playing on instruments that constantly were developed to gain more loudness. We see this for example, in how the gut strings of the violin were replaced by strings made of steel during the late 17th century, empowering the violin section with a much louder volume. In parallel, the wooden flute evolved to a metallic version, and brass instruments such as the trumpet and the trombone improved likewise. These ongoing modifications in the orchestra required changes in vocal practice. One example is when the tenor Gilbert-Louis Duprez invented a means to sing the "high c" with a full voice in 1837. Earlier, high tones in the tenor voice were managed through singing with the so-called "head voice", whereas Duprez introduced his new technique to bring also the "chest voice" up to the high pitches [3], enabling louder and more heroic singing. In parallel, the vocal parts created by composers such as Wagner, Berlioz and Verdi were stretching the boundaries of the human voice. In order to find and train singers that could manage the high-strung vocal parts, such as Wagner's *Tristan* – by contemporaries deemed as "unsingable" [12] – the German *Fach-system* emerged [16]. According to this now internationally established practice, an opera-singer's vocal career is structured in accordance with the available repertory, allowing the artist to perform a rather narrow range of roles supposedly fitting for each type of voice. This system has evolved in order to provide singers to the opera houses, but has detrimental consequence such as that it tends to narrow the individual artistic freedom for singers and even has negative impact on their health [22, 24, 28].

Composers Stretching Boundaries

Thus, the specific way of utilizing operatic voices, as we know it today, evolved throughout the centuries in a history of innovations, co-evolving with the repertory and the orchestra. Composers have continuously been exploring the human voice as well as making use of novel instruments in order to enhance expressivity and create novel artworks. Many of the canonical composers were in fact singers themselves, e.g. C. Monteverdi and G. Rossini. Moreover, composers of opera have often merged newly invented instruments in their orchestras, as was the case when Kastner, for example, introduced the saxophone and Messiaen utilized the synthesizer *Ondes Martenot* in their operas[2].

Questioning a Traditional Framework through Design

The artistic framework and possible ways of interpreting a particular opera are in most parts predetermined even before rehearsals start, as most operas in the common repertory have been staged many times before. Moreover, as the music in most cases was composed a long time ago, there is little room for the singers to partake in the overall compositional decisions. Albeit there are numerous examples of influential contemporary singers (notably Cathy Berberian, herself a composer, and groups such as The King's Singers and Electric Phoenix) that have been muses for the creation of important vocal works, it is rare for singers to have influence on the musical foundations – nor has technology seldom afforded feedback to the performers themselves. The singers that took part in our work all expressed a wish of participating more in the aesthetic shaping of their art form. Acknowledging opera-singers through designing an interactive instrument for them challenges century-old power structures in opera through letting singers actively taking part in shaping the performance.

A DESIGNERLY APPROACH TO DESIGN OF MUSICAL INSTRUMENTS FOR THE OPERA

The Vocal Chorder introduced here, is part of a larger research *program* aiming to open and populate a new *design space* [36] in opera. According to Redström [21] a research program in an interactive design research setting consists of three steps: (1) formulation of a program, often starting through extensive exploration of the aesthetic qualities of the material at hand – be it electricity, interactive textiles or, as in this case, opera, (2) realization of the program through design experiments – *exemplars*, and (3) finally articulation of the experiments through reflection. The latter often leads to reformulation of the overall program. Redström has used this framing of design research to open design spaces such as "slow technology", interactive textiles or aesthetic ways to communicate energy consumption in the home [9, 21]. Of key importance in a designerly research exploration is to let the particular exemplars both explore possibilities and inform the overall research program. That is to say, through the actual design process, the key knowledge is gained [10].

Through our work with the *exemplars* The Vocal Chorder, reported here, The Charged Room [33] and The Throat III [5, 6, 31] we are taking our first steps towards the articulation of a research program investigating new aesthetic expressions for opera. A main defining property of exemplars in this design space is emancipation of the artist through the use of an interactive instrument. To explain what we mean by this, let us go into a quite detailed account of how the Vocal Chorder emerged.

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[2] Jean-Georges Kastner: *Le dernier Roi de Juda* (opera, 1844); Olivier Messiaen: *Saint-François d'Assise* (opera, 1975-83)

THE VOCAL CHORDER DESIGN PROCESS

Drawing on autobiographical design procedures [27] that *"rest(s) on the user's genuine need for the system"*, and that allows for *"a much tighter coupling between user input and implementation"*, we departed on an intense journey of material explorations (here we follow on the materiality strand in HCI [7, 37] that we will account for below. As the first author is an opera singer and composer, the early explorations built to a large extent on his own needs.

After describing his explorations and needs, we turn to performances by other opera singers reporting on their experiences of performing with the device.

The outcome of this process was not only an interactive instrument, The Vocal Chorder, but in fact several different versions of the instrument as well as range of performances with operatic music composed specifically to enhance experiential and aesthetic qualities of the artifact.

Figure 2. Sensors consisting of wheels, housing, cabling and potentiometers (in blue in the upper right corner detail)

Starting the Material Explorations

When computers started to encompass real-time audio processing, performing with laptops on stage became more and more common. Around 1999, laptop computers were powerful and stable enough to allow for using them live whilst performing music. A few years later, around 2003, they could also process images and video in real-time. On the one hand, this opened up for performing in novel ways in "laptop performances". On the other hand, this would normally mean that artists were constantly sitting behind computer screens during concerts and shows. At the time, however, new technologies such as sensors and wireless connectivity were becoming more commonplace, providing a new material that could be used to design novel interactive instruments. Many different ideas for how to create a bodily instrument allowing for interactions with sensors and wireless connectivity were discussed and dismissed before we arrived at the design we describe below, where we finally arrived at a solution that let performers immerse in the interface while performing.

Choosing our Components

We set out on our explorations with the wish that the design should dodge the need to be monitored from the outside by an artist sitting behind a computer screen. Rather, the performance should arise as an autonomous activity by the interactions with and through the instrument. This wish for an emancipating instrument on stage placed strong demands on robustness and reliability of the components and in the overall design of the artifact as well as in the software. We could not risk designing an instrument where singers would not be able to fulfill a whole performance on stage. To feel secure on stage, performers need to rest assured that the instrument and all the components will endure the physical demands on stage and will not let them down while performing. We can simplify what is needed into three sets of components: *hardware, software* and *music*. The hardware consists of all the physical parts we needed to place on stage, which in the end became a combination of sensors, steel wires, cabling, computers, two projectors and a synthesizer. The software had to process and remap incoming signals to outgoing sound and visuals. And finally, we needed new music that would thrive on the particulars of the artifact.

Hardware

Musical Instrument Digital Interface (MIDI) is a standard for communication between digital musical instruments and computers. In order to transform movement to electric signals, we used a so-called voltage-to-midi-converter[3]. The converter had eight inputs where eight independent streams of variable electric current could be transformed to MIDI. In order to produce the currents, eight *potentiometers* were used (see upper right detail in Figure 2). A potentiometer is a simple device where turning a knob changes the amount of voltage that is allowed to pass through it. By turning the knob, the changes in current would occur that we wanted to transform to MIDI and later to music and visuals. To find means to twist the potentiometers we needed to transform movement from the body in space to the turning of the knob. The most straightforward way to do this would perhaps have been to mount larger knobs on the potentiometers, but we wanted to achieve a larger interaction that would allow the performer to inflict changes with bodily movements. We tried various ways of turning the knobs with cords that were wrapped around them. But the need for more performativity led us to try steel wires leading from the floor to the ceiling, enabling the performer to stand when pushing and pulling them over the potentiometers. The potentiometers where therefore mounted in the ceiling on wheels made of styrene which were mounted in metallic housings enabling the steel wires to roll them back and forth. Thereby the wires influenced the eight potentiometers (see Figure 3).

[3] Rolls MP-2884, Voltage to Midi Converter.

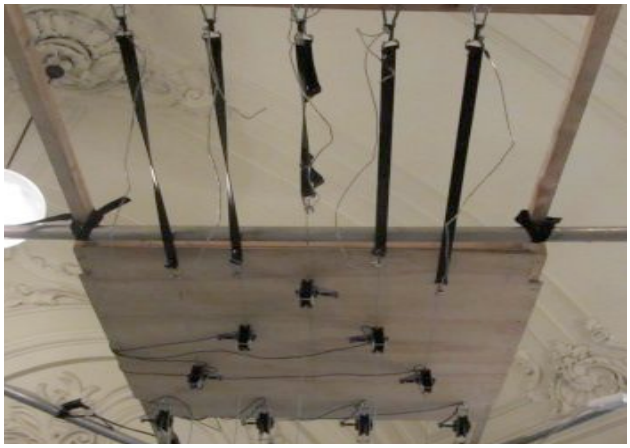

Figure 3. Potentiometers mounted in styrene wheels, allowing the flexibility of rubber to roll them via the wires

As we wanted the movements of the performer to be large and even allow the artist to lean on the wires, we needed a construction that would endure the weight of a person. Therefore, thick rubber bands were fixed at the end of each wire. The rubber bands allowed for flexibility that let the wires roll over the wheels to twist the potentiometers with large pressure. Moreover, a physical housing was built, enabling the performer to step into the artifact in order to interact with it from within, see Figures 5 + 6. The whole construct was 3.5 high and the surface measured 2*4 meters.

Software

To be able to remap incoming MIDI-data originating from the potentiometers to sounds and visuals, we used the software Max/MSP/Jitter (Figure 4). This programming environment enables simultaneous processing of MIDI, audio and visual data[4]. The software had to map the eight separate incoming streams of data into both music and in visuals. It enabled the movements of the performer via the wires to simultaneously inflict changes in sound and vision. As can be seen in Figure 5, two projectors showed an interactive pyramid, which was rendered with Max/MSP/ Jitter. The music that was composed for The Vocal Chorder, was inspired by a short story by Ray Bradbury, "Tomorrow's Child", that revolves around a child that was born in another dimension. The story opens with the line *"He didn't want to be the father of a small blue pyramid"* and we wanted to convey this emotion in the performance. Through the performers interactions, the pyramid responded to the movements of the singer that at the same time created accompaniment for the voice in the music.

[4] www.cycling74.com

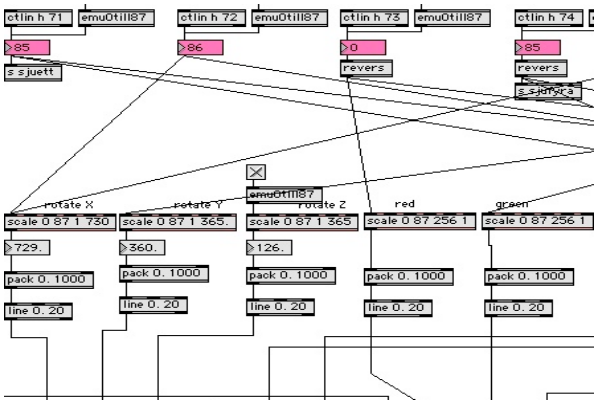

Figure 4. Detail from a patch in Max/MSP/Jitter showing mapping of parameters from incoming data to audio & visuals

Music

In parallel to these material exploration processes, music that would thrive on the artifact's particulars was devised. To be able to use The Vocal Chorder for accompaniment, music that could be performed via the wires was needed. This called for a particular solution in the musical structure and in the resulting composition. Most music can be analyzed and subsequently parsed into a block of tones that sound simultaneously, called a *chord*. Normally a chord is played by a guitarist or pianist using both hands.

Figure 5. Singer interacting with sound and visuals

Here, we wanted to simplify this so that a singer could interact with the artifact without being an instrumentalist. We realized that if we could alter the playing of chords so that they could be forwarded one at a time, the performer would control the ongoing pace of the music. To achieve this, the device was equipped with a chord-forwarding feature – a dedicated wire operated by the singer that would forward one chord at a time when pushed over a preset break point. When a row of chords is at hand, they constitute a *chord sequence.* We devised a long chord sequence that would allow the composition to be forwarded by the performer by bending one of the strings. The bending of the strings in

order to advance the chord sequence became an important building block for both the design of the artifact as well as for the music composed for it as it emancipated the singer.

Allocating wires to different components of the performance
The other wires were allocated to change the sound of the synthesizer as well as modifying the interactive visuals projected by the two projectors, as seen in Figure 5. For example, bending wire number three would inflict changes in the sound of the chord and at the same time make the pyramid turn slowly in space. Likewise, bending wire number five would change the volume of the chords, and at the same time alter the colors and patterns of the projections.

Sensory Digital Intonation
At this point, having carefully explored and then subsequently chosen our materials and constructing the artifact, it was time to prepare our first public performances with it. In order to fine-tune a multi-faceted digital instrument as this, a procedure where *"artistic intuition and experience continuously influence the technical development and vice versa"* and *"that has similarities to what musicians call intonation"* [32] takes place. This is, in short, the procedure where precise considerations regarding the aesthetics within the interaction is undertaken. For example, carefully judging how far the wires are to be bent before a chord is sounding, or setting how multiple parameters that are inflicted by the same wire interplay with each other in an aesthetically pleasing way. Using *Sensory Digital Intonation* we fine-tuned the artifact towards performing with it, balancing the many parameters in the software against one another, as seen in Figure 4.

But this design did not come about without involving singers in the design process. Let us now turn to four example performances with the instrument, at different stages of the instrument development, influencing the design.

PERFORMING WITH THE VOCAL CHORDER

The first incarnation of the Vocal Chorder had as its main goal to enable the first author of this paper to establish an autonomous, interactive embodied performance, where visuals and accompaniment came together in a homogenous gestalt. As mentioned above, a design process where the user and the designer are one and the same, constitutes what Sengers refers to as *autobiographical design* [27]. Thus, the account will hereinafter use the first-person noun "I" when personal accounts by the first author are cited.

Case 1: Autobiographical Performance

In my working diary I wrote that one of my outsets was to *"develop a new bodily interface and to integrate it in an operatic context"*. Now, having carefully prepared the artifact, it was time to perform with it. In opera, repeatability is a core feature, as the repertory is rehearsed over and over again in order to reach a point when it can be presented for an audience. Our procedure followed this pattern, with one week of intense rehearsals before the audience came, during which the overall aesthetic concept emerged in dialogue with technological fine-tuning.

As we had chosen the materials in the hardware carefully, few if any problems with wires, rubber bands, styrene wheels or mechanical housing showed up during this time. However, other unforeseen technological challenges surfaced in the software. The at the time novel Mac OSX (10.2) turned out to have a fairly unreliable MIDI communication. I wrote in my diary *"the performances were completely governed by the technical conditions"*.

When performing, it is very frustrating not to be able to rely on the supporting structures of the performance, be it an orchestra playing out of tune, or as in this case, an unreliable digital instrument. I realized that the data communication was the problem rather than how the processing of that same data was done. I had to come up with a solution to stabilize the communication. In my diary I wrote:

"I have had similar technical problems before and I have learned that you have to consider your technological tools as acoustical instruments - i.e. you must treat them with care and in the same way every time you use them. In practice this means that I have to start different devices in the same order each day (or search for other arrangements if something is not working/communicating), and then launch each piece of software in the same order as well. This procedure materializes almost as a ritual. Then and only then, technology behaves predictably".

This is a lived experience of the reflective conversation with the materials that Schön refers to when he talks about the *reflective practitioner* [26]. We managed to rectify the problems through a careful procedure for starting up the ingoing computers, synthesizers, projectors and most particularly the software. Thus, the rehearsals could lead up to four public performances. In a review it was reported that: *"The result comes forward as well worth seeing, even cool, considering that it results from experimenting without a preset libretto [...]"*[5].

From this response and others that also mentioned that the performance had liberating qualities, we understood that we had found something interesting, taking us closer to the kinds of experiences we were seeking.

Case 2: Explorations of Durability and Embodiment

Our next iteration of the artifact was an audience-interactive version. In this phase, The Vocal Chorder was touring as part of an interactive exhibition where audiences were invited to perform with it. We encouraged the audiences to be rather playful in their interactions with the artifact, allowing us to explore the durability of the materials. In order to do this, the second author of this paper – who is a professional

[5] Review by Thomas Michelsen in "Politiken", March 25, 2004. Translated from Danish.

dancer – demonstrated the stamina of the artifact, pushing the limits of the construction in order for the audience to dare to be playful and perform extreme movements with it.

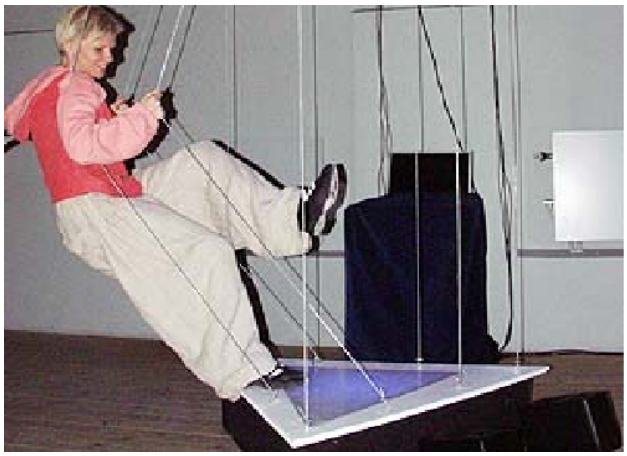

Figure 6. The demands for durability were probed.

Inspired by how the wires of The Vocal Chorder has similarities with human vocal chords we now wanted to incorporate vocal sounds in the artifact itself, transferring the manipulation of the wires to direct playback of prerecorded sounds of the human voice. This made The Vocal Chorder accessible to the public who are not trained opera singers.

Figure 7. Vocal Sound used in case 2, 3 and 4. The movements of the performer in the artifact scratched playback of the sound.

By this change, we also wanted to explore the feeling of embodying the voice with the movements in the artifact. The sensory setup was aiming at affording a playful but deep interplay between voice, body and machine. In a newspaper article a journalist who got to try the Vocal Chorder during its tour expresses his experience as:

"It is not some orgiastic technology. The sensory interplay between people, dancers and things lets something deeply human and lively emerge. In this interaction liveness is born" [6].

We feel that he his pinpointing something important here: when the singing, movements and the forwarding of chords come together in a live real-time performance, it is not a mechanical pushing of strings that the singer experiences, but a living experience that is created. While it may take some time to learn an instrument, the end goal is to become *one* with the instrument – embodied – allowing for an immediate sensation of both performing and experiencing at the same time.

Cases 3 and 4: External Singers in The Vocal Chorder

In the third iteration of the instrument, we shifted away from the general public, back to professional singers to test and further develop the instrument. But this time, it was not only the first author of this paper who got to interact and work with the instrument, but instead two professional sopranos. They participated in a course in Extended Opera at The University College of Opera in Stockholm.

In this iteration, we wanted to return to letting performers accompany themselves through forwarding of chords. The music we chose for this iteration was a composition by 17th century composer Orlando Gibbons, called *The Silver Swan.* The singers first learnt to sing the song with normal piano accompaniment, and then they were introduced to a reduced score for The Vocal Chorder with only seven chords. These chords were recorded by the singers themselves, and implemented in the software (see Figure 7). We allocated the strings to one pre-recorded chord each, summing up to seven chords. One of the strings was now used as a *disturber,* a string that did not have a sound of its own but that would disturb the sound of the other strings, allowing more variation in the accompaniment. The sounds were allocated along the wires so that the chords were not triggered on a specific break point as earlier. Rather, the sounds were scratched by precise interaction by the user carefully pushing and stretching the wires of the artifact. This gave the performer a sense of *connecting* with the vocal sounds by carefully listening to the response of the artifact, whilst performing the aria along the accompaniment created by themselves by leaning, stretching and pulling the wires from within the large bodily interface.

One of the singers later reports on this experience:

"I was asked to improvise with The Vocal Chorder in A Silver Swan *by Gibbons, and noticed that this was a task I had to consider carefully. Not because others judged my performance, or me, but because I noticed that I did that myself, and therefore felt unfree even if the intention was the opposite. Beforehand, I did not think it would be problematic, I've been doing some improvisation before but it was many years ago and I had perhaps forgotten how one gets into it, and I noticed more prestige in that I did not want to do something that might sound silly, or was not good enough. [...] I do not mean that we should go on to make the mistake of not singing properly, but music is a living art form and the music needs to breathe. No appearance is exactly like the next, it is not natural for us humans. It was interesting that this appeared to me to while working with The Vocal Chorder."*

[6] Article by Calle Pauli in DN På Stan, May 20, 2005. Translated from Swedish.

Figure 8. The first external singer in The Vocal Chorder

The solo singer is here relating to a holistic and relational experience of her voice that arouse from performing with the artifact. In The Technology as Experience framework, McCarthy and Wright [15] refers to this kind of experience as *sense making*. They propose six different strands of sense making. One of them is *interpreting*. According to them, interpreting is characterized as *"an unfolding experience [that] involves discerning the narrative structure"*. Here the solo-singer was uncovering the hidden narrative structures in her own professional practice – the narrative that says that an opera-singer cannot improvise, cannot become part of the "living art form".

Furthermore, McCarthy and Wright discuss sense-making as a process of *reflection*: *"make[-ing] judgments about the experience as it unfolds"*. By making the performance a real-time synchronization between voice and accompaniment, we are allowing the singer to make their own judgments come into play: not sounding silly, choosing the tempo that expresses the sentiments they want to express, and so on. One year later, another singer was introduced to the same setup. In her reflections both *connecting* and *interpreting* is reported:

"I pretty quickly got a feeling for the instrument. One of the major challenges consisted of getting a flow in the style and voice in combination. An additional challenge was that things happened with technology at times and it was challenging to try to stay in the moment and find a flow in the performance and not be disturbed by technological hassle."

In order to comply with the unforeseen obstacles that interacting with the device offers, the performer realizes that connecting with it, and staying in the moment helps to overcome the challenges. The singer then relates to the bodily experience with the artifact:

"There was also a strong and nice experience to see how it became like dance and choreography of the various arias we did together with technical instruments, how the instruments, in combination with us, gave the music form and life in unexpected ways.". We see this as evidence of how the instrument opened up for different forms of sense making through performing interactively with it.

Figure 9. The second singer in The Vocal Chorder

The first singer continues:

"We got to play in a way opera singers rarely get the chance to do; exploring movement and playing with sounds, everything did not necessarily have to be beautiful or perfect [...]. It was much more like a theater monologue than a regular song. As I got to know Vocal Chorder and felt confident in improvisation, I got a completely different relationship to it, and when we came to the last concert I felt really totally free."

These two singers both relate to processes of becoming more and more embodied with the instrument. It is not a one-step process, but something that requires some work before arriving at the experience of being "totally free". The use of the artifact offered new perspectives on experiencing their own voices and performances, as phrased by the first singer: *"I had no other accompaniment than myself and did thus not need to be clearly and correctly relating to another human being in order for the music to work, I was in charge of time and could take breaks too"*. Interacting with the instrument had a noticeable positive impact on her vocal performance, offering a new freedom and adding new flavours to her voice, and she continues:

"*As regards to singing technique, I tried to keep it much more naked than I otherwise would have sung in school, it felt like the right thing in the face of this piece. How good it was, it is still difficult for me to judge, but I'm at least less afraid of going to be in this situation again, and I stretched a little on the old boundaries."*

The second singer concludes, referring to her colleagues that performed with other interactive instruments during the course:

"Another thing that was so interesting and nice was to follow the development of others with both their arias and their work with the technical instruments they had been assigned. How it from the first tentative meeting with the

new technology changed to almost becoming part of the person who performed with it."

When it comes to our aim – the empowerment of opera singers – the following quote indicates that we accomplished that: *"I learned that there is more to opera than just learning a score, showing up to a rehearsal and singing it – we are musicians"*.

CONCLUSIONS

Through our designerly exploration, lasting over several years, several incarnations of the instrument, we arrived at a device that offered (1) a tool for singers to appropriate and take control over the rhythmical pace and overall artistic and aesthetic outcome of their performances, (2) an enriched sense of embodiment between their voice and the overall performance; and (3) a means to empower opera singers on stage.

The bodily experiences and sensory engagements that have been accounted for here have materialized alongside the artifact itself. In a quite surprising way, power hierarchies and the history of opera have been explored through this design procedure. We did not expect that performing with the instrument would lead to the kinds of reflections reported by the singers who discussed how the instrument made the innate power structures in opera came to the fore for them. Another of our singers reasons around empowerment and her change in opinion after working with our interactive instruments: *"I thought at the time that I wanted to 'play by the rules' and succeed in opera through more typical pathways. After this semester I have come to realize that there is no* one *path to success, and that I need to follow my instinct to create, and see where that takes me, instead of waiting for someone else to give that to me. What a gift that is, and what an experience this has been."*

There are lessons learnt in our design process that are applicable not only to our research program for opera, but possibly to other on-stage interactive technologies: to explore robustness and durability, aesthetic expression through bodily movement, and how to create tools for empowerment.

Material Explorations and Durability on Stage

We explored the many ingoing components by designing for the extreme requirements that follow from putting an interactive device on stage. We found that an almost ritual approach when handling materials such as computers, software and sensors was essential. As opera normally is rehearsed meticulously before the audience meets it, a rehearsal is in fact an inquiry into the endurance of the materials. The repetitions of rehearsals call for stamina in the performers as well as in the instruments in the orchestra, the scenography and the scaffolding.

In addition, when a performer meets an audience, the robustness of the design is tested under somewhat extreme conditions – not only in terms of physical robustness but also in terms of robustness in delivering an aesthetic experience, shaped in the moment between singer and instrument.

Bodily Expression and Voice

As can be seen in Figures 8 and 9, the singers are not only singing and pushing the strings, they are at the same time engaged in a on-stage performance. Their movements within the instrument are expressive and aesthetically startling for the audience. Here, it was important to strike a balance between the complexity of learning the instrument, the expressivity of the instrument and the requirements on both singing and manipulating the instrument at the same time.

An Instrument for Empowerment

In our work, we enabled opera singers to perform in ways that were, in some respects, quite the opposite of what they typically do. The Vocal Chorder became a tool for empowerment. When singers took the demand over crucial musical and visual elements in the performance, while interacting with the device, it not only changed their performance, but it also led to reflections on their profession. Through the creation of this new interactive instrument, we aim at opening a new design space and at the same time uncover hidden assumptions while re-activating traditions in a stagnating and overly hierarchical practice, opera.

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