SOFT INTERFACES

Crossmodal Textile Interactions

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Abstract

The importance of crossmodal interaction within the contemporary cultural, technological and scientific panorama has evidently gained significant attention due to its remarkable advantages in creating a meaningful, interwoven, and integrated experience. The use and recontextualization of textiles in such exploratory quest into the human senses has proven to be critical. Computational science, algorithmic logic and digital devices have always been rooted and closely interwoven with textile crafts and practices. Recent technological advancements have further combined technology and textile, generating interactive textile surfaces, constructing endless possibilities for multisensorial experiences. Within my practice-led research, I investigate the evolution of e-textiles and work comprehensively on developing functional soft interfaces and crossmodal interactions in textiles, by investigating textile as the next link between perception, human senses and digital environments. On that basis, the focus of my DLA masterwork, is materialized by developing a technology and implementing it as an artwork. Soft Sound is the result of a prolonged artistic-research on the intermedial relations between sound, textile, haptic space and tangible interfaces. A collection of electronic textiles exploring the phenomenology of perception by creating a dialogue between senses, textile and the physical implementation of this work as a technological tool. A multisensory experience examining the correlations between textiles and touch, using sound as a material force.

Theses / Tézisek

1. **Textiles are the original digital medium.** Textile art and computer sciences have always been deeply rooted and invariably interlinked.

2. **Textiles are the next interface for human interaction.** Textile are changing by definition, becoming augmented and extendable, via special programmable properties, introducing a new dimension of expressivity.

3. **Interactive textile structures construct multisensory experiences.** Textile interfaces must be designed by weaving the multisensory aspects of the auditory, tactile, visual and kinesthetic senses within a real-world context.

4. **Textile medium provides an active engagement with sonic material.** In textile-sonic interaction, it is the relationship between the gesture and sound that shapes our experience and extends creative action through participation and play.

5. **Sound is a vibrational force, therefore sound has tangible existence.** The vibrational nature of sound gives rise to our tangible as well as intimate experience of it. Sounds creates movements and drifts of frequencies occurring in the physical space. To work with such waves, is to work with material agency.

6. **Sound is inevitably an expression of its medium.** Sound is vibration, traveling as a wave pattern perceived by the human ear. Its quality and characteristic are intrinsically linked to the material substance and the physical space it travels through.

7. **Interaction translates action into being.** Interacting with the materiality of sonic textile is akin to a from of creative making that involves acts of touch, listening, and movement.

8. **The democratization of knowledge is imperative for the evolution of interdisciplinary practices.** Dissemination of knowledge and creative community collaborations create fertile ground for new technologies and integrative, multifaceted projects.

1. **A textilek eredendően digitális médiumok.** A textilművészet és a számítástechnika között mélyen gyökerező, szoros kapcsolat van.

2. **A textil egy újfajta kapcsolódási felület, interfész az ember-gép interakcióban.** A textilek definíciója programozhatóságuknak köszönhetően megváltozott, meghatározásuk kiterjesztésével egy új dimenziót nyitottak meg a textiltervezésben.

3. **Az interaktív textil struktúrák multiszenzoriális élményt nyújtanak.** A textil interfészek tervezésénél alapvető szempont a különböző érzékelési modalitások közötti átjárhatóság nyújtotta élmény.

4. **A textil és a hang médiumának érzékelési módjai között szoros kapcsolat áll fenn.** A textil-hang interakciójában az érintés és a hangzás közötti kapcsolat formálja és terjeszti ki tapasztalatainkat.

5. **A hang egy fizikai jellemzőkkel rendelkező, kézzelfogható médium.** A hang mint valamilyen közegben létrejövő rezgés bensőséges tapasztalatot tesz lehetővé. A hangok a fizikai térben előforduló frekvenciák mozgását eredményezik.

6. **A hang saját médiumának kifejeződése.** A hang hullámként terjedő, az emberi fül által érzékelt rezgés. Minősége és karakterisztikája alapvetően a materialitásához és a fizikai térhez kötődik.

7. **Az interakció a cselekvést a létbe állítja.** A hangzó textilekkel való interakció a haptikus, akusztikus, kinesztetikus cselekvések integrálását jelenti.

8. **A tudás demokratizálása elengedhetetlen az interdiszciplináris tudományterületek fejlődéséhez.** A tudás terjesztése és a kreatív közösségi együttműködések termékeny teret hoznak létre az új technológiák és az integrált, sokoldalú projektek számára.

Chapter 1

INTRODUCTION

1.1 Background

About the title

Soft Interfaces is the combination of two disciplines and concepts. *Soft*, referring to the flexible, textured nature of textiles, and *Interface* relating to a device or program allowing users to communicate with a computer or system. Soft Interfaces is an evolution in the ever expanding realm of interaction. A proposal to return to materiality, countering the contemporary tendency towards immersive intangible virtuality. A practice with the intent to de-hierarchize the senses and create a more intuitive, organic communication with digital environments. The international standard on ergonomics of human system interaction defines user experience as "a person's perceptions and responses that result from the use or anticipated use of a product, system or service".[1] Soft Interfaces examines and promotes the role of textiles within this context. It was also the title of a course given at the Textile Department of Moholy-Nagy University of Art and Design.

In my practice-based research at the Doctoral School of the Moholy-Nagy University of Art and Design, I am exploring the integration of art and technology, as well as the relation between digital media and the human body. Within the concept of human-computer interaction (HCI), I am researching textile interfaces, soft circuitry, interaction design, and intelligent materials alongside wearable technology as artistic mediums and forms of expressions. In the narrower extent of my research field, the focus is on observing smart materials, electronic textiles, and the integration of interactive technologies into materials, hence creating tangible interfaces and opening possibilities for novel tools and improved methods. My aim is to identify such processes, principles and techniques that have changed material design, and conceive new directions with progressive means. In my past research examples, I have examined the manifestations of the results in the previously mentioned new practices, through specific art pieces, working prototypes and examples.

This research proposes to develop an art-based study on the crossmodal, finding inspiration from theoretical models, the philosophical movements of phenomenology and new materialism, as well as underlined by the re-enchantment with nature and matter. The final outcome is achieved, within the Research through Design (RtD)[2] process, reaching results by way of different evolutionary steps. This effort was undertaken within my studio EJTECH, as materials, systems and the dedicated technology needed to reach the desired outcome did not exist. In my artistic practice I am exploring new ways of materiality in our supersaturated techno-cultural world, where permanence is fluidness itself. My passion on the physicality of textile parallel to the physicality of sound, the material power of textures and of sonic vibrations to alter bodily perception inspired this work. Human bodies and machines can touch each other, resonate together through vibrations and create alternative ways of knowing. The shared corporeality of textile and sound and the physical interactions between human bodies, machines and computer-based systems lie at the core of my practice-based artistic research. The activity of making textile instruments is integral to my artistic practice. I refer to myself as a textile designer. I do not conceive myself as a programmer, a technologist or a sound designer, even though I learnt a lot about these related fields during my doctoral studies. The field of electronic textiles, requires collaboration and interdisciplinary teams. Seamlessly merging different disciplines has proven to be challenging as it is not always straightforward process to interlink crafts. This is an important premise, as it puts this research in perspective. My background played an important role in the RtD process. The intuitive, or tacit knowledge became essential for and during the research. Tacit knowledge, being experiential and subjective, took form through action, becoming visible and detectable through visual expression. I was filled with curiosity and energy to explore and try out different combinations of textiles and technologies as materials and branched out into diverse unexpected directions. During the past years I have had the possibility to work on the investigation of textile and sound relations, next to the academic research in the university, thanks to different scholarship programs, such as the Kitchen Budapest Talent Program, the Hungarian National Eötvös Scholarship and the New National Excellence Program.

This research creates a dialogue between a theoretical analysis of the relation of textile, technology and the senses, the technical implementation of physical tools, and the artistic development of the masterwork. The chief aim is to extend the materiality of the textile medium, to transform the material into experiences, and to break the conventional stereotypes on fabric, presenting a new type of textile with unprecedented possibilities through advanced technology and transdisciplinary cooperation. The "fabric of reality", a metaphor referencing how the sole concept of reality is a complex system of intertwined elements, leading into one perception of wholeness, demonstrates how deep-seated textiles are within our culture, awareness and understanding of the world that surrounds us. In this chapter I will present the subject of the thesis. Following, I will introduce the research questions and then provide an outline of the thesis.

1.2 Subject

We are facing a compelling shift in paradigms on a cultural, technological and social level. Our techno-cultural world fundamentally has changed and is continuously changing the forms of experiences related to the world. Our society's supersaturated, present day informational social model rewrites plenty of fields, thus the previously established boundaries of disciplines are dissolved, creating unsuspected common ground between different areas in life. The traditional borders of art, creative industries, science and technology are constantly becoming obsolete. The previously individually kept and hermetically practiced disciplines now pervade each other, creating hybrid situations on their edges, surfacing new qualities. I am observing this transparency between the different areas, the cross-platform situations, as well as the most recent works, achievements, developments and possible uses of intelligent materials. The two guiding principles of my artistic research are the experimental, interdisciplinary thinking and the integrative approach. Instead of visual concepts or speculative design, I make working prototypes. This attitude has led my practice-based artistic research to the approach of trial and error, which is an important characteristic of interaction design. I consider the new developments and technologies as creative tools and open possibilities, not as creative aims.

Currently, we are living in an information based society, surrounded by dozens of intelligent devices and objects that can handle data autonomously. The use of intelligent materials is an actual science. Its regularities, formal language, technological possibilities have been changing day by day. These rapidly evolving technologies can open up new perspectives in material design, which are completed not by the technology, but by the creative human itself. The results of contemporary technology and material research offer many possibilities for innovation that raise new possibilities in the field of material design, as well as within textile design. The innovation and the potentials of new interaction models, the mapping and understanding of user experiences, give a basis to a voluminous amount of research and development projects. The experimental, aesthetic, functional application and adaptation of the new types of materials are extremely popular tendency in the world of new media. Intelligent materials has brought a still unknown, new generation of materials into the field of textile design. These materials are facing the traditional working methods, processes, techniques and fabrication with new challenges. It motivates the designers to develop and learn new working processes such as electronics, information technology, physical computing, as well as physical and visual programming. In the future it is expected that everyone will be familiar with programming, and it will become a fundamental part of the culture and design. It is an imperative goal for me to develop my educational skills alongside to my research activity. To do so, I try to share and transfer the knowledge with workshops and courses, which can be another source of innovative and creative ideas, spreading along the democratization of technology and the principles and movements of such as DIY (do- it-yourself) and DIWO (do-it-with-others).

This thesis aims at developing conceptual and methodological tools in order to incorporate sound, as an active element, to the discipline of textile design. The ambition with this research project is to make suggestions on how textile designers can work practically with textile sound design, in a far more advanced, dynamic manner rather than as a sound insulator. This thesis describes commonly used methods and processes used in textile design to make it possible and see in what ways will these be affected when sound is added as new design tool. A number of design examples will be presented as methodological samples of different ways to work with textiles and sound. I will demonstrate the various layers of interconnection between textiles, touch and sound and the ways they can reshape analogue and digital environments. I favor the notion that artistic research provides an advanced insight, and aid to harness the potential of new materials and structures. Artistic knowledge is a special form of knowledge. It includes sensual – emotional experiences and insights – it is feeling rendered tangible.

This thesis will question the relationships and multiple approaches of textiles with states and forms of interaction. Furthermore, I will direct my attention to the nexus between textile, sound, haptics and new ways these mentioned fields can interact. I will start by expanding on my exploratory quest at the relation between textiles and computation, following with the human senses, and sonic interaction design, closing with my educational experiences. In art, as well as technology, there has been a resurgence of interest for the multisensory experience. Considering literature from diverse fields such as social anthropology, human geography, neurobiology and psychophysiology, I will present multiple positions on the classification, education and function of our sensory systems. In the thesis I will examine the works and thoughts of Annie Albers ”matiére”, Gilles Deleuze ”theater of materials”, James J. Gibson, and Juhani Pallasmaa among others.

This thesis will show a dialogue between theory, technique and artistic practice. It brings into conversation distinct analyses, techniques and aesthetic issues to discuss, and a journey that investigates the relation between textile, computing and sound axis. Since the project is transdisciplinary, its contributions span across three research areas. First, the project contributes to the field of human-computer interaction by augmenting the textile medium when seamed with technology. Second, the project observes and contributes to my fields of interest within the crossmodal, multisensory integration. Third, this project contributes to the field of sonic spatial and interaction design.

The present inquiry emerges from several years of artistic practice and technical development of new textile interfaces, models of such form of intimate tangible interactions.

My MA degree work was Chromosonic, a programmable color changing, sound visualization textile interface. The textile display reflects on the exponential growth of digitalisation in the physical world. This is a 200 x 80 cm woven textile, augmented and controlled via a microcontroller. In the three years of my doctoral studies, I further developed this kind of theoretical, aesthetic and technical interest by engaging with a variety of issues, such as exploring a new materiality and observing the differences between the digital and the physical, while trying to blur the boundaries that separate them, alongside extended practical research on the crossmodal phenomena. I use the material force of sound and the materiality of textile as key elements in electronic textile interface design. Here lies the transdisciplinary aspect of this inquiry: analytical resources, artistic vision and scientific findings that equally have contributed throughout the research. Their combination and mutual influence is embodied in a final artwork.

1.3 Research questions, Dissertation outline

In the following section, I will define the core research questions that this work will investigate, and provide an outline of the thesis.

Research questions
What relationships exist between sound, textile, space, and technology?
What are the multisensorial aspects of electronic textiles and how do we perceive them?
How to create crossmodal perception and multisensory integration through the textile medium by linking different sensory modalities?
How can the relation between textile, sound and technology extend our understanding on the performance of the material?
How to use sound to create artistic textile expressions?
How to recontextualize the interaction between textiles and human?
How can we redefine our textile-related perceptions?

Dissertation outline
Chapter 2 In this chapter, I will map out a selection of key works that have investigated the relation between textile, technology and sound. An important criteria of this selection was the aesthetic nature of the works.

Chapter 3 In this chapter, I will review a range of resources that afford an understanding of the crossmodal and multisensory implications of textiles. It does not aspire to provide a fully exhaustive review on the topic.

Chapter 4 In this chapter I will present the discourse of the concept of sound as a vibrational force that provides a significant argument to this research.

Chapter 5 In this chapter I will address the discussed theoretical and scientific discourses through my art-based research. I propose my mastwork, Soft Sound, as a research medium for the study of crossmodal experience. I will present the current state of artwork, alongside technical details, philosophical background and research methods.

Chapter 6 The last chapter will be concerned with an overview of my educational experience of key workshops and courses on the subject of soft interfaces.

Chapter 2

TEXTILE DIMENSIONS

”Any sufficiently advanced technology is indistinguishable from magic."

Adam C. Clarke

While fabric of reality surrounds us, our world is lined with textile. Our bodies are protected and covered by textile. Through textiles we describe ourselves, our society, and our place in the universe. Textiles are the metaphors that string together the macrocosm and microcosm, the interwoven reflection of interpersonal relationships, the second skin and the next interface for human interactions. This world that is interlaced with yarns and threads, can evolve into extensive forms, shapes and crafts, only limited by imagination and creativity. The dawn of human civilization was the day we donned clothes. Since then, we wrap in covers to protect from the cold and walk on carpets to separate from the ground. We rise our symbols and float them in flags, and we braid ropes build bridges and conquer nations. Recently we have grown fibre structures into tissues for organs, and digitally woven the world wide web. Textiles today are undergoing a new unfolding where important research is being made in order to augment their properties and by doing so, give them new, expanded functionalities. This progression is parallel to the studies being done on digital systems and their manifestation on our physical environments.

Textiles’ unique characteristics of flexibility, modularity - connectivity prone, and innate intimacy, give them a tremendous potential for creation and transfiguration. The use of textiles and other flexible materials for building have aesthetic, functional and environmental advantages. This is why textiles are now seen as the fifth key building material alongside steel, stone, concrete and wood.[3] Not only have textile crafts shapes societies and politics throughout history, they have also been a powerful force towards developing further technologies, as well as driving economies. ”The origins of chemistry lie in the colouring and finishing of cloth. The textile business funded the Italian Renaissance and the Mughal Empire; it left us double-entry bookkeeping and letters of credit, Michelangelo’s David and the Taj Mahal. As much as spices or gold, the quest for fabrics and dyestuffs drew sailors across strange seas. In ways both subtle and obvious, textiles made our world.”[4]

2.1 Textile as a digital medium

Textiles are the original digital medium. There is strong, compelling connection between textile and technology. As Virginia Postrel claims that weaving was the original binary system is at least 9000 years old. Warp threads are held in tension, and weft threads go over or under them: ”Over-under, up-down, on-off, one-zero”.[5] To control weaving as it is fundamentally binary, punch cards are used. ”By the time Joseph Marie Jacquard’s card-driven machine came around in 1801, human weavers had been imagining and recording complex either-or patterns for thousand of years.”[6] The investigation on the relationship between digital and textile performance in haptic and visual interfaces is compelling and has consequences far beyond that of simple digital interactivity. Computing’s material past has a mostly overlooked elemental connection with textile design, where its labor models and production methods are deeply embedded in the history of software and hardware manufacture and assembly lines. Most regularly woman have been behind the manual labor responsible for weaving memory, threading hardwired programs and integrating circuits.

In the book, *The Fabric of Interface*, the link between weaving, sewing, and quilting, with contemporary technologies is explored with the intent of inspiring new ways of looking at hardware or software design. This insight also offer a new interpretation on sensorial experiences, as well as personal networked media practices. ”In attempting to uncover the little-explored material, ideological, and social links between networked, mobile media practices and textile and needlecraft culture, it is important to recognize clues that have long hovered near the surface. In particular, metaphors of textile and craft permeate the history of computing and communication networks. Software developers and engineers ’weave’ code that includes ’threads’, such as bulk calls, to subroutines and threads of execution. Internet administrators and users ’weave’ the ’web’ with ’threaded’ discussions and by ’linking’. Data structures – from lists to trees can be ’zippered’, and when files are compressed and uncompressed they are ’zipped’ and ’unzipped’. Problems in existing programs and their underlying software code are repaired with ’patches’ made from additional code. Digital images are ’stitched’ together or ’quilted’ by image-editing programs to produce larger images, such as landscape panoramas and game environments.”[7] Curiously, all of this material is guided, and directed throughout the distributed network topology of the internet via nodes of gridded circuits known as ”switched fabrics or switching fabric”.[8] As proven, the imagery and technical jargon of computing is fashioned from processes surrounding the textile craft. It is undisputed that the entwined history between computing and textile is substantial. Despite the presence of so many language examples being not only shared between textile crafts, digital media and computing, but also undoubtedly originating from textile definitions, rarely have these been treated as emblematic or meaningful between digital communications and what has been dismissed as simple “home craft” or “woman work”. Researchers in the late 1990’s, during the rise of the internet, did point out however some of these links between digital culture and craft practices. Eric McLuhan questioned: ”What kind of patroness would suit this virtual world of the net and the web?”[9] and nominated, Arachne and Penelope, the ancient weavers in Greek mythology, to represent the internet as the decentralized system it was to be, as well as symbolizing the endless production of digitally networked living. A resurgence, or offspring between textile culture and computing, is the development of smart fabrics and electronic textiles. I will expand on the following subsection 2.2, as it is utmost important to notice and acknowledge the superimposition of these. These already mentioned layers on which textile and digital media overlap, can dim the importance of how gendered, low-paid manual labor, often drawn from textile manufacturing has literally shaped the history of computing. This raises important questions about gender, race and manual labor in pre-tactile digital culture. I find it important to highlight this fact, even though this is not the topic of this dissertation. By tracing the role of needle craft and textile techniques in the production of hardware and software since its conception in the last centuries, I will connect historical links across textiles and computing within globalized electronic industries. Weaving, textile assembly, and digital culture share a long history. In the following, I introduce Joseph Marie Jacquard, Charles Babbage, Ada Lovelace, as well as MIT’s Lincoln Laboratory and the Apollo space program, as prominent historical examples. I think it is important to understand the historical trajectory, where the discipline of electronic textile originates, that is why in this section I will give an overview on the topic. All of these are considered as evidence of textile culture’s fundamental role in the conceptualization of computing.

In the early XIX century, Joseph Marie Jacquard’s conceived the first industrial loom that worked with punch cards which stored the complex weaving sequences read by the loom’s rods. This was the first hint of primitive computing memory, where a stack of cards would contain and save the information in order to produce specific images, motifs or patterns on a textile. These punch cards could be stored away and used again at any specific time to reproduce the desired weave. In her study, Hannah Higgins claims that Jacquard's punched card serves as "the mechanism of transition between the soft grids of textile technology and the hardware of the information age; it translates the net from its physical expression in textiles to a modeling form that would tabulate, sort, and integrate."[10]

Figure 1: Jacquard Loom card, (1801-1990s)

The Jacquard loom's groundbreaking concept of "programming" a machine using punch cards, has had enormous consequences that still shape the nature of electronics and computing industry today. This system eliminated the need for real time human calculations during the production of a textile piece, and eventually these principles were later used in the development of digital calculus, with the difference that while weaving utilized arithmetical structures, digital devices use algorithmically symbolic translations of physical data.[11] Using such programs enabled speedy, accurate repetitive production of complex weaves, making costly, skilled weavers obsolete. This shift opened the door to the rise of the amount of the loom tenders that were woman, an important trend noted by Charles Babbage. Babbage was a visionary that realized the value in a device that not only executes calculations, but can run parallel processes. This device he would call, The Analytical Engine. It would not run on the typical binary system electronic computing does, but on a decimal system. The device was never built due to the high complexity of its mechanisms. Babbage saw the binary code of the punch card system of the loom as the master key to programming computing machines, this his legacy, he articulated through the textile manufacturing language. In 1843, Ada Lovelace, often considered the world's first programmer interpreted the Analytical Engine as a device that would not only be making calculations, but it would also reframe the process of production. This female key presence in modern computing's early history wrote: "Babbage's Analytical Engine weaves algebraic patterns just as the Jacquard-loom weaves flowers and leaves."[12] While origins of early computing were based on the automation facilitated by punch cards, far more sophisticated XXI century computers found their versatility in hand weaving in order to create hardware. As computing continued to evolve, textiles and hand production techniques migrated from the exterior, into the interior of the modern computer by the means of woven cores and integrated circuit boards. Two of the most significant computing projects in the XX century, the invention of a real-time, interactive computer at MIT in the 1950's and the construction of the navigational systems that took man to the moon and back in the 1960's, were considerably made possible due to hand sewing and weaving textile techniques reflected on electronics assembly.

Whirlwind project was developed at MIT's Lincoln Laboratory, and it was the single most prominent computer project of the postwar decade. To run faster calculations and have greater capacity within computer systems, the need for reliable RAM (random-access-memory) grew. Whirlwind was that breakthrough that led to a new form of energy. Coincident current (or static) magnetic matrix storage, known as magnetic-core memory, was based on principles of electric current and magnetization. Design and production of this standard, reclaimed womens textile labor back into technological development, as practices such as weaving, needlepoint, embroidery and beading were indispensable for the development of this technology. Cores were mounted like beads by stringing them on a wire, following the form of traditional weaving with slight differences. This was the leading form of computer memory and remained as such until the 1970's when IBM shifted focus to semiconductor solutions. Core memory's material form was a wooden or metal frame strung with a grid of fine wires and its production was slow, intricate, and laborious.[13]

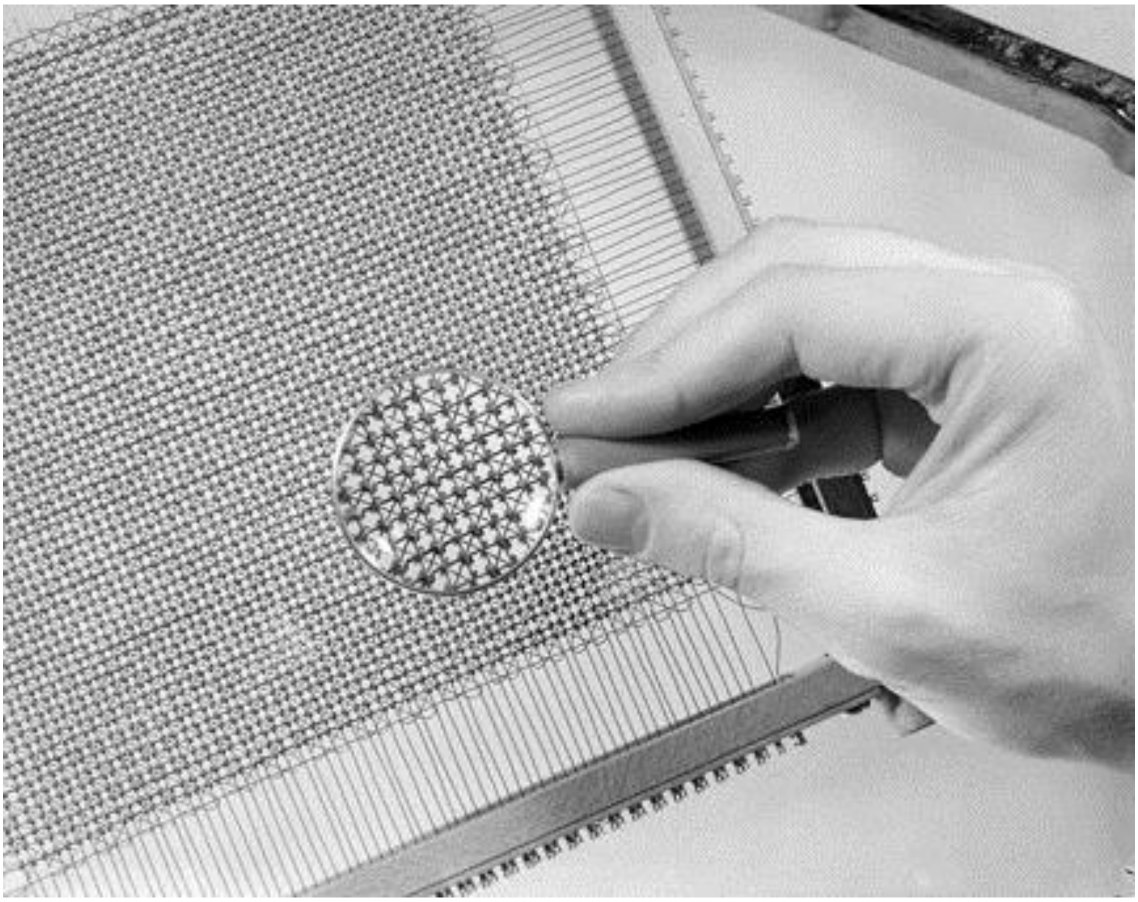

Figure 2: Close-up of magnetic core memory showing 64x64 arrangement of magnetic elements on surface plane

The second postwar computing project made possible due to use of textile assembly concepts was NASA's prestigious *Apollo moon landing program*. A very similar process was behind the space programs memory system. Known as rope memory, preferred by NASA because of its durability and reliability as well as being flexible and compact, consisted of strands of cores threaded with relatively loose lengths of bunched wires. NASA hired textile workers to fly man to the moon. Even after the shift to entirely plant produced semiconductor-based memories in the 1960's, firstly in the Western United States, then in Asia, women remained responsible for hardware assembly, soldering integrated circuit boards and microchips.

Our hand held, pocket sized marvel, mobile media, appears to be a seamless, smooth, unmodulated surface, yet underneath it hides textured patterns and channels. Filaments and lines crafted with the hands of unseen workers across the globe. Both textiles and softwares are highly structured, complex systems, resulted from massive amounts of calculations. As a computer or smartphone converts the binary code of ones and zeros into meaningful information by switching electrical currents on and off, the already previously mentioned textile loom transforms rows of perpendicularly stretched thread into meaningful computing, resulting into an intricate woven textile, working under the same on/off logic. This mode of handling information otherwise known as binary or digital data, is the core fundament for computational logic. This being the ability to make the most basic distinction, the capacity of making any distinction at all. ”The digital is the capacity to divide things and make distinctions between them. Thus not so much zero and one, but one and two.”[14] For Galloway, the digital is nothing but ”one dividing in two”, as well as the analog is nothing but the ”two coming together in one”.[15]

2.2 Soft Interfaces

As highlighted previously, there is a noticeable overlap between textile culture and computing. This is the development of smart fabrics and electronic textiles. Electronic textiles point to a new horizon that connect traditionally distant practical fields, such as interactive communication technologies with textiles and soft materials. Smart textiles are relatively young, constantly refreshing and prominently transdisciplinary field. Smart textiles can be seen as a new type of, soft hardware, where computer software can influence, control and react to the textile expression. These smart textiles, also known as intelligent or electronic textiles (e-textiles), are perpetual combinations of textiles and technology united through specialized materials and techniques. Interestingly golden, silver or other metallic coated threads have been around and used for embroidery already for more than a thousand years.[16] Yet only recently they have proven to be essential due to their conductive properties within the field of e-textile and soft circuitry. Compared to traditional textiles, smart textiles have added values and enhanced properties. They can be programmed, they can sense change, react and adapt to external behaviour and environments or inputs. Van Langenhove and Hertleer refer to smart textiles as "the textiles that are able to sense stimuli from the environment, to react to them and adapt to them by integration of functionalities in the textile structure. The stimulus and response can have an electrical, thermal, chemical, magnetic or other origin.”[17] Smart textiles organically develop alongside with the exponential advancements in technology. They depend on new materials, on better ways to connect textiles and technological components, and more specific production processes. Cherenack and van Pieterson describe the evolution of smart textiles in three phases, that create a more systematic approach to differentiate between smart textiles. According to him: ”The first category of smart textiles stayed close to the vision of wearable computing – to design a fabric computing platform. An important goal was to design easily reconfigurable interconnect technologies inside textiles using fibers and yarns with a single functionality (e.g., electrical or optical conductivity).”[18] The second category of smart textiles ”exploited various new textile fabrication methods such as embroidery to achieve hybrid smart textiles”[19], where the fabric formed an essential part of the textile device or circuit and more functions were achieved within the textile itself. The third category was ”...to create more complicated fiber-level electronics”.[20] This field of research is referred to as fibertronics, and focus more on technology development and systems built from the fiber upwards.

Back in the 1880’s a company known as *The Electric Girl Lighting Company*[21] leased girls wearing electric light bulbs on their foreheads and batteries attached to their clothing to paying customers for flexible, maneuverable lighting, opposed to the stationary electric lights of that time. Electronic components close to the body and the understanding of e-textiles has changed radically by the late XX century. Amor Munoz’s work called *Yuca_tech: Energy by hand*[22] is a contemporary example of how this concept has evolved. This art project consists of creating community work to solve local problems, by using low and high tech resources. Her work combining tradition and innovation, uses solar panels to power LED lighting in everyday objects such as hats or sandals. She also proposes to share this energy by creating a charged battery bag, worn by street vendors and sell energy at 5 pesos to passersby who need to charge their phone. Actual computers started to appear close to or strapped to the body in 1950’s. Thorpe[23] and Shannon developed the first wearable computer used to predict roulette wheels in 1955 and Mann[24] the backpack-mounted computer to control photographic equipment in 1981. It was on the 1990’s when a group at MIT started to explore how electronic devices and soft materials could be more gracefully and organically integrated. Before these endeavour, electronic components were very much separated from textiles. This meant a challenging, yet essential step into fully blending technology and textile into one media. Sabine Seymour writes about the vast variety of projects found at the intersection between science, design, fashion and technology.[25] She discusses smart textiles in contexts such as social aspects, services and e-textile craft, noticing the sustainability issues of such positive notions and their potential, as well as the hard to recycle electronic waste.

Textile as a craft has survived the industrial revolution and in a great part has evolved into today's technology. In other aspects, what used to be done by a craftsman is now done by a machine. Specialized techniques and e-textile practices are a return to the basics of craft techniques and hands-on skillmanship such as weaving, crochet, and knitting, resurfacing creativity. E-textiles are considered as a contemporary craft, refer to a group of individuals experienced and knowledgeable in the use of materials and tools involved. As it was the case with woven core memory, the current state of electronic textiles heavily rely on manual skill and technical expertise, as well as care and foresight of the maker, due to the fact that automated manufacturing methods for combining textiles and electronics are yet to be invented. I will expand on four projects, the first three examples are *1-Bit Textile*, *The Crafted Logic* and *The Embroidered Computer*, technological wonders are part of Stitching Worlds, an artistic research project by Irene Posch and Ebru Kurbak. The fourth, a poetic ode to the importance of Jacquard in technology, *Playing Cards* is an artwork by Glithero. I have chosen to mention these projects as examples, as they successfully connect arts, design, open culture, digital fabrication, information technology and electronics by cleverly using engineering and scientific methodologies of textile technology.

Example 1

1-Bit Textile is an embroidered textile bit, the basic unit of information in computing, which can be controlled electromagnetically. By switching the electromagnetic field created in the coil, the magnetic bead can be flipped. The aim of the 1-Bit Textile is to create electronic components from scratch through textile routines. In this research project, the artists want to make further investigations into crafting textile actuators, to display information, create storage elements and relays.[26]

Example 2

The Crafted Logic is part of the mentioned larger research project focusing on creating electronic components from scratch. This piece fundamentally aims to replicate logic-gates, the building blocks of digital electronics via pure textile handcrafts. A speculative object implementing a Boolean function, in order to perform logical operations on one or more logical inputs, then producing a single logical output. "Every single digital device operates on some combination of the basic logic functions AND, OR and NOT, NAND, NOR, XOR and XNOR; even the most complex circuit can be reduced to them in the final analysis."[27]

Example 3

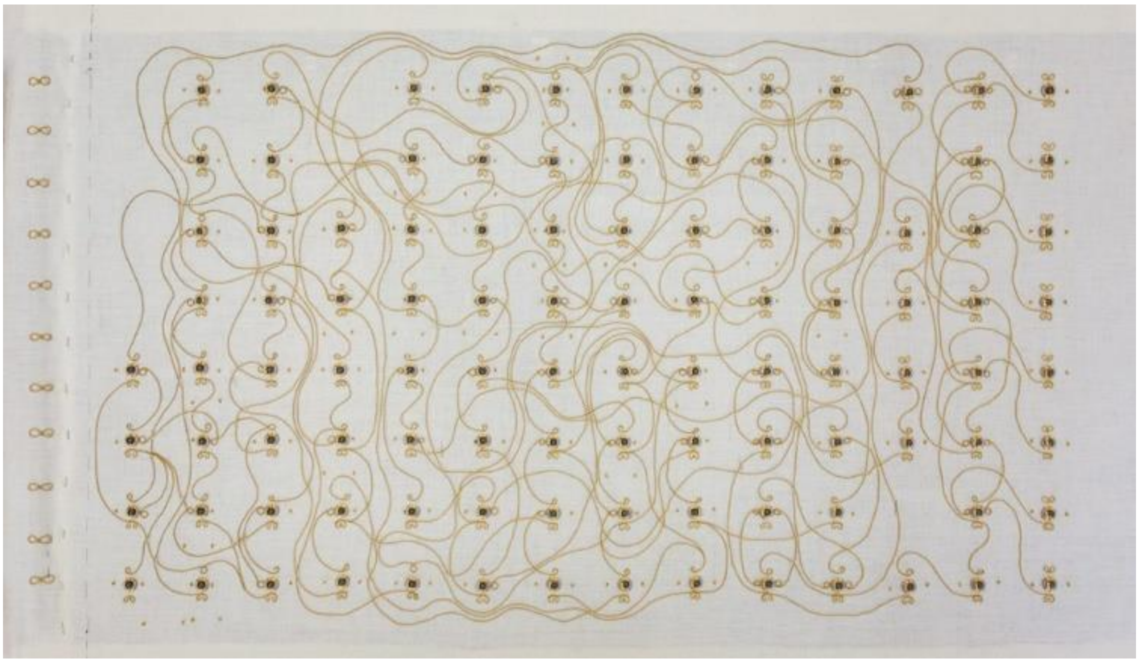

Figure 3: Irene Posch, Ebru Kurbak The Embroidered Computer, 2017

The Embroidered Computer is a programmable 8 bit textile computer crafted from gold embroidery threads and knowledge. Entirely built from conductive threads, metal, glass and magnetic beads by using traditional crafting routines and patterns, an amazing piece that questions our interaction with, as well as the current state and aesthetic practices surrounding digital and electronic technologies today. This piece, technically speaking, consists of textile relays, similar to early computers. The use of gold materials traditionally was used purely as a decorative function, whilst the beautiful patterns dominating this work also fulfill electronic functions. Usually hidden in black boxes, these lay bare core digital routines adorn this work of art. In this working piece, users can actually program the textile to compute for them. [28]

Example 4

Figure 4: Glithero (Tim Simpson and Sarah van Gamaren), Playing Cards, 2014

Playing Cards is a project on the importance of Jacquard and the punch card system as an inspiring subject, has led Glithero (Tim Simpson and Sarah van Gameren) to weave a table cloth and six napkins, where the design of the fabric is the code itself. This project is an ode to all Jacquard woven fabrics and celebrates the beauty and materiality of the punch cards and their mesmerizing flow through the machines. The spread out table cloth depicts the punch cards with the written program in pattern, while the accompanying napkins depict missing information – the holes punched from the cards that build up under the Jacquard puncher's machine in the creation of the cards.[29]

Having recognized the previous examples as relevant insights to the present state of textile and technology, it is important to also notice the reaction within this field to the overwhelming growth of digital landscapes in our lives, a new craving for depth and tactility has led us to reconsider the importance of materials once more. Gesture and touch focused interaction with textiles are the main trigger between digital and textile interaction. As smart devices become more and more part of our everyday life, tactility has gained fundamental importance when controlling and communicating with such devices, earning ground from a secondary aesthetic to becoming a primary interest of inquiry. Tincuta Heinzel claims that "textiles are not materials with fixed properties anymore. They are objects that can virtually change their states, transforming themselves, acting according to the data of the environment"[30], they are "...a fragile tissue that tends to dematerialize if we get too close and whose consistency is only fluidness itself."[31] When we approach the new electronic and reactive textiles, it is not so much the properties of the materials which are to be emphasized, but their performativity and the control of such performance. The notions of texture and touch gaining new connotations, while the new textures and smart gestures are introducing a new expressivity. The performance capabilities of electronic textiles push our attention to the convergence between textiles and our own interaction with them and through them. It is precisely the complexity of these forms of interactivity that makes electronic textiles an extensive source of reflexive material and brings into question not only that which composes and makes up the electronic and reactive textile medium, but also their content and significance.

Textile Interaction Design is a new discipline still being formed. It is the area of haptic (touch-based) human-computer interaction which has gained importance recently, opening a range of applications that use touch and gesture as an interaction technique. The area of tangible textile interfaces focuses on tactility as a controlling mean in order to communicate with other systems and softwares in an organic, innate manner. Textile interfaces have physical benefits, for example raised embroidery can be used to guide the user's hand naturally into position to use the interface without sight. Johanna Drucker when writing about interfaces**,** asserts: "In a very real, practical sense we carry on most of our personal and professional business through interfaces. Knowing how interface structures our relation to knowledge and behaviour is essential."[32] Interface has become a XXI century central emblem, continuously invoked in diverse discussions and contexts. This fascination "describes a cultural moment as much as it does a specific relationship between human user and technological artifact"[33], according to Branden Hookway. *Interface Criticism: Aesthetics Beyond Buttons* a collection by, Christian Ulrik Andersen and Soren Bro Pold explains that "interfaces can embed choices, conduct languages, and ultimately values, worldviews and aesthetics into technical infrastructures...Today we perceive our environment through interfaces."[34]

2.3 Textile and Sound

In this section I will direct my attention to the relationship established between textiles, haptics and sound, concentrating on new ways these can interact. I will present the following examples of exploring this aspect: *Soundw(e)ave*, *Woven Song*, *XY Interaction*, *Sonic Structures*, *Text in Textiles, Nama*, as well as two of my own works, *Ocho Tonos* and *Soundwear*. All of the examined projects are relevant, as they all outline the tight connection between sound and textile.

We perceive textiles and patterns primarily visually and tactually. However, there are a lot of shared expressions we naturally use for both the senses of sight and hearing, including pattern, rhythm and composition. The sense of hearing is not a topic expected to be part of the conversation when talking about textile or surface design. Within my research, I am keeping track of such analogies while investigating textiles and electronics in order to seamlessly translate between these senses. Textiles are mostly considered, in connection with sound, as good insulators. The contemporary usage of long drapes or curtains as noise barriers began during the XIX century. The other common association made between sound and textile, is the low rustle, or swish, an inherent connection between the materiality and movement, central to its aesthetic identity. However, recent developments and their present programmability is changing these definitions. Today's research is transforming textiles into musical instruments, or tools for sound visualization and measurement. Walter Pater's much quoted maxim: "All art constantly aspires towards the condition of music."[35], found in the essay on *The school of Giorgione*, describes the idea of how music, by proving to be an excellent example on inclusion, as well on mixing media, has become a model of absolute art. Music has exceeded above fine art. This motion, in which music exceeds over fine arts, is where the unification of subject-matter and form, become one. Noticing this intrinsic orientation of art, we can begin to understand the trend of augmented textiles in connection to sound and touch, as an artform.

Example 1

Soundw(e)ave are three Jacquard woven textiles that show the spectrogram of an audio file. Created by Christy Matson by recording the noisy sounds of computerized and fully automated Jacquard looms to weave different compositions. This piece pointed the artist towards a kind of digital craftsmanship**.**

Example 2

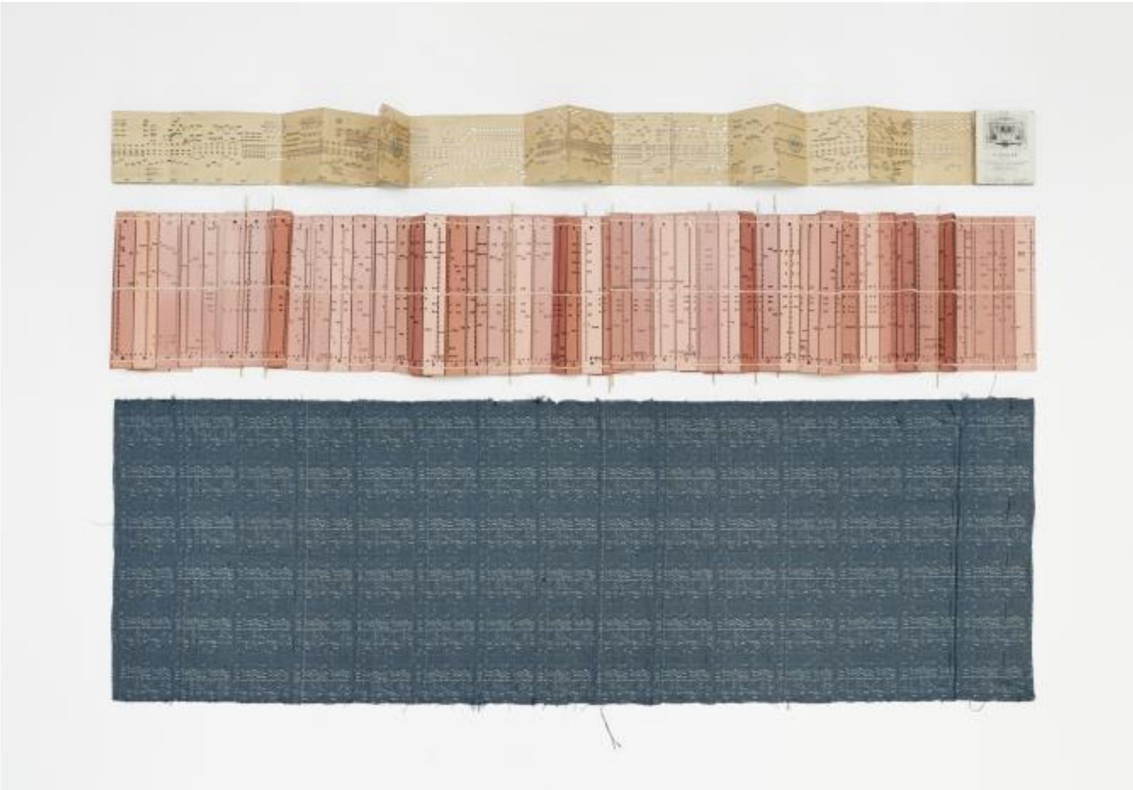

Figure 5: Glithero (Tim Simpson and Sarah van Gamaren), Woven Song, 2013

Woven Song is another project by Glithero. This art piece aims at bridging the worlds of a weaver and a barrel-organ player. Like jacquard looms, barrel organs are also controlled by punch cards. Glithero combined the two types of cards to weave music as tangible embodiment of both crafts. Organ cards of the Boogie Woogie were translated into a pattern for the loom and the finished textiles display what happens when fabric is fed musical notes.[36]

Example 3

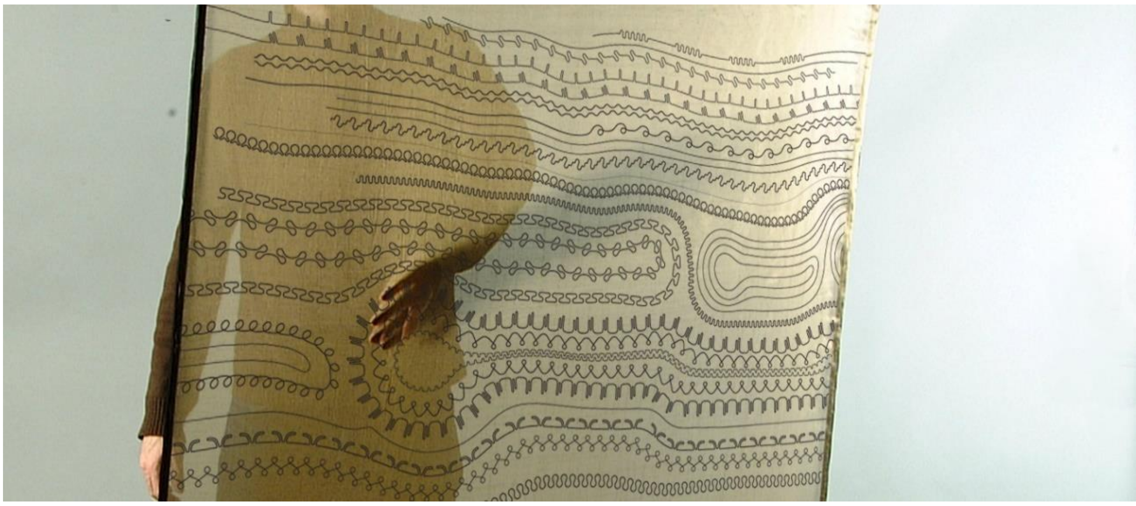

Figure 6: Maurin Donneaud, XY Interaction, 2012

XY Interaction is a musical fabric created by Maurin Donneaud. A matrix based sensor seamlessly integrated into the structure of a textile, entirely built from soft, textile materials, creating a fully functional, high resolution XY interface. Conceived as a performative musical instrument, this fabric can read hand gestures performed on it, focused on electronic music composition. This expressive surface, a practical idea on how a fabric can be used to interlink the soft, textile dimensions of touch, to sound. A tool for public performance, this interface understands symbolic vocabulary as well. When the user traces a circle or a triangle on the textile, the computer is informed about the sign and can navigate in the software using these forms chosen by the designer. These almost danced gestures over XY interface, result as an intuitively generated musical performance.[37]

Example 4

Sonic Structures by Christy Matson is an interactive installation composed of hand-Jacquard woven cotton and copper, and an electronic circuit that measures changes in electromagnetic frequencies as a viewer touches the cloth. As the changing frequencies enter an audible range they are heard through the speakers mounted on the wall near the weavings.

Example 5

Text in Textiles created by Anna Biro, is an installation, composed of three individual pieces. Biro used audiotape recordings with immigrants living in Montreal as threads in order to give a second life to this rich collection of memories. While touching and walking across the tapes weaved fabric, the sonic carpet, users can activate the recordings from the tape, and became active participants in a tactile and acoustic creative process. Thus, the human body acts like a resistor, which is a simple electronic component, and becoming part of the circuit.

Example 6

Figure 7: Luiz Zanotello, Nama Instrument soft circuit interface, 2013

Nama is the work of Luiz Zanotello, an open source textile interface, which is an audiovisual interactive installation, as well as a tangible instrument. It brings a sense of the absence of gravity. Acting on the physical-perceptual aspects of the movimentation of a piece of fabric, the interaction occurs through desires and temporalities on an organic web of certain compositional unpredictability, bringing audiovisual feedback as return. Unlike other gestural based controllers, there is something organic about the interaction. The textile interface can be folded, twisted, danced and manipulated in as many ways imaginable in order to bring the intangible tangible, and to touch the very moment of the virtual. The concept and development of Nama connect to various areas, including the design of computer codes, of tangible interfaces, of organic systems and generative audiovisual design.[38]

Textiles create new methods to interact with sound, where vision, hearing, and touch tie into one another and communicate onto each other. Each of these examples shows textiles as interfaces, acting as input, where people can trigger, affect and modify sounds or can control digital devices and applications, where for the amplification of sound uses a traditional loudspeaker system, or as a final output, solidified into a woven pattern, when sound is inputted.

Kitchen Budapest Talent Program

After my MA degree, the following step in my research field was a scholarship by Kitchen Budapest in 2014. During the Talent Program[39], I worked together with Esteban de la Torre on a research project about textile interfaces, realized in two artworks, *Ocho Tonos* and *Soundwear*. During the six months five teams had the opportunity to create a product or a service. The Kitchen Budapest supports and funds young people from different fields to create and develop their innovative ideas with professional mentors and their knowledge and tool park.

Ocho Tonos is an audible textile interface for tactile and sonic interaction by means of tangibles. Exploring the relation between sound and textile and experimenting with the boundaries of our senses, whilst changing the way we perceive fabric, surfaces and their manifestation as sound. Recontextualizing our tactile interaction with textile acting as an interface, where each element triggers, affects and modifies the generated sound's properties. Creating a soundscape through sensor technology enticing audiophiles to interact and explore with reactive textile elements. The nexus of the body, the senses and technology. Ocho Tonos is a symbiosis of the unique handcrafted traditional textile techniques and the immaterial digital media.

Soundwear is exploring the relation between textile and sound, focusing on the idea of using textile as an audio emitting surface. We created a soft speaker from textile and applied it onto clothes in order to emanate the sonic vibrations. Not only we perceive audio through hearing, but due to the pulsating nature of sound, the host textile reverberates as well, throbbing, allowing us to experience sound through the bodily experience of touch. This handcrafted technique immerses the wearer into a novel, multisensorial experience. Soundwear technology is user friendly and can be connected to everyday electronics, such as a smartphone, computer or any other music player using a standard 3.5mm jack plug.

Chapter 3

PERCEPTION AND THE SENSES

"If the doors of perception were cleansed, everything would appear to man as it is, infinite."

William Blake

Sensing is the physiological capacity of discerning and classifying data assimilated from external physical phenomena, in order to identify, interpret, represent and perceive the environment. Perception is not the passive receipt of these process, but shaped by learning, memory, expectation and attention. Sense-related work pioneered in the 1960's remains, up until today, extremely relevant. Contemporary artist and designers are constantly inspired by such experiments, building on them and adding to these views, via technological means. The growing need for new sensory experiences, can be witnessed as a global trend. Whether it be in major museum exhibitions, such as the *Design and the Elastic Mind* (2008) at MoMA or the *Speculations on Anonymous Materials* (2014) at Fridericianum, to big businesses aiming to affect shopper memory and shopper state of mind, to wearable technology, seeking to expand, via enhanced senses, our perception of the world and space that surrounds us. It is important to note, as man and machine become increasingly connected, each sensory system, the nervous system of man, and the digital inner workings of machine, are used to perceive and absorb information from our environments, as well as from each other. The interrelation of the senses, directly linked to how we experience, has been extensively questioned and studied. In social sciences literature, a textile vocabulary has been found to be the most accurate and descriptive when trying to express the multisensory character of our lived experience. Michael Serres depicts "tissue, textile and fabric" as "excellent models of knowledge"[40], whereby knowledge can be understood as a perceptual experience, "the sensible, in general, holds together all senses, all directions, like a knot or general intersection."[41] On these ideas, David Howes, anthropologist and sene guru, reflects and "no matter how prominent or engrossing one strand of perception may appear, it is still knotted into the fibers of our multisensory experience."[42]

3.1 Intermedial Relations

New, surfacing technologies do not threaten the existence of the visual arts. On the contrary, they represent a provocation that is on its own, a benefit. Hannes Böhringer observes these new technologies as the forced self-reflection of art on it own strengths, and the realization of what it is and is not capable of. Accordingly, this means that art in itself is the philosophical state of technology.[43] With the appearance of these new technological practices, the puzzling interconnecting of such cross-media possibilities is an exquisite challenge. According to Marshall McLuhan: "technology is not an independent or alien object, it complements integrally our sensory and cognitive system; as a medium, it conditions not only communication modes but also the way we perceive and conceive our environment. When these ratios change men change."[44] Encountering new technologies become unavoidable. This is exactly why these should be embraced, and treated as tools, not as obstacles. According to Nam June Paik: "skin has become inadequate in interfacing with reality. Technology has become the body's new membrane of existence."[45] Technology continuously extends our senses and transforms our general understanding and conception of solidity, tangibility and self, furthermore it has led to the fundamental rethinking of art, its forms, methods and purposes.

Imagery itself has continue to further evolve, resulting in a shift in the fields of perception, language, and forms of movement. This interesting feedback loop, influences traditional technologies and media as well. This is a crucial process as visual language plays a more important role than ever before. As Juhani Pallasmaa writes ”the human vision is itself an artifact, produced by other artifacts, namely pictures.”[46] The noticeable hierarchy of the human senses presents a compelling situation, where sight, the sense that by choice is used the most to discern and distill information, is overburdened. Through screens and because of the internet, the inflation of this sensorial modality has resulted in a flattened version of subjectivity. While the use of new technologies creates unexpected situations, and surfaces issues that were previously not questionable, the traditional or old technologies retain its inherent materiality. The artist interacts with gestures and constant dialogue throughout the creative process. This materiality is what up to recent times was impossible to achieve, even with the most interactive new media. However, as we have witnessed, and is undoubtedly a predictable tendency within the history of computer simulation, is the gradual augmentation towards tactility. According to Derrick De Kerckhove, this development starting with the two-dimensional, then three-dimensional, rapidly headed into haptic and force feedback simulation, like an ”electronic vortex that absorbs you”.[47]

What is a medium?

A medium is the intervening substance through which sensory impressions are conveyed or physical forces are transmitted. To Marshall McLuhan, media are ”the extensions of man”.[48] He further asserts that not only spoken word, a photograph, comics, the typewriter and television are media, but also are money, wheels and axes.[49] Under this philosophy, all media are ubiquitous. This notion has caused much confusion, as technical, modal and qualifying aspects presented by different scholars and research traditions, have ambiguously tried to emphasize and narrow down to efficient operable definitions of the notion of medium. It is a challenge to define what a medium is, when everything can be identified as a medium. This concept leads back to the ancient truth of the infinite complexity and abundance of our world. New technologies enhance this contemplations, as this new perspective provides fresh intersections and criteria to observe what surrounds us. When such overwhelming and colossal implications cause disorientation, Antoni Tapiés recommends the following: ”I wish we lost our faith in what we would like to believe in and what we consider stable in order to remind ourselves that the discovery of another infinity is ahead of us.”[50]

What is intermediality?

The phenomenon when media intersect and overlap, entirely or partly is called intermediality. These are a complex set of relations between media, always multimodal. Intermediality is a motion that cannot be fully grasped and understood without the notions of mode, modality and multimodality, this is why intermediality is about studying and examining all kinds of modalities of media and the most defining modal differences and similarities between media. E-textiles in essence are cross combined and integrated media, to many degrees. Whether it is the knowledge and textile structure unified with electronic components, or integrated circuits, to the usage of sonic phenomena in order to create a weaving pattern.

What is multimodality?

As human beings, our reality is limited to what we can perceive. Modality and mode are terms widely used across various fields. Within the media studies and linguistic context, multimodality refers either to the combination of media such as text, image and sound, or to the amalgamation of sense faculties, such as the sense of touch, sight, or hearing. To claim a medium is multimodal because it combines visuality, materiality, and spatiality is a truism, as there is no media that are not being realized by at least one mode of each modality. Multimodality in a more adequate sense, means that one medium includes many modes within the same modality, as all media are in the least slightly multimodal on different levels. Currently, the avant-garde of engineering research is "multimodal interactivity"[51] specially focusing on the tight connection between movement, touch and hearing. Such novel interfaces force us to discuss the digital texture and touch. As advantages of multimodal interfaces Blattner and Dannenberg discuss: "In our interaction with the world around us, we use many senses. Through each sense, we interpret the external world using representations and organizations to accommodate that use. The senses enhance each other in various ways, adding synergies or further informational dimensions."[52] Besides our attempt to try and categorize perception, it becomes fascinating that after a certain point, Aristotle's 5, it becomes impossible to systematize these idealized categories, and in turn we find bridges and doorways that lead coherently between different sensory modalities. We can approach this phenomenon from an interdisciplinary point of view in a number of ways. Modern philosophy calls this multimodality.

Phenomenology, from the Greek phainómenon "that which appears" and lógos "study", being the in-relation-to phenomenon, is the study of subjective experience and of consciousness. Phenomenological philosophy as a contemporary trend, under the implication that there is no object without a subject, emphasizes the nature of human perception while questioning the present dominance of vision over the rest of our senses. Husserl, Sartre, Michel Henry, Heidegger, and other existentialists, philosophers and sociologists deliberate on how we cannot escape the experience and individualized perception of our own body, and how our concept of is completely based on this private experience. Kata Vermes philosopher suggests that if multimodality is considered as being present from the very origin of our subject, and that if these perceptions cannot be simplified and shared between one another, but can be best explained by Aristotle's sensus communis, then there lies the possibility that these phenomena can be investigated to much more complex and deeper extent.[53] Aristotle's taught that there is a cumulative sixth common sense. A sense that is not connected to any physical organ, but is able to sense an emotion primary to all our senses: intensity, movement, unity, form.

3.2 Crossmodal Interactions

The fundamental process for the integration of the unified perception of the world that surrounds us, elementally defining our lived experience, is the addressed crossmodal activity. Recent interest within the contemporary scientific, cultural and technological landscape, contribute to this interdisciplinary, interwoven discourse. The recognition of the cross linking of our sensory modalities into a fabric of perceived reality, not only evidences our deeply ingrained, subconscious connection to textiles, but also works as perfect metaphor for the materiality of textile itself. My practice-based research fabricates possibilities to explore multisensorial modalities, by interlinking the textile medium, with interactive design and sound art forms. I place the focus of my research on integrative approach, bringing together haptic, visual and spatial acoustic experiences in order to provide a novel design model for the study of the crossmodal.

In this part I will expand on the multiple views and classifications on the function and understanding of our sensory system within Western culture. Taking in account literature from diverse fields such as neurobiology, psychophysiology, anthropology and human geography, I will discuss how the senses have been historically represented, from the Enlightenment onwards, focusing on the contemporary growing interest and research of scholars that challenge the traditional perceptual theories and the current established hierarchy of the senses. Throughout the XX century, social movements and the emergence of exponential technological advancements, had led us to what is defined as the Information Society. This present condition has allowed and incited significant attention to the issues contemplated by the crossmodal, sparking discussions, and more importantly scientific research and art-based practices exploring the multisensorial embodiment of information. This investigation, importantly made from multiple perspectives and scientific points of view, aims to point out the role of the crossmodal in perceptual experience. Since antiquity, perception, the process by which we create a coherent view of the world, built by sensory impressions, has been discussed and examined by various schools of thought, inevitably suggesting different degrees of sensorial hierarchization. Aristotle, for example, believed touch to be the most critical of the senses due to its fundamental nature. Plato viewed touch, smell, and taste as lower senses of lesser value, as he believed they obstaculized the achievement of pure truth. In Western culture, the Age of Enlightenment, followed by the Scientific and Industrial revolution would indeed change the approach and education towards the theory of perception. Of all the senses, only the sense of sight was not scrutinized and ranked of lower importance. Vision has been thought to be able and provide within two dimensions, the multidimensional reality of the world. Information gathered through the senses, and eventually the senses as such, became subordinated by scientific analysis. This rigid hierarchization of the senses, described by Bachelard as ”geometrism”[54], or by Ivins as ”optical consistency”[55], outlines how the pansensual experience is abstracted only to vision. Science, technology and cultural products themselves were shaped by this prioritization of vision. To some extent, sight and hearing were considered to be the most noble of the senses, hence associated with the upper classes of societies, while smell and touch were lower senses associated with the working class.[56] Juhani Pallasmaa resolves ”our contact with the world takes place at the boundary line of the self through specialized parts of our enveloping membrane.”[57] Pallasmaa approaches the glorified sense of sight as merely being an extension of the sense of touch.

Since the cultural changes brought by the Industrial Revolution, up until the current Informational Society, recognition and representation of the senses has not remained unquestioned. New cultural conditions demand reconsidering the old classifications and perceptual theories on the vertical hierarchy of the sensory system. Such shifts have made knowledge being privilege of few obsolete, allowing free access to information via open source initiatives as well as the free or low cost transfer of information. This change ushering in the Post-Industrial Society, has encouraged an open mindstate towards the interdisciplinary and participatory practices, very much contrasting the specialized divisioned labor characterizing the Industrial Age. The design of multisensorial systems has found way into a wide array of aspects in modernity, from e-commerce to medical applications.

It seem obvious to associate what each sense organs assimilates; sight to eye, hearing to ear, smell to nose, and taste to tongue, but it becomes difficult when trying to identify what sense organ senses touch. During the Renaissance, studies on anatomy described the focal organ for touch as: ”the entire body, the nerves, skin, fingertips, tongue, palms, the region about the heart.”[58] In this case, where touch seems not to fit the same concept as the rest of the senses, where a dedicated, delimited organ has a protagonist role in perceiving a specific sense, is very interesting when studied closer. Ashley Montagu proposes that the skin is the most ancient and sensitive organ, from where the rest of the sensory organs initially originated. Supporting this idea, stands the fact that touch is the first sense we develop and it is not only the most intimate but the most sophisticated as well. As Jacques Derrida examines the ”touch centric”[59] tendency and recognizes in the texts of Jean-Luc Nancy, the act of touching cannot be simplified into a single form, but into ”local, modal, or fractal” forms of touch that cluster ”the sense, the senses, the sense of the senses, the experience of the sense and the sharing of senses”.[60] According to the brilliant Bauhaus textile artist and designer Annie Albers: ”The fact that terms for these tactile experience are missing is significant. For too long we have made too little use of the medium of tactility.”[61] She often refers to tactile sensibility as a specific quality of textile surfaces. This mentioned quality came to fruition by what she called matiére, borrowed from the latin materia. ”Matiére it is to be defined by grain, roughness, smoothness, dullness or gloss etc., qualities of appearance that can be observed by touch and are consequently not concerned with lightness or darkness. There seems to be no common word for the tactile perception of properties related to the inner structure of the material, like pliability, sponginess, brittleness, porousness.”[62] Albers writes ”quality of structure is (...), a matter of function and therefore the concern of the scientist and the engineer.”[63] This thought resonates with the e-textile field, as a competent constellation as the artist should be able to double as an engineer or scientist, at the least to a basic extent, and vice versa, in order to make valuable, meaningful e-textile works. Another remarkable quality about texture, is that it can be perceived by the way matter folds. All materials fold in its own unique way. ”Folding-unfolding no longer simply means tension-release, contradiction-dilation, but enveloping-developing, involution-evolution.”[64] The textile is an expression of what Gilles Deleuze termed as the ”theatre of materials”[65], that is a space of senses and relations.

The prominent psychologist J. J. Gibson presented an alternative sensory classification mode in 1966. In this new approach, he divided the senses by sensory systems as a whole. Gibson introduced ”the visual system”, to replace the insufficient allocation for sight, the ”auditory system” to replace hearing, ”the taste system”, consisting of all the chemical senses, and the ”haptic system” for an expanded sense of touch, including the sensing of temperature, pressure, kinesthesia and pain, to which eventually he added body sensation and movement.[66] In his work *The Ecological Approach of the Visual Perception*, Gibson expands on the differences between his sensory system approach, and the traditional definition for senses. He writes that ”a system has organs, whereas a sense has receptors, a system can orient, explore, investigate, adjust, optimize, resonate, extract, and come to an equilibrium, whereas a sense cannot."[67] This approach, although mostly dealing with bimodal cases, such as relations between vision and touch, or vision and hearing, sets the foundations for the study on crossmodal development, as in its core, Gibson advocates the elemental cross-linking between the senses resulting into networks or as he refers to them, systems.

In this part I want to present the growing number of theoretical and scientific approaches celebrating the crossmodal character of perception, in order to provide a glimpse into the expanding interest, literature and research on crossmodal activity conducted over the last decade arguing that the changing political, technological and theoretical perspectives that have been shaping the Post-Industrial Society, has resulted in a shift in our understanding of perception. From a vision shaped by solid sensory hierarchization to one that is a liquid process of sensorial integration, resulting in the means of experiencing and relating to our world in the most meaningful and fully embodied possible manner.

The rise of the internet and the spread of new media. Scientific advancements, technological developments and globalization. Contemporaneity overall, permeated with powerful schools of thoughts like feminism, psychoanalysis, post-structuralism and theories of embodiment, question the traditional means of acquiring knowledge, understanding, therefore how we relate and perceive the world that surrounds us. Paul Rodaway, the author of *Sensuous Geographies*, reflects on "the inter-relationships between the different senses...in perception and the integration of sensory bodily and mental processes"[68], he argues that "everyday experience is multisensual, though one or more sense may be dominant in a given situation."[69] According to anthropologist Tim Ingold:"the perceptual systems not only overlap in their functions, but are also summed under a total system of bodily orientation...Looking, listening and touching, therefore, are not separate activities, they are just different facets of the same activity: that of the whole organism in its environment."[70] He continues by stressing that "the eyes and ears" and all sense organs consequently "should not be understood as separate keyboards for the registration of sensation but as organs of the body as a whole, in whose movement, within an environment, the activity of perception consists."[71] His thought finds support in the work of neurobiologists Newell and Shams: "our phenomenological experience is not of disjointed sensory sensations but is instead of a coherent multisensory world, where sounds, smells, tastes, lights, and touches amalgamate. What we perceive or where we perceive it to be located in space is a product of inputs from different sensory modalities that combine, substitute, or integrate."[72] Newell and Shams note that these sensory "inputs are further modulated by learning and by more cognitive or top-down effects including previous knowledge, attention, and the task at hand."[73] The study of neuroscientist Ross Deas on the perception of auditory space presents proof that "vibrotactile input shares many common features with auditory signals, and there is some overlap between the frequency range of the sensitivity of the ear and skin"[74], suggesting that auditory and tactile information is combined in the process of perceiving auditory space. The tight relations between our auditory and haptic modalities have also been addressed by Michel Serres, the french philosopher who writes of the body being involved in the process of hearing through skin, bones, skull, feet and muscles. He argues that the ear is essentially formed by the same skin as the rest of the body, hence it is also, as the ear does, able to receive and interpret vibrations.[75]

Constant communication between our sensory modalities strengthens the impressions we afford by the world we live in, but more importantly allows for such impressions to be firmly grasped and deeply comprehended. Crossmodal activity augments our perceptual ability and enriches our experience through intersensory stimulation. Such observations invite us to embrace pansensual cooperation as the very essence of our perceptual experience. Malnar and Vodvarka suggest that perception is an ”inherently interactive and participatory process” during which ”the objects of perception are as animate as the perceiver.”[76] As the perception of our own existence, becomes an ever intricate structure, continuously amassing complexity, awareness of self becomes the mean for the consistency of existence itself.

3.3 New Ways of Viscosity

The rule of vision was not always so widespread. Walter J. Ong while researching what the effect of verbal culture transitioning to written culture was, came to the conclusion that ”the shift from oral to written speech was essentially a shift from sound to visual space.”[77] Despite the migration of media, from sound to visual information, enhanced by technological advances, Walter J. Ong argues further innovations are the way to re-balance the senses' realms. Modernity, beginning with the Renaissance and the Scientific Revolution generally claimed to already have been heavily dominated by the rule of vision. Well known arguments by McLuhan and Ong consider the invention of printing as a reinforcement to this statement. I propose a continuation to this thought, that the display-centered society of postmodernism has brought. Philosophers of phenomenology not only highlight the fact that indeed modern age has considerably been defined by the authority of vision, but it also intensified its negative effect. Heidegger had foreseen this, and demonstrated it in his thesis: ”The fundamental event of the modern age is the conquest of the world as picture.”[78]

According to Pallasmaa: ”The eyes want to collaborate with the other senses. All the senses, including vision, can be regarded as extensions of the sense of touch – as specialisations of the skin. They define the interface between the skin and the environment – between the opaque interiority of the body and the exteriority of the world.”[79] For example, this shift from the vision-based Net Art to the multisensory works of Post-Internet Art shows a change and a need for the de-hierarchization of our senses, enriching us in a crossmodal perception, meanwhile criticising and questioning our current vision-based everyday life. Perhaps these examples could illustrate the means by which we can influence our total physical sensation by activating more sensory organs. Quoting Juhani Pallasmaa: ”Vision places us in the present tense, whereas haptic experience evokes the experience of a temporal continuum.”[80]

EJTECH exhibitions

These thoughts and ideas led to the theme of the two solo exhibitions of EJTECH, *New Ways of Viscosity* (2016) at Collegium Hungaricum Berlin*,* and *Sensorium* (2017) at Trafó House of Contemporary Arts that reflected on the above described phenomenons.

Synopsis of *New Ways of Viscosity*

As recoil to the exponential invasion of digital carvings landscaping our lives, a craving for tactility, depth and dimension has led us to long for lost materiality and reconsider the role of physicality and substance once again. In its origin, this exploration began by binging on ultra high resolution renders, edging towards the improbabilities of awkward dynamics and impossible physics, swinging between self evident CG and skin tight texturing. Conspicuous compositions, shiny still-life-inspired visuals blended into illogical geometries, distorted characters, plants and art history classics. This new kind of materiality was conceived for an onscreen lifespan only, luring the senses to a hyper-haptic awakening. This multi-dimensional ambition, unconfined, constantly and capriciously multiplied and transmitted, adopted and adapted, is flattened for the screen, fit to view in a browser. "Vision is an extension to the sense of touch" as Juhani Pallasmaa puts it in his book The Eyes of the Skin. All senses can be regarded as specialisations of augmented skin. Through this self denominated new materiality, we bring to the senses characteristics interconnected to virtuality, questioning this forgotten sensibility, where importance weights as heavy on the sense of touch, as on perception through sight. Nothing is in a fixed state. Everything is liquid. ≈ As if caught in an in-between state of bouncing between online and digital appropriation of offline existence, New Ways of Viscosity proposes the architecture of the internet not only as a virtual medium that has shaped the way with think, but as a tangible substance and material, with quantifiable physical properties in which we exist. Rather than an immersive installation, EJTECH renders an open invitation for the de-hierarchization of the senses by fabricating reactive structures from foam, textile and aluminium inciting a personal exploration through sound, light and the ever intimate tactile experience.

Synopsis of *S E N S O R I V M*

In the current hyper hectic character of contemporaneity, we are witnessing unprecedentedly significant changes in human civilization in a very short amount of time. Changes in our environments. Changes in our societies. Changes in our bodies. Our almost devotional relationship to technological advancements, focused mainly on intangible, virtual spaces, such as the internet, make us blind to the fact that these cyberspaces, clouds, and all computing power is very much a physical world process built on mined earthly matter. Hand held devices constrict our tactility to fabricated haptic feedback. Hyper communications keeps us misinformed and confused, rather than united. It is imperative that we construct new myths and rediscover a new sense of spirituality. A new spirituality that is intrinsically connected to a new materiality. No divine middle men. No digital false idols.

S E N S O R I V M is a pop-up cathedral. A tangible temple of new materiality. An initiation ritual into techno-spirituality. A liminal experience on liminoid ground.
S E N S O R I V M addresses the present stale state of misdirected spirituality through an interactive exercise of spatiotemporal material process. Through extensive research of the crossmodal, EJTECH proposes a tactile experience into light and sound, an open invitation

for the de-hierarchization of the senses by creating interactive interfaces from textile, minerals, plantae, and other unexpected elements inciting a personal, intimate exploration into materiality. The honest, intuitive, instinctual interaction that occurs when participants discover their expressive touch and gestures translate into sound, unearth a forgotten connection usually connected to elevated states of consciousness, or the virtuous sincerity of children. The state of now.

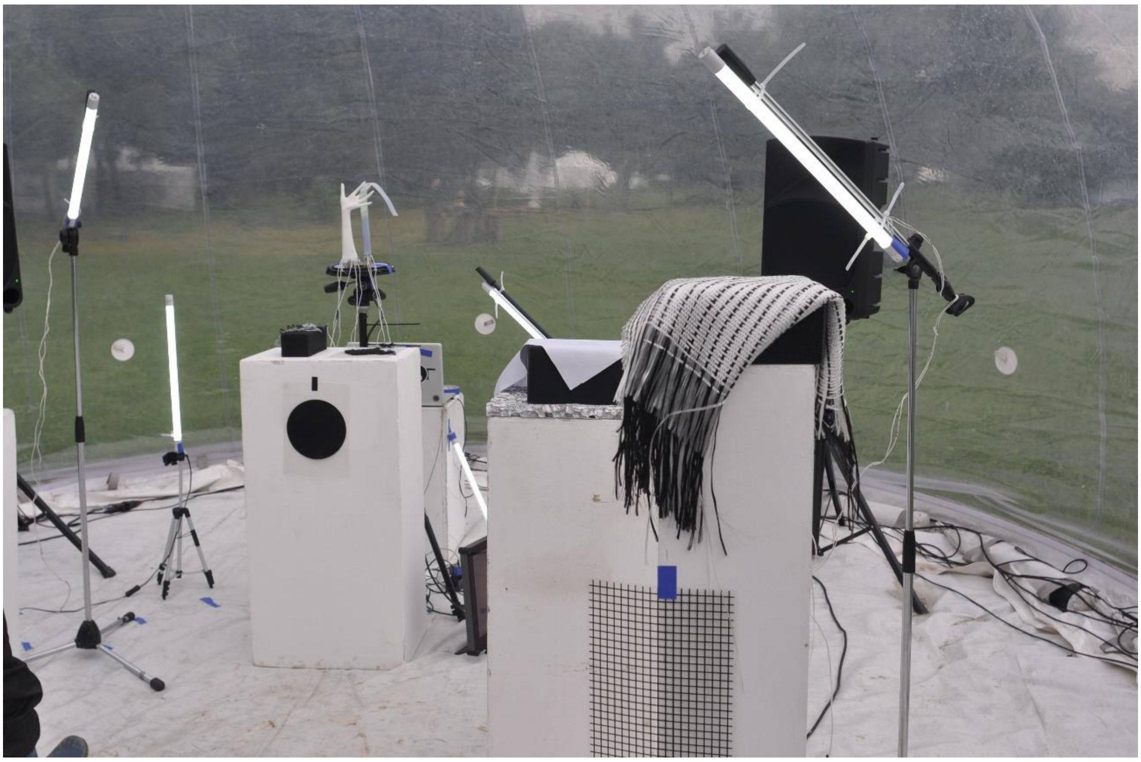

Figure 8: Sensorium pop-up exhibition at Kolorado Festival, 2018

Chapter 4

SONIC DIMENSIONS

"All sound is an integration of grains, of elementary sonic particles, of sonic quanta."
Iannis Xenakis

Through the sense of hearing, we obtain an abundance of information discerned from pressure waves entering our ears, perceived as sound. Sound provides a wholesome, continuous contact with our surroundings, and the events happening around us. It is an integral, unavoidable part of user experience, yet, its potential has greatly been overlooked and mostly used as mere background music, or more recently, accentuating events via auditory icons or earmojis.

4.1 Sonic Interaction Design

Sonic interaction design is considering sound as an active medium, in an embodied and performative way that can enable new phenomenological and social experiences through interactive technology. This evolving new field challenges the traditional gaps between the tangible and the immaterial, everyday sounds and music, functional action and expressive gesture, human and nonhuman agencies, by combining different disciplines including interactive arts, electronic music, sound synthesis technologies, acoustics, perceptual, cognitive, and the emotional study of sonic interactions, as well as interaction design, and communication studies. Therefore, sonic interaction design can be defined as an interdisciplinary field of research and practice. It follows the trends of the so-called third wave of human-computer interaction, where culture, emotion, meaning and experience, rather than only function and efficiency, are the scope of interaction between human and machines.[81]

Usually in digital products, sound has been largely used accompanied by screen-based interaction or to present information in the form of sound. Interactive sonification is a useful approach to monitoring activities related to sport and everyday tasks, but the user is engaged only in reduced hand movements which is limited to the mouse and screen icons, thus the performative aspects of sound cannot be exhibited to their full potential. For fostering an embodied experience, both the interface and its sonic behaviours have to be designed with much attention. The advancements and continued availability of physical computing resources has enabled major developments in tangible interfaces. The research and interest for creating a more expressive interaction, has created impressive proposals of new musical instruments. These interfaces are focused on engaging with the user's gestures, and subtle interactions through physical manipulation of the interface. Such explorations into a more organic, intuitive interaction, are not only complementary to the traditional computer software interaction of keyboard and mouse, but the empty-handed gestures widely used in HCI research in virtual environments and interactive art installations. Both the field of textile interaction design and sonic interaction design have multisensorial aspects, therefore, interactive experiences have to be designed with much consideration of the auditory, tactile, visual, and kinesthetic senses. Both research fields engage with a range of other research topics. The multisensory aspects of the interactive sonic experience that sonic interaction design and e-textiles are concerned with, must be designed in close detail with consideration of the auditory, tactile, visual, and kinesthetic senses in a real-world context. To come closer to reaching such a complex goal, the field of sonic interaction design and e-textiles, currently still in an early, experimental, stage, must engage with a wide range of research topics, including the perceptual, cognitive, and emotional study of sonic interactions. Improved models for the reception and performance of sound, better sound synthesis technologies and the design and evaluation methods addressing the individual and social experience revolving around sound object. I am interested in the corporeal experiences evoked by the inherent specific material properties, as well as the temporal and spatial qualities of sound. For example, the difference between visual cues, and those incited by the vibratory, malleable character of sound. Realizing this specifics to the sound medium and how these affect our understanding of interaction, enables us to thoroughly analyze and grasp this unique phenomenological, aesthetic and social aspect of the interactive sonic experience. An issue with the concept formulized to understand interaction, is the simplification of it being just a series of input-output processes, assuming the default set of relations between the user/interactor, object/instrument and the interaction environment is infinitely stable. This is a fundamentally abstract definition of interaction as it does not take into consideration, for instance, the effect time has over the environment, therefore potentially altering the interaction altogether. Arjen Mulder the Dutch biologist and media theorist defines interaction ”is a mode of bringing something into being – whether a form, structure, a body, an institute or a work of art – and, on the other hand, dealing with it.”[82]

Sound has peculiar spatiotemporal and material characteristics, that as a medium, distinguishes it from other sensory modalities. The inherent materiality of sound, particularly, how via interaction it can be shaped, malleated and modulated, proving it to be intrinsically tangible, and not exclusively an acoustically perceived phenomenon. The body is constantly navigating through space and time, seeking out what Gibson called ”invariant structures”[83], the crossmodal phenomena found in the environment that helps us guide sensorimotor action. This is one of the central elements when considering embodied action and perception within sonic interaction design. As an example, higher frequencies, being of directional nature, are highly dependant on the perceivers position in relation to the sound source as well as the physical features of such environment. According to Andrew Pickering, sound acts on the world, through its ”material agency”[84], a force on other material beings.

In the 1950’s and 1960’s the work of composers such as Steve Reich, John Cage and Nam June Paik, experimented with the malleability of sound via physical interaction using audiotape. Since then, the interest of expressiveness in the musical gesture has come back into focus, using sensing and actuating techniques. New hybrid interfaces, once again add a new dimension to material play and bodily exploration of sound. In sonic interaction, it is the relationship between the gesture and sound that shapes our experience, while the materiality of sound only achieves truly embodied quality through physical interaction. *The Sound of Touch* is an interface created by David Merrill and Hayes Raffle in 2007. It is one of the clearest examples in the study of material textures and sculpting sound. A wand-like interface is used to record, store and playback sound based on the interactions with a natural, physical objects and textured materials.

Sound can be molded by our actions, and this, in turn, can modify our auditory perception. For example, Yon Visell, Karmen Franinović developed *EcoTile*, a floor-tile interface for audio-haptic simulation of different types of grounds.[85] The floor is composed of tiles that provide vibrational and sonic feedback in order to generate audio and haptic sensations of walking across different surfaces. Via sound and vibrations a wooden tile and become and simulate the squishy effect of walking on new snow. The vibrational nature of sound delivers an intimate, tangible experience. We can sense the vibrations from sounding objects, on our body and in our bones. Low frequencies, omnidirectional in nature, emanated by powerful subwoofers, send thudding rhythmical sound waves, connecting bodies and spaces into a singular dense dancing matter.

Philips Pavilion designed by Le Corbusier, Iannis Xenakis, and Edgard Varése for the 1958 Brussels World's Fair is a key historical example of the ways in which the perception of aural architecture influences bodily perception of space. Le Corbusier and Xenakis instead of placing a series of systems of speakers into an architectural shell, designed a hyperbolic paraboloid geometry for directing and influencing the behaviour of the sound. Xenakis routed the pavilion with over three hundred individual loudspeakers, specifically positioned to maximize how the different frequencies in Varése's eight-minute *Poème électronique* would come into existence inside space. Low, rumbling frequencies were handled by heavier speakers near the ground, while the smaller speakers followed the interior surface and parabolic curves in order to allow sound to travel across and through the building, forcing listeners to continuously reorient their bodies and shift their listening perspectives. While sound is contained in a space, it cannot come into existence without time. According to Fourier, the phenomenality of sound is marked by its temporal attributes: period, frequency, and amplitude.[86] Sound synthesis uses artificial techniques to manipulate timbral, rhythmic and dynamic behaviours.

Figure 9: Philips Pavilion at the time of the '58 Expo in Brussel

4.2 Sound as a vibrational force

Sound as an informational source is described in terms of the auditory attributes, such as timbre, tone, duration, loudness. These characteristics are analysed and give relevance to the delivery of musical meaning. But sound is not only about meaning. It is also about physical energy shared. Sound as a vibrational force[87] links human bodies and matter at a material level, via physical resonation. This notion indicates an understanding of sound as a material force, that resonates technological tools and alongside humans in a rhythmic, cyclic experience, connecting these in a technical and cultural level. This action enables the corporeal mode of knowing.[88] Human beings perceive sound, either when it is heard by entering the ear canal or when it is physically felt. It is on and in our physical body that acoustic waves become discernible. Sound is an effect of the nervous system caused by perception. However, sound does not only originate outside the body. Within our working organs, our pumping blood also produces sound. Even though it is almost inaudible, it is ever present and can reveal important information about our present state of being. This field is called auscultation.

The study of sounds material capacity and cultural implications has developed rich accounts of how acoustic waves affect the human body in many different levels. Goodman and Henriques argue that the tangibility of sound waves can induce emotion arousal, from pleasure to pain, from a chaotic mindstate to blissful peace. Through his studies of this theory, Henriques suggests, that beyond our traditional sound receptors, this waves become a vibrational vector through which memories surface, emotions come to emerge and meaning is expressed. When such waves come in contact with our body and resonate within, Henriques argues, a form of embodied expression takes place. It has only been until recent time that the physical qualities of sound have been studied, and noted as an important aspect of the human experience. For centuries, only music and the human voice have been regarded as attention-worthy phenomena, and as Sterne notes, have been privileged over other instances of sound.[89] Recognizing sound as a vibrational force, following Goodman and Henriques, I explore the entire spectrum of this material phenomena. I push beyond the limits of symbolic meaning associated to sound, and observe sound as an acoustic vibration that produces corporeal, perceptual and physiological experiences. I choose to engage with this affective bodily experience emerging from complex relations between the physical and the psychical, the conscious and the preconscious.

4.3 Sound and Matter in Design

When playing traditional musical instruments a sense of touch is of immense importance, however, a rich tactile response is lacking in the current generation of digital musical interfaces. The materiality of textiles with their sensory-rich qualities can give a novel approach to the design and evaluation of future digital musical interfaces. Haptic, derived from the Greek word, haptesthai means something that can be touched or grasped. In interactive music the use of haptics, that is, tactile and proprioceptive feedback, was pioneered, among others, by Claude Cadoz. Cadoz created *The Cordis Simulation System* that captured physical gestures via force and position sensors and reacted to the player by providing haptic feedback.[90]

Michel Waisvisz composer and performer developed *The Hands* in 1984, a gestural controller-instrument worn on the hands that placed sound literally between the musician's fingers: catching, stretching, and compressing it as the same sound transited through the air. "If our goal is musical expression we have to (...) engage with the system: power it and touch it with our bodies..."[91] Waisvisz created this new musical instrument, together with engineers and software developers at STEIM, in Amsterdam. It leveraged wearable technology using a wide range of sensors, including tilt, pressure and infrasound sensors with a keyboard to capture different aspects of a performer's motion.

Figure 10: Michel Waisvisz performing with The Hands

For Waisvisz, The Hands represented a means to touch sound, through which the player can extend his musical skills. In his own words, what was needed was an instrument that would enable a player to "operate, navigate, compose, mold and play sound in a sensible, refined and even sensual and groovy way".[92] Waisvisz thought that the electronic instrument and the human body shall literally touch each other to allow musical expression to move past the symbolic interaction provided by electronic systems and embrace corporeal modalities of interaction similarly to traditional instruments. In his own words, "we should abolish the illusion of 'control' (...) get inspired by change, miscalculation, invested instinct, insightful anticipation, surprise and failure."[93] According to Waisvisz the playfulness and the quality of a musical experience relies and emphasises an open-ended interaction between the performer and the instrument and it does not depend on the control of the performer over his instrument. As stated by Waisvisz the aim will be to embrace risk, surprise, error and miscalculation as they are constitutive part of the relationship of human and technology that enrich musical expressivity.

Tactile and auditory cues can be used to improve seamless interaction in user interfaces. Our sensory systems perform well together. Our ears tell our eyes where to look. While sounds can be heard omnidirectionally, this results in a low resolution of information. Eyes on the other hand can focus on a comparable small area, but in a very high resolution. Studies reveal that auditory stimuli has shown to result in faster reaction that visual stimuli.[94] Touch provides high resolution information across the body, especially at the hands. Tactile feedback has a higher temporal resolution than vision, but lower than that of audition. Humans can hear sounds in a range between 20 to 20 000 Hz, varying on the age and usage of the hearing organs, while the frequency range sensitivity of skin to mechanical vibrations is significantly smaller, reaching around 1000 Hz, with maximum sensitivity and finest spatial discrimination at about 250 Hz.[95] The auditory system is very power and can recognize complex structures by listening and can discriminate fine subtle textures through our skin. These traits are highly underutilized in our everyday interactions with technology. The fingertip, for example, has a two-point contact discrimination threshold of 0.9mm in the absence of movement. It becomes much finer and distinguishable when minor movement is involved. The human sense of touch is incredibly perceptive and is composed of two subsystems, kinesthetic and cutaneous.[96] Currently, tactile devices, such as mobile phones or video game controllers, present information to these perceptual systems, in a blunt, obtuse manner. Force-feedback devices use low cost eccentric-mass motor actuators consisting on a mass mounted on a motor to stimulate this senses. In response to this brute approach to conveying meaning, high resolution information to the sense of touch, I research and develop high resolution textile actuators focused on cutaneous perception, as well as textile sensors to explore further sonic dimensions.

Sound and Matter in Design exhibition

Sound and Matter in Design exhibition took place in 2017 at the Design Museum Holon in Tel-Aviv, explores the ways in which spaces, environments, and everyday experiences are shaped by sound. As this exhibition demonstrates, sound is not merely a backdrop to the unfolding of our daily routines; rather, it is a central element that is shaped by culture and shapes it in turn.

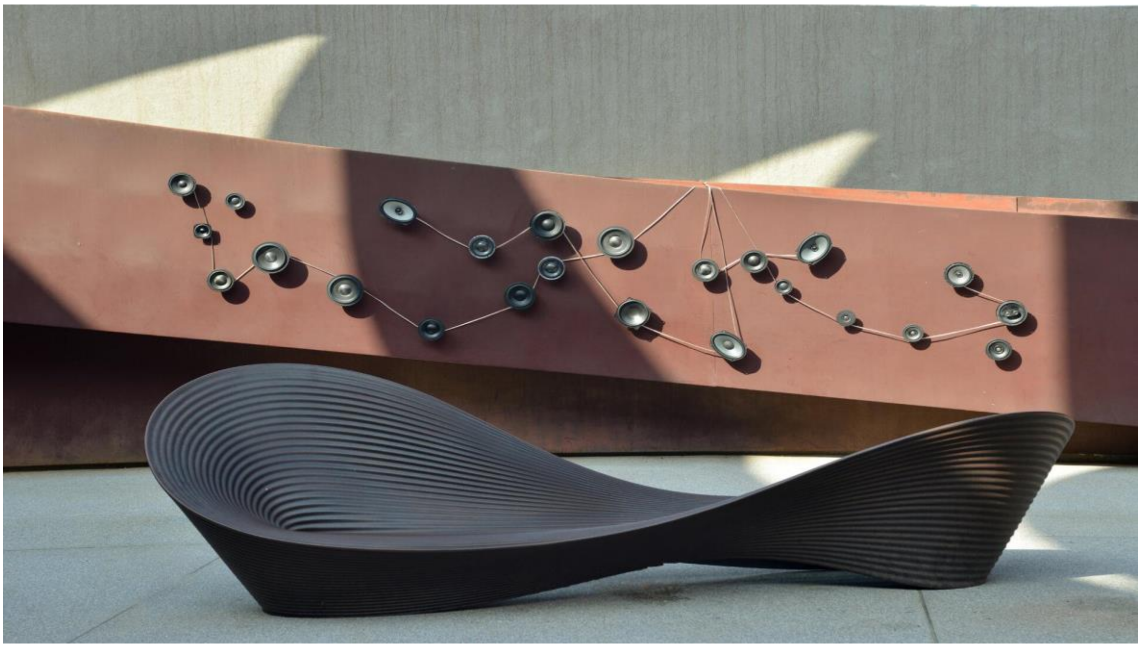

Figure 11: The Sound of Architecture, Sound and Matter in Design exhibition

Although the world of design is identified with physical as an abstract element – is one of the most significant „raw materials" in the designer's toolbox, regardless of whether he is concerned with the design of an object, an item of clothing, a room, or a building. Sound assists us in defining spaces and orienting ourselves within them. Since it is based on vibrations, it also triggers physiological and emotional reactions in the listener. When combined with social and cultural insights, the complex relationship between sound and matter, body and space, allows for a new understanding of the environment and of human behavior within it. This understanding is based on attention and listening, and not just an observation and touch. The exhibits on display were divided into three categories: stationary, mobile, and interactive objects, which exemplify the conceptual shift from object design to the design of a user experience. In the interactive object category *Liquid MIDI* was on display.[97]

Liquid MIDI is an excerpt from my artistic research focusing on experimental interfaces, and the recontextualization of tangible interaction for the creation of immersive soundscapes. Liquid MIDI is an experimental textile interface for sonic interactions, exploring aesthetics and morphology in contemporary design. The technology is screen printed directly onto a neoprene textile surface, then through an Arduino microcontroller communicates with the desired software using MIDI protocol.[98] This unique interaction with the textile interface allows the medium to become part of the message, where the interface becomes part of the process of creation itself. Sound is a medium that has been increasingly gaining ground in the visual arts during recent decades, despite this seeming contradictory. Technology plays one of the main roles in this multidisciplinary crossover, allowing not only for this amalgamation of the visual and auditory practices, but to further ventures into how do we form this experience and with what tools do we design this multifaceted, polysensorial undertaking. The flexibility of screen printing a working interface onto a bendable surface and being able to control digital devices and applications through it, opens doors to infinite possibilities, allowing to indulge in a hyper connected, interwoven experience. The aim was to create a more balanced, coherent multisensory perception of reality. The textile interface is capable of perceiving bodily expressions itself, and also presents a range of textural qualities that challenge bodily responses. The intuitiveness of the physical interaction can be created by increasing the perceived materiality of sound.

Chapter 5

MASTERWORK – SOFT SOUND

Soft Sound is an art-based study on the crossmodal, employing sound, textile, and space as one unified medium. This practice-led material research focuses on the use of sound as a material force, resulting into an audio-haptic surface. This augmented textile, proposes new possibilities to create, and interact with sound. An exploration on the amalgamation of textile and sonic art forms as a spatiotemporal material process, where transdisciplinarity in practice results into powerful moments of reflection, and intrinsically, the medium becomes the message. This project operates on the edge between technical and artistic exploration and focuses on the crossmodal manifestation of sound through matter, recontextualizing textile as a high definition sound source. This modular system enables for a large number of speakers, comparable to a large number of pixels in the visual world, creating a high-resolution vibro-tactile, sonic experience. A practice-based research on intersensory perception, observing the visual and tactile exploration of the vibrational force of sound, as well as the sound of immateriality expressed via the timbre of a textile medium. Soft Sound is a musical instrument, as well as an experimental sound system, investigating the spatial phenomena of wave field synthesis. While working and developing the technology for my masterwork, I was concerned with the indisputable importance of multisensorial experiences, not as a finished rigid art piece or product, but as a process and exercise in liminality. According to Jerome Rothenberg: “The function of art is not to impose a vision or consciousness, but to liberate a similar process in others.” I am preoccupied with questions and thoughts dealing with ever speeding pace at which contemporaneity rushes. We are witnessing some of the most significant changes in the shortest amount of time in human memory. Changes in our environments. Changes in our societies. Changes on our bodies. It is imperative for us, in this hectic climate, to construct new myths, and rediscover a new sense of spirituality. A new spirituality that is intrinsically connected to a new materiality.

5.1 Matter / Pattern

Particle physics has radically changed our view of what used to be conceived as matter; a colossal, dull lump of comatose particles. Recent developments in the study of the fundamental forces in the universe, known as the Standard Model, reveal exciting new concepts of the fabric of reality. Ranging from Particle Cosmology with the reproduction of models of the early universe, to the confirmation of the existence of the Higgs-Boson particle, or the attempt to construct a unified description of general relativity and quantum physics, thus creating one consolidated “theory of everything”, or “TOE”.[99] As these new findings bring new questions, undermining the idea of stable and predictable material substance, hastening a realization that our natural environment is far more complex, unstable, fragile and interactive than earlier models proposed. Soft Sound reflects on the potential of such malleable systems, employing sound as vibrational force[100] on textile structures, thinking about sound, not as an auditive phenomena or mere noise, but as a basic building block in our perception of physical reality.

The use of sound as a material force has been explored in the area of thermoacoustics, the interaction between temperature, density and pressure variations of acoustic waves. Within this field, the research expands from controlling temperature using acoustic drivers to thermoacoustic engines (TAE), devices that convert heat energy into work, however the relevant phenomenon to my research, are the spontaneous oscillations occurring in certain materials when heat is applied; these are known as “Taconis oscillations.”[101] These occurrence has been observed for centuries by glass blowers, also often referred to as singing glass. Although many times this sonic event is considered as a purposeless side effect, Georges Frederic Eugene Kastner a french physicist and musician, invented the pyrophone[102] in 1870, also known as the fire/explosion organ. Using the same principle seen in a Rijke tube, turning heat into sound, Kastner tuned glass cylinders by size and organized them musically triggering small controlled sudden explosions in order to make them vibrate. This early inspirational audiovisual musical instrument significant in connection to my masterwork, due to use and focus on its material properties and the mining of the hidden interactions between physics and matter. Another important inspiration in my research of modal vibrational phenomena are cymatics. Robert Hook, english philosopher, architect and polymath, observed in 1680, that by sparkling fine dust on a vibrating glass plate, patterns corresponding nodal lines of vibration would emerge. Experiments on this, the study of Cymatics were later perfected and systematically documented in the book *Discoveries in the Theory of Sound*, by Ernst Chladni in 1787. This raw manifestation of sound in another media, totally independent from the experience of hearing has served as a great tangible direction. By augmenting or amalgamating textiles with soft electronics, I have successfully excited and set these textiles into a vibrational frequency that becomes tangible, fully observable by the naked eye, and clearly audible. This explores a new dimension in the intersection between textile and sound.

When working with the textile medium, the vast amount of possibilities and configurations are breathtaking. During my practice-based research, I have experimented with numerous techniques and materials. The basic premise is to create a soft electromagnetic coil, and attach it to a textile membrane. This textile coil is connected to the driving signal, in order to reproduce sound. The first working prototype in the early stages of this research, was embroidered conductive thread onto canvas. This method, while being the first success, reproduced sound muffled, and at low volume. I continued to experiment with materials under the same technique. During these series of experiments I realized the importance of the materials used for membrane, as well as the important role electric resistance plays on the coil and overall result. Canvas gave way to new tests on membrane materials, as well as new structures. I have experimented with knitting patterns, using conductive yarn, yet these direction and such textile structures, proved to be very much sound absorbent and heavy. Unsatisfied with the overall volume that could be achieved with such techniques, I looked for answers in more traditional musical approaches to sound, such as acoustic musical instruments that use textiles or membranes. Inspired by the tightened skin or plastic over a drum, I replicated a tightly woven textile, using copper wire, over the mouth of a cylindrical body. These resulted in a clear, loud result. The only problem, is that this solution had entirely lost its textile characteristics. It has been a 3 year trial and error process, and while each technique explored during this process has its pros and cons, my aim with Soft Sound is to produce high-fidelity sound via vibrating textiles, hence I had to focus and single out possibilities with this target in aim. By using technical textiles, concentrating on those designed with an ultra tight structure, such as wind proof textiles or water resistant materials, lightweight, yet sturdy, I have been able to yield the most efficiency out of this system, in order to dedicatedly affect the air with the enhanced textile in order to produce high-definition audible sound. To set the textile into vibrational motion, laser cut conductive textile electromagnetic coils are hot-melted onto the membrane textile, which in turn, are connected to an amplifier receiving the driving signal. A permanent magnet is placed close to the electromagnetic coil to allow the mechanical motion in action.

Humanity has been familiar with metals for about 10 000 years. They have been indispensable in the development of mankind, including its vital connection to electricity. Conductive textiles, or semi-conductive textiles are fabrics that via various methods such as, woven metal strands or impregnation of carbon or metal based powders, can conduct electricity. These have a wide array of uses, from static dissipation in high performance firefighter equipment to EMI shielding on spacecrafts and other speciality purposes lightweight is imperative. I have laser cut spiral shapes from Copper and Nickel (CU+NI) plated conductive textile, to produce flat circular textile electromagnetic coils. Traditionally, such coils are produced by wrapping, hundredths, to maybe thousands of time hard copper wire around a cylindrical shape. These are heavy and hard and completely useless to my design. Instead, after much testing, I have settled for conductive textile spirals of about 8cm in radius, varying the amount of turns depending on the thickness of the path itself. I have deliberately decided to leave such spirals visible in the final result, even though they can be easily concealed. Modern technical society tends to hide all these intricate material processes, behind a flat, smooth surface, making us forget about the alchemy-like wonders of the inner workings of technology. I suggest the relaunch the historic sacral meaning of metals by revealing the raw electromagnetic spirals that make Soft Sound work.

The spiral is one of the most widespread shapes found in the natural world, seen in the form of embryos, horns, whirlpools, hurricanes and galaxies. It is also one of the most ancient symbols used by humankind. Findings of spirals being carved decoratively into objects, have been dated to as far back as 10 000 BC, during the Neolithic period. Examples of the geometric shape can be found in archeological sites around the world, such as the Newgrange entrance slab in Ireland using the Celtic triskelion, three outward spirals symbolizing earth, water and air, all driven by fire, having all four elements united as one life, creative power. Swastikas in Asia and India, which amongst many meanings and depending on its orientation, symbolize the path of the sun. In Latin and Central America, Quetzalcoatl, the Mesoamerican god of the wind, life and knowledge, wears a spirally voluted wind jewel around his neck. This is a conch shell cut at the cross-section, also worn by religious leaders and rulers, potentially symbolizing this recurring pattern that had great importance within these cultures. Even though slight mythological differences exist between the significance and spirals between one culture and the other, it is widely associated as a sacred symbol that represents an evolving path and ever changing processes, many times identified with the vector of time through space, the cyclical evolving journey of life and reincarnation within the pertinent belief systems, or the eternal expansion of creation from its origo. In latin "spiro" means to breath, and probably the first ever musical instrument invented was the conch, a wind instrument also known as a seashell horn or seashell trumpet. Spirals are used to represent shells. The spiral is the path that resolves conflict through a balanced natural unfolding into a harmonious transformation. Spiral processes in nature evoke a mystic journey of awakening.[103]

Even though there are numerous examples on visual representations spirals as of sound on textile, I would like to discuss the approach of the Shipibo-Conibo culture in Peru's Amazon forest. Icaros, according to the Shipibo custom, are songs inspired by the connections with the spirits of the plants and ancestors, written by shamans during visions in elevated states of consciousness. These icaros are used in healing ceremonies, and are also translated into colorful tapestries adorned by these stunning geometrical patterns. These tapestries are not meant or used as musical notation, but rather visually represent the physical vibration of a song, as also found in study of cymatics, as mentioned earlier. When placed side by side, a Shipobo pattern and a Chladni figure, the similarities are stunning. An ancient belief, observed by the Shipobo tribe before proof from modern science existed is that vibrations are foundational components of our universe. Space is probably a loop of loops, just as a piece of material is the web of fibers.

5.2 Technology / Energy

Within this subsection I will expand on the technical processes, methods, mechanics and further findings, encountered during the research and development of the working technology for my masterwork. The practical aim behind Soft Sound is the advanced exploration and recontextualization of textile as an electroacoustic transducer, enabling textiles to convert an electrical audio signal into sound, while adding tactility and physical presence to a sonic experience. The relationship between textile and sound have a history focused rather towards the damping, absorption or diffusion of sound within the study of acoustics, than as an actual sound emitter. Soundproofing, whether it be in professional music studios or striving for architectural silence, is achieved by strategically placing specialized textiles, or acoustic foam, such as sound curtains, acoustic drapes or noise blankets in a space in order to reshape its acoustics.

My master work explores and presents textiles as a viable and exciting new approach on working with sound, not only due to its inherent interactivity possibilities, its intuitive tactility and its deeply rooted tradition and implied meaning in modern civilization, but as an attempt to view textiles as a new medium with plenty of yet unexplored advantages. Textile and sound, both hold substantial roles as building foundations of a complex society, they also have shared elemental concepts such as rhythm, structure or pattern. Concepts that denote our perception of a fabric, being tangible or abstract, taking up space and time. These joint concepts are provocative and moving when creating a textile focused on sonic interactions.

During my successful pursuit to animate textile into the extent of producing audible sound, I have deconstructed a modern-day loudspeaker and stripped it from its rigid components in order to translate this technology onto an entirely flexible, durable textile. In the common dynamic loudspeaker, patented in 1924 by Chester W. Rice and Edward W. Kellogg, a diaphragm or cone is connected to a rigid basket or frame through a suspension attached to the “voice coil” wrapped around a cylinder which contains a permanent magnet. As stated by Faraday's Law of Induction a basic law of electromagnetism that predicts how a magnetic field will interact with an electric circuit to produce an electromotive force (EMF), is the phenomenon we refer to as electromagnetism. According to Faraday: “The induced electromotive force in any closed circuit is equal to the negative of the time rate of change of the magnetic flux enclosed by the circuit”. This means that when applying an alternating current, into a coil, next to a permanent magnet, depending on the state of the coil, this will be physically repelled or attracted by the magnet, at the applied frequency, and in turn creates mechanical force, causing the coil to move back and forth rapidly, pushing the air around it, creating sound waves. Whereas this concept bases the materiality of its enclosure, as well as the solidity, coil type and design, directly proportional to the quality of the sound, Soft Sound translates this constant, into the structure, shape of coil and materiality of the textile membrane. Through an extensive research, I have been able to calibrate an efficient balance between the physical textile sound system and the intended reproduction of sound.

The conversion of a repeated occurrences of an event per unit time, also known as frequency into audible sound is, in its purest form, the manifestation of this frequency into a mechanical motion, pushing the air around it back and forth in order to become sound we perceive via our ear canal. This is elementally the translation of an intangible concept, into a physical, tangible force.

Creating a system for high-fidelity reproduction of sound has been a fascination for audiophiles since the first phonograph was invented by Thomas Edison in 1877, an incredible yet rudimentary machine that was able to faintly reproduce sound by having a diaphragm attached to a stylus, trace grooves etched into a spinning disc or cylinder. This ”talking machine”, contemporary to the early attempts of creating an electric loudspeaker by the likes of Graham Bell, Ernst Siemens or the Path’e company, were quite inventive, yet significantly limited by their poor sound quality and the inability to reproduce sound at low volumes. Speech would become muffled, and music would become distorted, rendering these inventions near useless. As mentioned in the beginning of this chapter, it is the Rice and Kellogg patent for the dynamic loudspeaker that models the principles of the high-fidelity loudspeakers we are familiar with today. As technological developments have allowed, since the turn of the last century, advancements in sound systems have become impressively immersive, subtle and detailed. Evolving from mono to the first stereophonic, two channel method of sound reproduction, to multichannel formats such as quadraphonic or 4.0 surround sound. Working on 4 independent channels, or more, are used methods for creating in immersive sonic experience based on the spatial perception of sound. Although these advanced techniques are very effective on exploring a listening event, they remain short for evoking what Pallasmaa calls a “strengthened sense of materiality and hapticity, texture and weight.”[104] These systems limit such bodily experience of sound to the lower frequencies and rumble that is perceived by our skin and bones when extremely high volumes of sound are produced. This effect is widely used and exploited in film scores to create tension or in music, mostly electronic music, to force the listener into motion, via low, rhythmical thuds. Pioneers of this approach are Jamaican sound engineers, notorious for creating monumental stacks of dedicated speakers, physically built to faithfully reproduce designated sound frequencies ranges, such as tweeters or super tweeters for higher frequencies noted for their “beem”, directional nature, mid-range speakers, woofers and monolithic subwoofers to rattle the ground, the body and the bones, using the omnidirectional constitution of low frequency sound. These complex systems, in order to function at high efficiency, need to be calibrated properly for the respective desired sound, by matching amplifiers, preamplifiers, and all the electronic components involved. Composing an overall electronic signal equilibrium within these network is quite laborious, but when achieved efficiently, the result is astonishing.

For my final artwork, creating an efficient sound system, using experimental interfaces built from textiles, was quite a challenge. Amplifiers, indispensable in all hi-fi reproduction of sound, are electronic devices that take the input audio and increase the power of its signal according to the impedance of the speakers connected. Calibrating and cutting the coils in order to work harmoniously within this system, meant researching the best way to amplify the sound signal, without overheating or burning any of the elements. Experimenting with the various classes, ranging from the typically used for hi-end audio Class-A, Class A-B linear amplifiers, I realized that these, besides requiring a big power supply in order to work properly, also produced a lot of heat on the working textile due to their non PWM amplification. This solution, even if working, meant the soft, flexible lightweight textiles needed to be connected to a heavy duty, sturdy hardware. Another issue was the cost of such amplifiers, per channel. If only dealing with a stereo, 2 system, this could be relatively affordable, but when contemplating a 32 channel modular speaker system, the economic price elevated noticeably. Whilst researching and building my own amplifier, I tested Class D amplifiers, also known as switching amplifiers. These are very efficient amplifiers, as they have a very high power conversion efficiency, meaning in a reduced power waste as heat. Also, can be built into reduced sizes, at a reduced cost. Inspired by previous examples, and as mentioned, I have envisioned Soft Sound as a modular system that opens the possibility for a multichannel, multisensory experience. Fascinating works such as the Philips Pavilion designed for 'Expo58 in Brussels by the intriguing Le Corbusier have a vital influence on my work. This multimedia spectacle created in collaboration with Iannis Xenakis and Edgar Varése is a beautiful example on crossmodal practices celebrating technological progress. As the final outcome of my artistic research, I will present iterations on the working art piece and developed technology exploring the possibilities of multichannel control and the effects of sounds vibrational force exerted by a textile.

5.3 Sound / Perception

Sound as anthropologist Georgina Born states, is "alogogenic"[105] meaning: unrelated to language, non artifact, having no physical existence and nonrepresentational. It is a self referential, aural abstraction. Soft Sound has the intent to broaden this properties of sound, and make it available through a visio-tactile experience. As mentioned earlier, the human ear can perceive from 20 to 20000 Hz, the skin's sensitivity to mechanical vibrations and temporal resolution is smaller with a range of about 1000 Hz where the frequencies around 250 Hz are the most sensitive and with most spatial discrimination. Humans do not just experience sound through the eardrums. When most people are presented with a recording of their own voice, they seem to find it unexpected and weird, even though they have been listening to that voice throughout their life. This is because, when a recording is played back, they will only hear their own voice, and do not experience the vibrations created inside their body and skull when they speak. The art of listening has been an obsession for mankind since the dawn of perception. Humans have been building musical instruments by tightening dried skins over wood, hollowing bird bones. These primitive musical instruments, some dating over 41 000 years of age have overall been agreed as having ritualistic purposes. It is quite interesting to note the fact that these instruments, while depending on their own acoustic body to define timbre, tone and other sonic qualities, were also built and thought for playing in certain contexts and spaces. Acoustic archeologists such as Reznikoff propose, although without conclusive proof, that Palaeolithic cave paintings are directly related with the present resonance within the space. Properties such as placement and amount of painted animals or motifs inside an archeological site, appear to be directly related to the amount of echo counts and other acoustic properties of sound. An astonishing find regarding the importance in the phenomenology of sound.[106]

Soft Sound establishes a link between the textile and the listener, not through an auditory experience only, but by the vibro-tactile properties embedded, as well as the visual feedback this situation creates. The implications within the study of this subjective experience, the intentionality of sound and touch, point towards the unveiling of a very seldom explored dimension of textile interfaces. While it is an essential characteristic in user experience, as well as interaction design, haptic feedback, augments flat, otherwise meaningless experiences, into a physical, memorable event. Take the example of the clicking sound or very mild, stabbed vibration produced by a mobile device while texting. Although more advanced users might decide to turn this feature off, the default settings are set to give out this sonic haptic feedback in order to allow the user to fully grasp and live the action of texting. A temporal guide of what letter has been inputted, and when is it time to type in the next. Same applies to on-phone cameras. Without the emulated shutter sound, short vibration and click, users would not know whether the photo was captured or not. These are examples of rewarding user experiences achieved by synchronizing sound and touch, and are pertinent when considering wearable technology, however I have personally chosen not to work exclusively on the body, as my fascination for material in relation to human reaction, space and sound is stronger.

By using sound as a material force, via textiles, a further spatiotemporal process is unveiled. While it is inherent to the sound medium to be inevitably entangled to its spatial-environmental context, Soft Sound focuses on the material agent of the sound source as a focus of this study. This unexpected interaction between textile and electronics, give way to the active process or “poesis” of a textile soundscape, a multisensorial experience. The textile material, its weight and structure used as a membrane is what defines Soft Sounds’ distinct timbre. This characteristic is what is also referred to in psychoacoustics as tone color, tone quality, and not surprisingly it is considered the texture attributed to an instrument. Hence we can comfortably conclude that the texture of the textile used as a membrane, will not only be experienced through touch, but this same property will be translated to the sonic characteristics of such. Soft Sounds’ textile timbre is intrinsically connected to is materiality. Soft Sound is a textile interface, a modular sound system establishing a direct link between the textile and the listener. The multi channel network requires specialized musical compositions to explore the psychoacoustic phenomena of wave field synthesis. A specialized software was patched using MAX/MSP visual programming software in order to control the flexible array of textile speakers, independently. Envisioned as a microtonal musical instrument, opening the possibilities to use standard tuning based on the standard A=440Hz, the International Standards Organization’s recommendations for concert pitch, or to easily switch alternative temperaments, such as the A=432Hz, known as Verdi’s A, a beautiful tuning based on Pythagorean harmonic ratios.

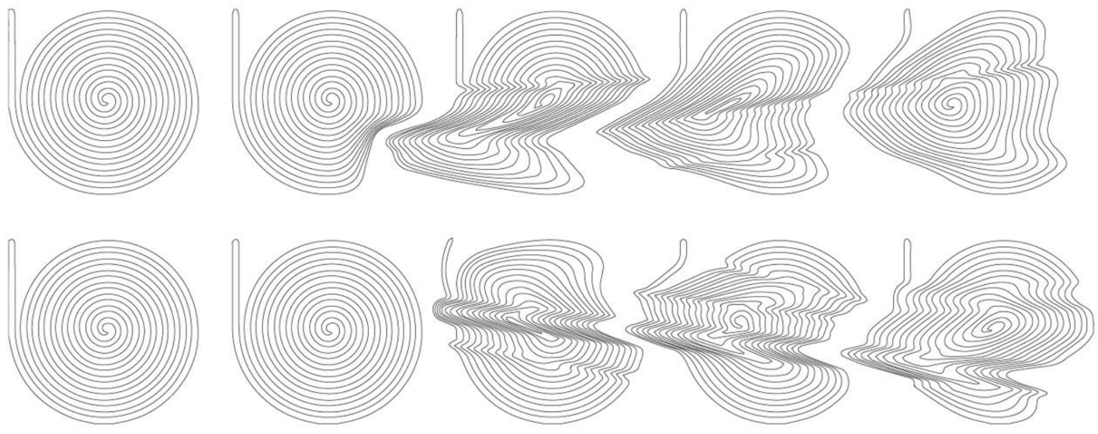

Figure 12: Spiral coil variations for laser cut

Fifure 13: Soft speaker vibration test

Figure 14: Laser cut copper coil on transparent textile

Figure 15: Sof speakers series experiment on one textile

Figure 16: Soft speaker shape experiment on technical textile

Figure 17: Soft speaker shape experiment on technical textile

Figure 18: Stereo soft speaker testing at WeMake makerspace, Milan

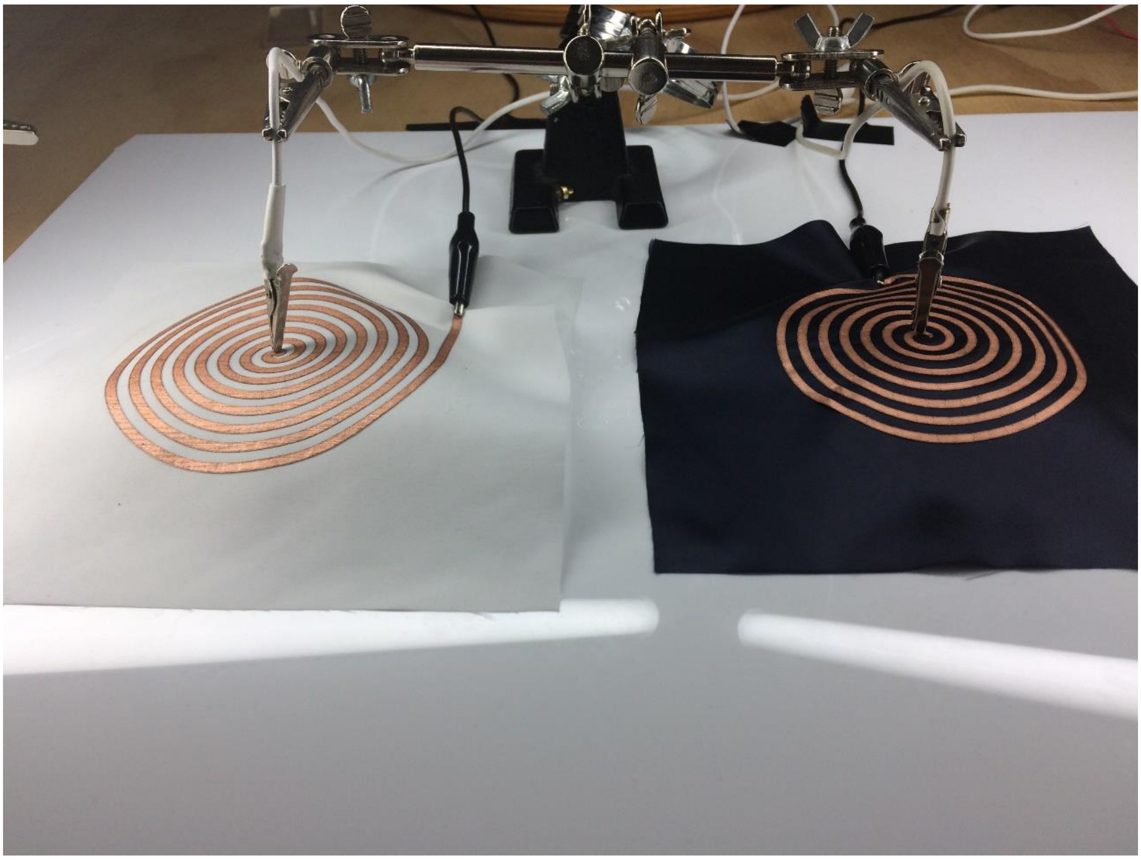

Figure 19: Stereo soft speaker testing at WeMake makerspace, Milan

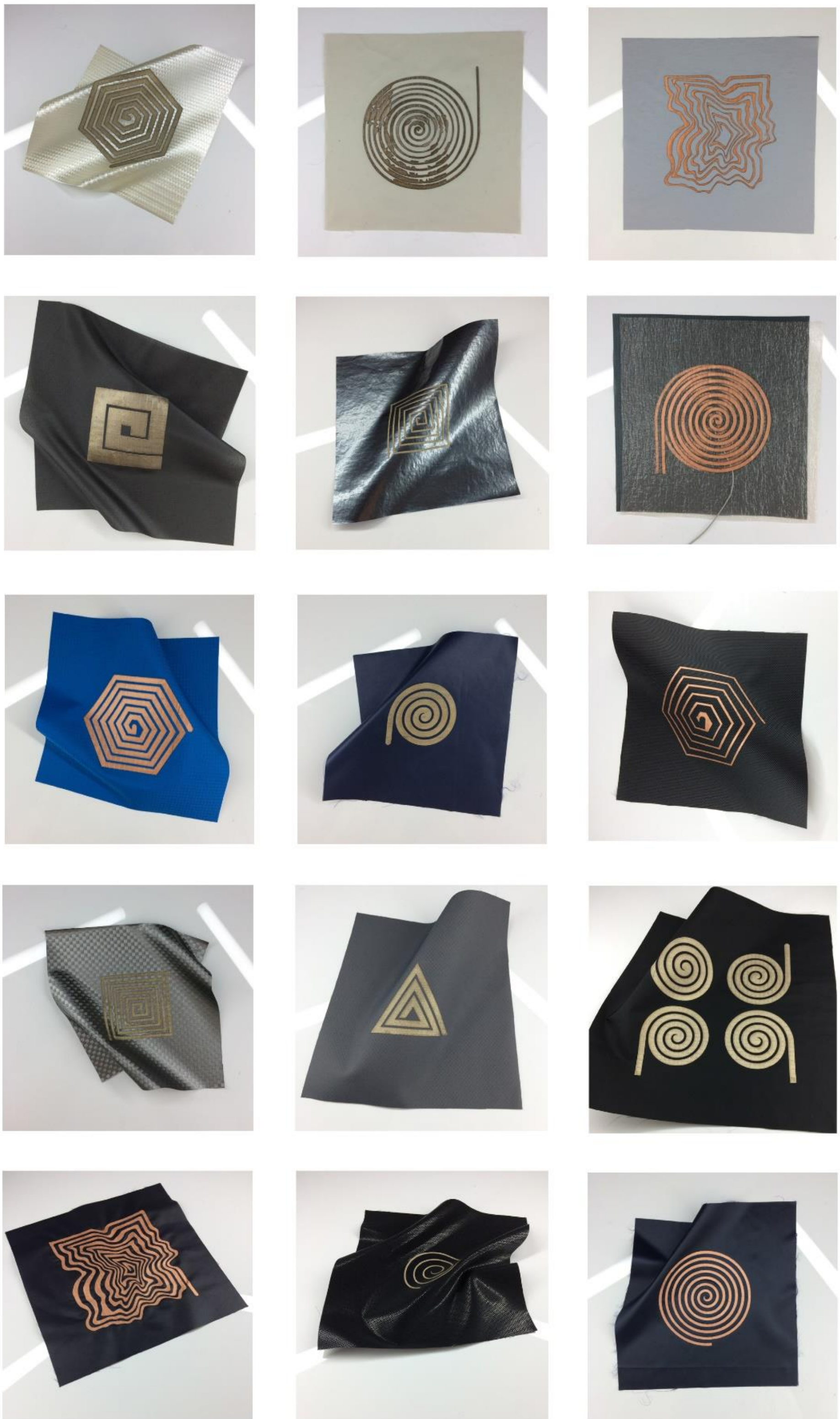

Figure 20: Soft speakers on various textiles, calculated coils in different forms

Production / Vision

Soft Sound is the result of a long research process spanning over three years. The first experiments were done under the Talent Program scholarship in Kitchen Budapest. The aim at this early stage was to get a working prototype: A textile that would emit sound. This was achieved, and as part of an early vision, these working, yet not as sophisticated and efficient textile speakers were embedded onto clothing. The concept behind *Soundwear* (Chapter 2.3) was to create a wearable to replace the usage of headphones. The user would have a one channel speaker embedded onto its clothing, in order to listen to music, as well as feeling it. The main challenge with this early stage, was producing a proper coil. Also, amplification proved to be important, and very hard to pinpoint the sweet spot between the amplifier and electromagnetic textile coil. During this early stage, most of the material tests where across textile structures and media, including knitted, hand woven, felted textiles, screen printing, as well as testing on neoprene and soft shell. The latter ones chosen due to their sturdiness and heat resistance.

During continued research, thin copper sheets were tested to be very efficient for creating a flat coil or spiral. These sheets, also failed to be as flexible and would break or crack with simple bending. It was also complicated and time consuming to hand cut the desired shape. During this stage, the second iteration of Soft Sound, the research was done at WeMake in Milan, under a 3 months scholarship. WeMake is the leading maker space in Milan, with access to a wide range of machinery. This proved to be very useful as I could test and prototype quickly, dismissing failures and building on successes. During this time, I also investigated and found a very low resistance conductive textile to replace the thin, brittle copper sheets. Originally I tried to vinyl cut the coil, yet soon found laser cutting to be the ultimate solution. Laser cutting is very precise, but textiles are very flammable, hence easily burnt or charred. A high power laser cutting machine is needed to cut such textiles precisely, at a high speed to ensure clean edges. This technique also allowed me to cut the exact same coil many time, in order to test the difference in sound quality when experimenting with new materials for membranes.

It is part of the EJTECH work process, to document stages of successful attempts and development. This work in progress has been exhibited in Japan, USA and Europe. It has also gained recognition by the media and has been registered in the CreativeApplications.net, as well as added to the library of MaterialConexion Flagship in New York. Numerous companies have contacted EJTECH in order to purchase this textile or service, that in my vision, besides being a material research art object and practical study on the crossmodal, is a technology that due to the previously mentioned, can be seamlessly applied to interior design, such as sounding curtains, or space dividers working as a sonic display, these being in large scale such as an airport or any other public space, to the private home of an audiophile. Soft Sound could be applied for interiors of automotive design, as well as on wearable tech and fashion tech as an augmentation to everyday interactions. This technology as a product has the advantages of lightweight, foldable textile structures, with the enhancement of multichannel sound.

Chapter 6

EDUCATIONAL EXPERIENCE

The research field of e-textiles is beneficial to the educational world, because it increases art and textile students engagement in new domains, such as programming languages and electronics. I share my knowledge to contribute into e-textile development projects and highlight the richness and creative potential of this practice. In the field of e-textiles the practitioners are required to understand both the explicit and the tacit knowledge of multiple disciplines. For example, circuit schematics or weaving patterns embody explicit knowledge, while learning how to solder and operate a weaving loom require tacit knowledge that comes from practice and experience. Currently, due to the lacking of a formal degree on e-textiles, practitioners must obtain this knowledge from books, online documentation or by attending educational courses and workshops.

6.1 Democratisation of Knowledge

How to Get What You Want is a do-it-yourself wearable technology online documentation site started in 2009 by Mika Satomi and Hannah-Perner Wilson. The site aims to be comprehensible, accessible and maintainable resources, as well as a basis for further exploration and contribution with the documents of wearable technology and soft circuit solutions. Many interesting techniques and possibilities, involving fabric sensors and textile electronics solutions for making sensors, actuators and soft circuitry are shared on the website in order to explore them further towards future ideas. The website also contains collections of material and tool resources and example projects that explain the integration of individual solutions for smaller projects through step by step tutorials. With their twisted criticism towards human-computer interaction they want to inspire others to question the current wearable technology trends. The website follows the Open Source Hardware definition[107], allowing people to freely use and modify the designs, as well as produce and publish new designs based on their works. They define their database a documentation of their trade, and one of the ways they pass on their knowledge.

6.2 Disseminating Knowledge

In this part I present the workshops I held, three courses at Moholy-Nagy University of Art and Design – *Go Green*, *Textile Interfaces*, and *Dynamic Surface*s - , MOME OPEN, and *Wearable Futures* course at Hochschule Luzern. I regularly held workshops together with Esteban de la Torre in many countries, hosting between 10-20 participants each time. The participants' background is various, from electronics beginner to experienced engineer, and from fine artists to industrial designers. During the workshops, we demonstrate or display our own technique on e-textiles. Participants are then asked to create their own projects using the introduced materials and techniques. These workshops provides a chance for participants to physically observe the processes and results that they can see in the online documentations. It is also an opportunity to get in touch with the actual materials as well as with people with similar interests, serving as a place to start local communities among practitioners.

MOME COURSES - GO GREEN, SOFT INTERFACES, DYNAMIC SURFACES

Title	**GO GREEN** (2017/2018 II. semester, MA1)
Place	Moholy-Nagy University of Art and Design, Budapest
Students	Bakács Orsolya, Bokányi Nóra, Eifert Kata Nóra, Lőrincz Lili Hanna, Módra Bettina, Schneider Anna Borbála, Szekeres Ákos
Description	With this project we aim to discuss the future of conductivity and to raise the awareness for nature and to empower and motivate students towards a symbiotic living with nature. Including mindful design approaches for sustainable e-textiles and diving into how technology will change the industry and at the same time benefit the planet, the students will create green sensors that are conductive and biodegradable. They learn how to get data from plants, and use them for making interactive textiles or wearable tech garments. They will develop adaptive and responsive surfaces through natural materials, processes and poetic forms of interaction. Artists and designers have been proposing the ideas to grow textiles as the ways to think about environmental, sustainable, ethical issues surrounding the textile production. The 7 participant were MA fashion and textile design students. We propose to think about these issues including how e-textiles play a role towards sustainable living, create possible futures for second skins, sensors, adaptive and responsive structures.
Aims	Making plant sensors for plant-generated music. Combining traditional textile techniques with technology and nature.
Results	Bakács Orsolya *„Club tropicana"* Bokányi Nóra *„Le-vele"* Eifert Kata Nóra *„Jungle"* Lőrincz Lili Hanna *„Hanna hangja*" Módra Bettina *„Élő minta*" Schneider Anna Borbála *„Poree"* Szekeres Ákos *„Voices in my head"*
Link	https://vimeo.com/260261564


Figure 21: Lőrincz Lili Hanna, interactive structure design with ivy leaves

Figure 22: Eifert Kata Nóra, interactive structure design with leaves and leather

Title	**SOFT INTERFACES** (2015/2016 II.semester BA3, MA1 and 2016/2017 II. semester, BA3, MA1, Course Week)
Place	Moholy-Nagy University of Art and Design
Students	2015/2016 II. semester*:* Paulovics Ivonn, Várai Lúcia, Gyimóthy Noémi, Czakó Sára, Krónusz Fanni 2016/2017 II. semester, Course Week: Györök Borbála, Török Anna, Karakai Hanna, Bajkó Renáta, Gy. Molnár Naómi, Fábry Levente, Tóvaj Rozália
Description	A course focused on recontextualizing textile as an interactive medium. Soft interfaces, hacked textile surfaces in order to create an organic, intuitive communication with digital environments. During the course students learned about basic concepts of e-textiles, soft circuitry physical computing, microcontrollers, open source approaches, various electrically conductive materials and special paints in order to create textile sensors for controlling sound and light. The students combined different fields, such as textile design, sound design and interaction to discover multisensorial experience by adding new qualities to traditional textiles. The focus of the course was on the combination of visual, haptic and acoustic experiences.
Results	2015/2016 II. semester Paulovics Ivonn *„Camilla”* Conductive thread on fur Várai Lúcia *„Al_03.mov”* Woven aluminium wire Gyimóthy Noémi *„Based on a true story”* Interactive screenprint Czakó Sára *„Southern Yucatan in August”* Interactive screen print with plant Krónusz Fanni *„Ericeira”* Interactive screen print
Link	https://vimeo.com/160525505
Results	2016/2017 II. semester, Course Week Györök Borbála *„Happiness”* Conductive thread on fur Török Anna *„Pet the snake”* Metal flakes, conductive thread on leather Karakai Hanna *„Untitled”* Silkscreen, conductive thread on canvas Imets Villő *„Interstellar”* Metal flakes, conductive thread on neoprene Bajkó Renáta *„Touch*” Screen printing, conductive thread on canvas Gy. Molnár Naómi *„Untitled”* Conductive yarn, copper textile, knit Fábry Levente *„Textile drums”* Screen printing on cotton canvas Tóvaj Rozália *„Varrat*” Conductive thread on cotton canvas
Link	https://vimeo.com/212476434

Figure 23: Várai Lúcia, interactive structure design with cotton thread and aluminium wire

Figure 24: Bajkó Renáta, interactive screen printing on textile

Title **DYNAMIC INTERFACES** (2017/2018 II. semester, BA3, MA1, Course Week)

Place Moholy-Nagy University of Art and Design

Students Kovács Réka, Jankovits Anna, Schneider Anna Borbála, Magos Nikolett, Angyal Zsanna Boriska, Vincze Borbála

Description Introduction to reactive, color changing, reversible and permanent pigments, paints and dyes. Theoretical and practical course on thermochromic, photochromic, hydrochromic, reflective, fluorescent, liquid crystal and other dynamic inks. This course is focused on the understanding of fundamental properties and effects of dynamic or "smart" inks and pigments, as well as towards creating a fully working prototype of a textile display. During this study and practice, participants will work with augmenting textiles using microcontrollers, conductive textile and threads, lasers and other elements in order to display visual, changing, information on textile.

Results Kovács Réka

Jankovits Anna *„Elnök úr"*

Schneider Anna Borbála *„Április 8"*

Magos Nikolett *„Sign"*

Angyal Zsanna Boriska *„Genie smiley"*

Vincze Borbála *„Big bear"*

Link https://vimeo.com/262666890

Figure 25: Magos Nikolett, thermochromic dynamic textile interface

Figure 26: Vincze Borbála, thermochromic dynamic textile interface

MOME OPEN

MOME Open was established as a support center for Moholy-Nagy University of Art and Design in 2016, which aims to develop and launch new adult education programs from autumn 2016. MOME OPEN seeks to fill the gap in 21st century knowledge with the creation and operation of artistic, cultural, educational and economic training areas to create outstandingly high quality workforce in the creative sector.

Title	**SOFT INTERFACES: Technology&Textile. Introduction into e-textiles**
Place	Moholy-Nagy University of Art and Design
Students	Huszti Melinda, Jakab Priszcilla, Kustyán Anett, Lőrincz Szilvia, Oberfrank Luca, Százdi Mónika, Varga Anikó, Vig Virág
Description	During the eight-week course, participants learn about smart textiles, basic concepts, techniques and methods that combine art and technology through theoretical presentations and hands-on workshops.
Key themes	Smart Textiles, Innovative Technologies, Interactive Materials, Wearable Technology, Interaction Design, Dynamic Surfaces, Physical Computing, Programming & Prototyping
Link	http://open.mome.hu/soft/

Figure 27: MOME Open workshop at MOME Z

Figure 28: MOME Open workshop closing

Title	**WEARABLE FUTURES**
Place	Hochschule Luzern / Lucerne University of Applied Sciences and Arts, Switzerland
Students	Lisa Scherebnenko, Simon Hischier, Jennifer Papatzikakis, Chiara M. Davanzo, Patrizio Welti, Valentin Berger, Melanie Burkhard, Kouto Deiara, Salome Bruggisser, Leila Saad, Andrea Fortmann, Matthias Goldenberger
Description	We were invited by Gordan Savičić multimedia artist and Christoph Zellweger interaction designer to give a three-day long workshop, Wearable Futures at Salon_IDA (Interdisciplinarity in Design and Arts) for 12 participants with a background in jewellery design, fine art and computer science. The topics were Textiles Sensors, Dynamic Surfaces, Soft Circuitry and the students had to built an interactive system as an outcome of the workshop.
Results	1.*The Very Important Message* by Lisa Scherebnenko, Simon Hischier 2. *Changing Skin* by Jennifer Papatzikakis, Chiara M. Davanzo 3. *Hurricane Tongue* by Patrizio Welti, Valentin Berger 4. *Digital Touch* by Melanie Burkhard, Kouto Deiara 5. *Embarrassing Me* by Salome Bruggisser, Leila Saad 6. *Too Much Love For a Skeleton* by Andrea Fortmann, Matthias Goldenberger
Link	https://www.hslu.ch/de-ch/design-kunst/studium/studienuebergreifende-module/ida-im-bachelor/modulangebot-2018/modulangebot-2018-ida-201-210/ida208-wearable-futures/ https://vimeo.com/272208958

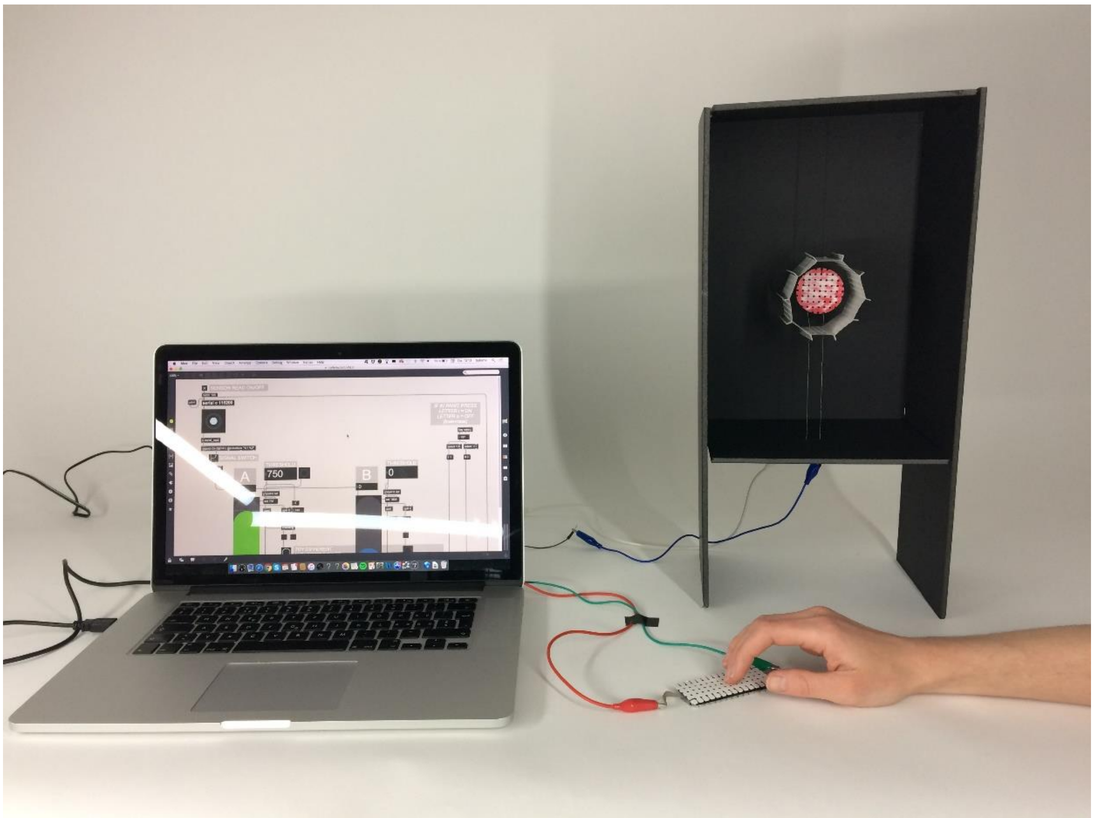

Figure 29: Salome Bruggisser, Leila Saas, interactive system, soft sensor, dynamic surface

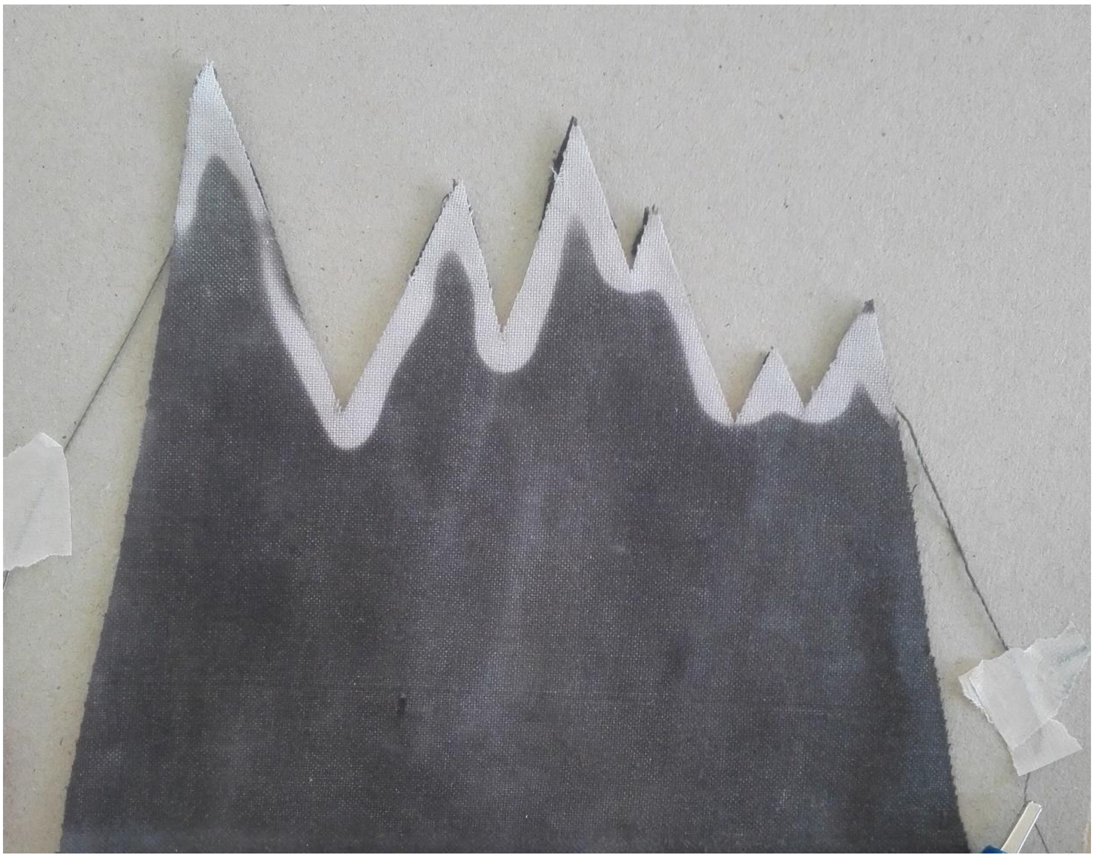

Figure 30: Dynamic surface experiment with thermochromic ink

6.3 Community

Many practitioners in the field of e-textiles participate in the DIY community, by documenting their techniques online on various platforms such as Instructables and GitHub, as well as on their own blogs and websites. Some practitioners hold workshops or teach at educational institutes. These workshops and face-to-face meet-ups encourage collaborative learning and working models, fostering an attitude that thrives on sharing knowledge and skills openly. Physical meeting also foster discussions and healthy critiques of work, something which the anonymity of the internet often lacks. DIY (do-it-yourself) or DIWO (do-it-with-others) communities serve as a platforms for exchanging both explicit and implicit tacit knowledge, motivating creative processes and encouraging collaborative work.

The E-Textile Summer Camp

E-Textile communities are in many ways connected. On the one hand they exchange ideas on the internet and on festivals and meetings where artists, researchers, educators, engineers, designers, makers, hackers are involved. An important annual meeting is E-Textile Summer Camp in France, which brings together e-textiles and soft circuitry experts. It is organized around a theme (e.g. Beyond Kitsch) or different focus-groups, (e.g. Go small Go wireless, Industrialization, Tools for practitioners, Make your tech and wear/use it too, Knitting Electronics)

Swatchbook Exchange

Swatchbook Exchange is a platform for sharing physical work samples in the field of electronic textiles. The exchange wishes to emphasize the importance of physicality and quality workmanship in an increasingly digital world. Everybody who has attended the E-Textile Summer Camp at least one time is allowed to take part in this exchange. Individuals and collaborative efforts participate in the exchange by submitting a unique swatch design of their own, and in turn receive a compiled collection of everybody else's swatches. Participants in the Swatch Exchange have diverse links to the e-textile community, including academic researchers, textile designers, industrial designers, artists, electrical engineers and enthusiastic makers. There are no guidelines defining what these samples could or should be, only that they relate to the field of e-textiles, and fit in a 15cm x 15cm surface area.

WeMake makerspace

During my Hungarian National Eötvös Scholarship program in 2016, my goal was the learning, acquisition, and application of the practice-based methodology of the „maker" movement operated in cooperation with democratized technologies and network communities to make the preparation of my masterwork related to this theses. The three-months long scholarship in WeMake makerspace in Milan was linked to practical activities of my doctoral research via the methodology of research through design. For interactive installations and tactile interfaces, the use of software-based tools and programs is required. I used the opportunities offered by the Eötvös scholarship to expand my knowledge regarding these. In my research I mainly examined the visual programming languages required for physical programming (which means controlling motors, sensors, actuator by computer), and specialized on sound. Milan is a center hub of technology and innovation for design and the textile industry. WeMake makerspace in Milan is an open, horizontal creative space, a meeting point, which allowed me to meet and work with prominent experts. Digital technologies are utilized within the framework of interdisciplinary projects combining sociological, artistic as well as technical skills and content. Their primary purpose is to explore the possible novel applications at the intersection of art, science and technology, to create collaborative projects between the different disciplines with their well-equipped and expanding knowledge and tool park. In their realized projects, they integrate artistic vision, social design and the possibilities of modern technology. WeMake helps realizing complex, innovative, knowledge-based projects with their highly qualified team of experts. With the open source approach making different technological knowledge available and accessible to everyone. This practice-oriented community makerspace focuses on three areas: electronics, textile, and digital fabrication.

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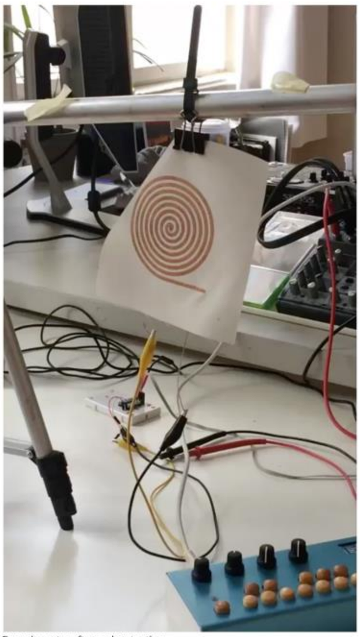
Appendix

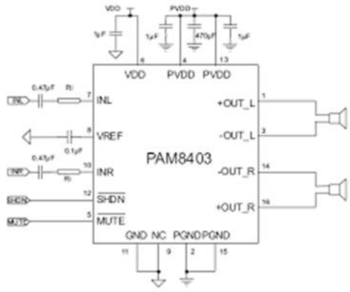
Experiment: thermochromic textile speaker test

Experiment: laser cut test on woven conductive textile

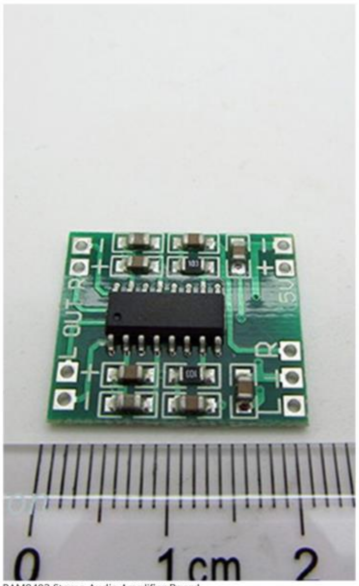


Experiment: soft speaker testing

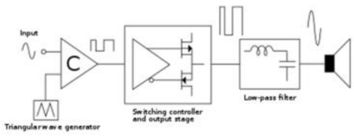
Experiment: laser cutting copper textile

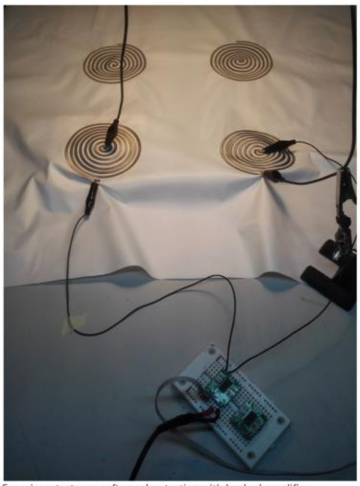


Experiment: testing waveforms in Ableton Live



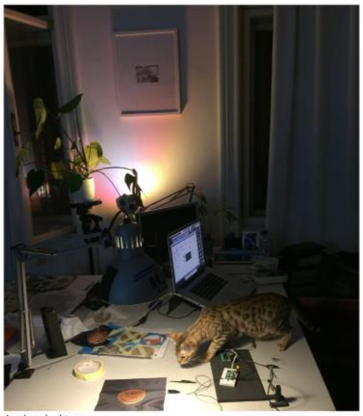
PAM8403 Stereo Audio Amplifier Board





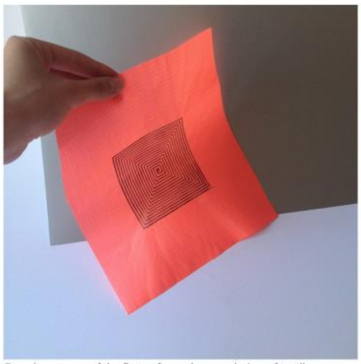
Experiment: stereo soft speaker testing with hacked amplifiers

Experiment: laser cut nonwoven copper textile

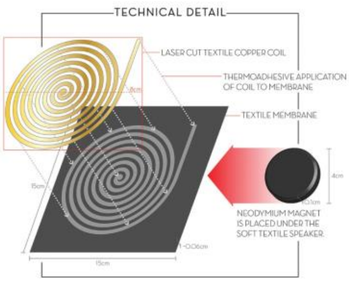


Analog desktop

Testing frequencies

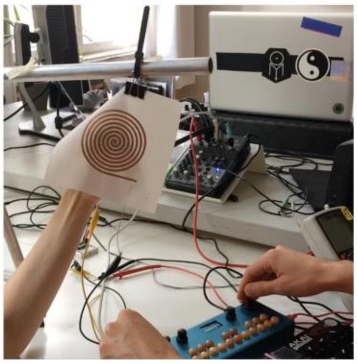


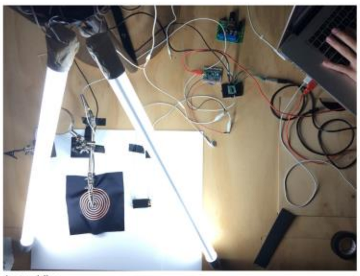
Experiment: one of the first soft speaker on windproof textile



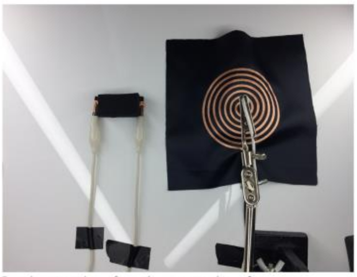
Technical details

Types of conductive textiles

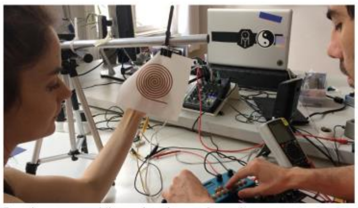




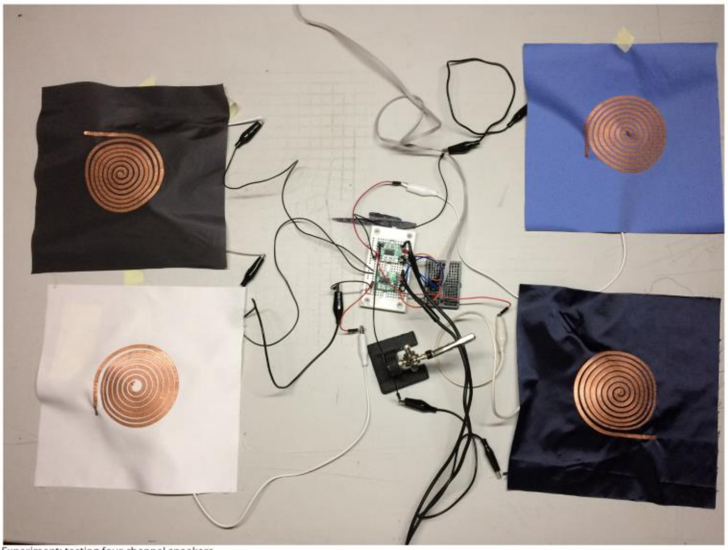
Assembling

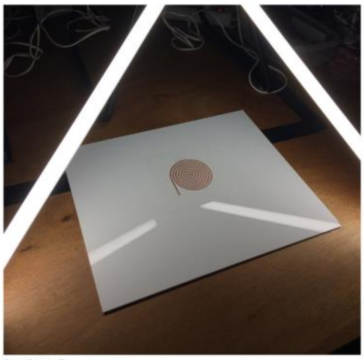


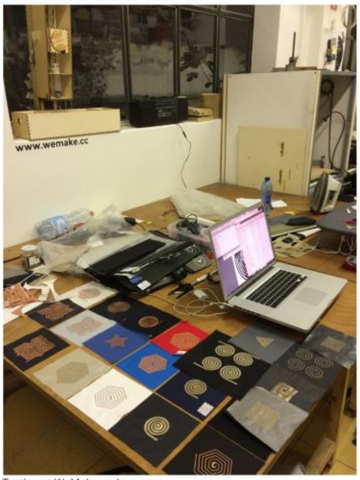
Experiment: testing soft speaker connected to soft sensor



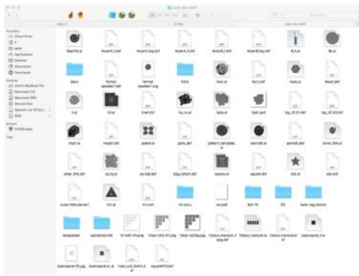
Experiment: assembling and testing a soft speaker


Experiment: testing four channel speakers

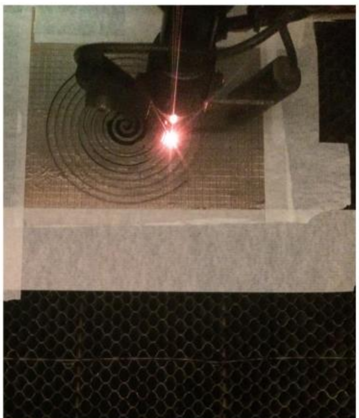

Speaker coil



Testing at WeMake makerspace


Digital desktop

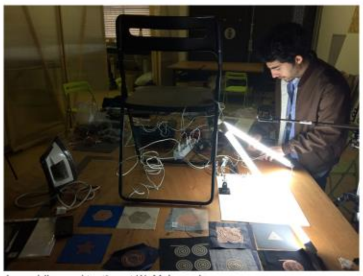

Laser cut coil on transparent textile




Experiment: coil design


Experiment: embroidered soft speaker on technical textile


Experiment: laser cut calibration


Assembling and testing at WeMake makerspace


Woven conductive textile

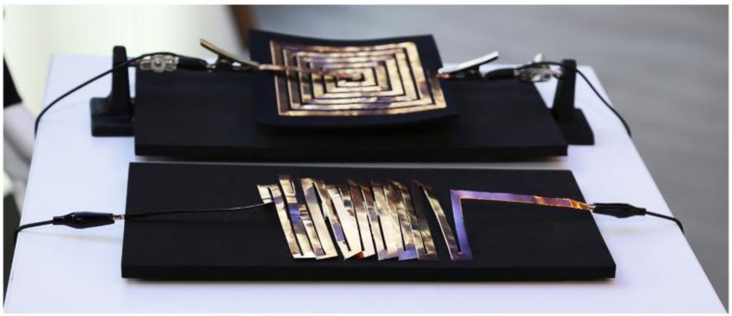

Experiment: woven speaker

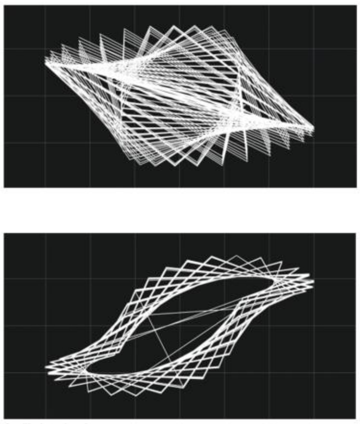

Experiment: liquified speaker test

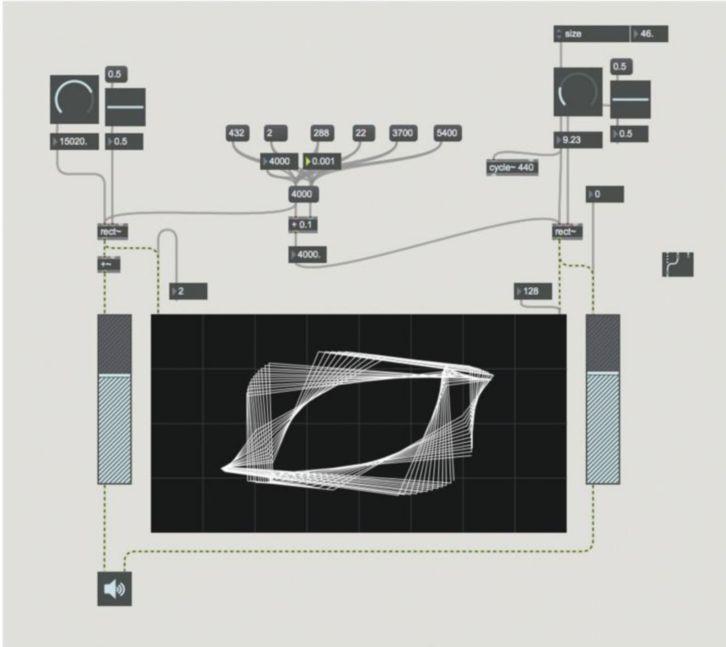

Soundwear


Kozma scholarship exhibition

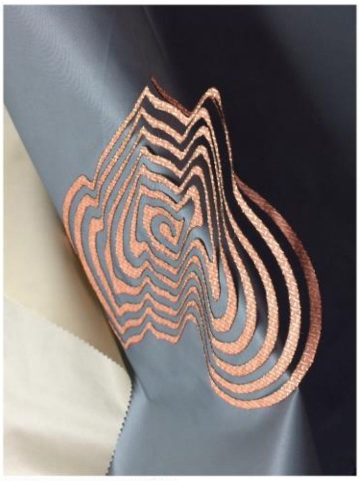

Experiment: speaker connection test


Early soft speakers with copper foil on neoprene


Oscillation visuals



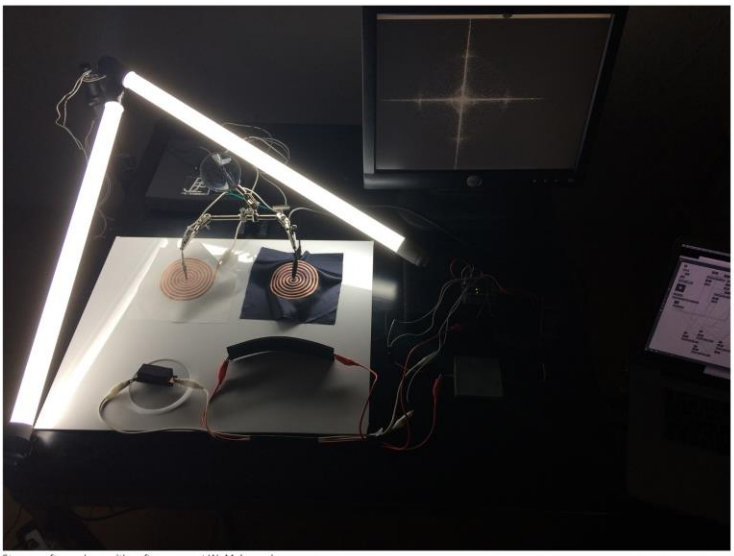
MAX/MSP patch


Experiment: soft speaker variation

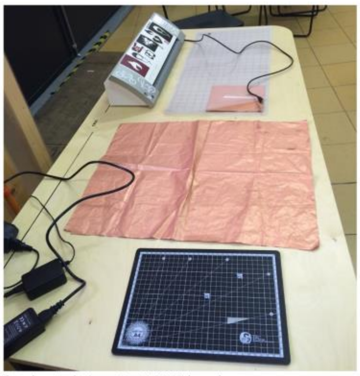

Experiment: laser cut calibration test

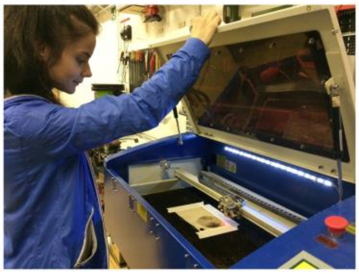

Stereo soft speakers


Soft speaker series at Kozma exhibition

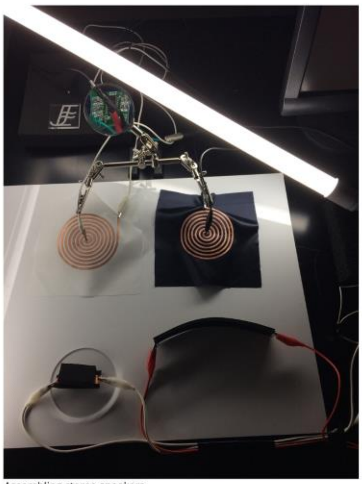

Stereo soft speakers with soft sensors at WeMake makerspace


Experiment: embroidered speaker on technical textile

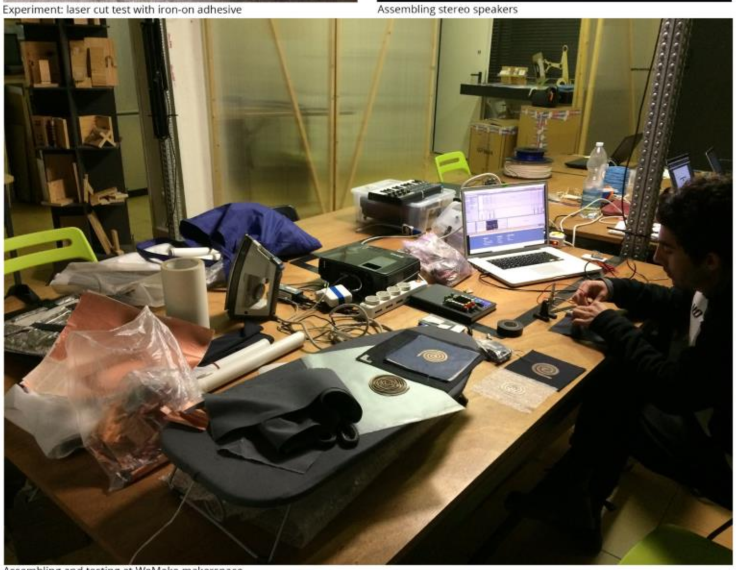

Experiment: plotter cut test at WeMake makerspace

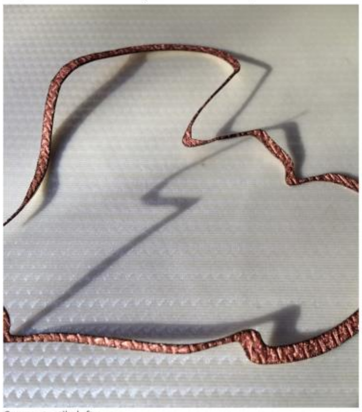


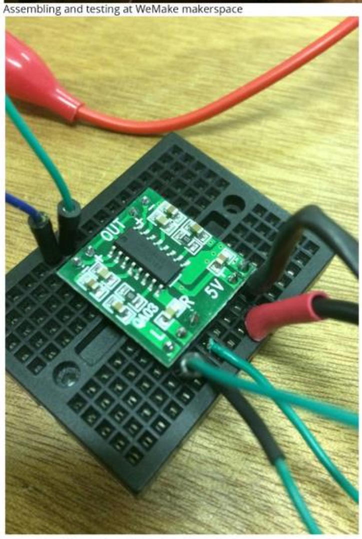

Experiment: laser cut test with iron-on adhesive


Assembling stereo speakers


Experiment: laser cut testing at WeMake makerspace


Assembling and testing at WeMake makerspace


Copper textile leftover


Stereo amplifier on breadboard


Soft speaker shape variations

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Declaration of Originality / Eredetiségi nyilatkozat

Alulírott Kárpáti Judit Eszter (szül. hely, idő: Miskolc, 1989.04.06, anyja neve: Molnár Sarolta, szem. ig. szám: 396809KA), a Moholy-Nagy Művészeti Egyetem Doktori Iskola Iparművészet DLA doktorjelöltje kijelentem, hogy a Soft Interfaces. Crossmodal Textile Interactions című doktori értekezésem saját művem, abban a megadott forrásokat használtam fel. Minden olyan részt, amelyet szó szerint vagy azonos tartalommal, de átfogalmazva más forrásból átvettem, egyértelműen, a forrás megadásával megjelöltem. Kijelentem továbbá, hogy a disszertációt saját szellemi alkotásomként, kizárólag a fenti egyetemhez nyújtom be.

Budapest, kelt: 2018. 08. 26.

Curriculum Vitae

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EDUCATION

2013 – 2016 Moholy-Nagy University of Art and Design, Doctoral School - abszolutórium
2010 – 2013 Moholy-Nagy University of Art and Design, Textile Department, MA
2007 – 2010 Moholy-Nagy University of Art and Design, Textile Department, BA
1999 – 2007 Herman Ottó High School

PROFESSIONAL EXPERIENCE

2014 - EJTECH studio - co-founder
2014 Kitchen Budapest Innovation Lab - researcher
2016 - Moholy – Nagy University of Art and Design, Fashion and Textile Department – lecturer, course leader

EXHIBITIONS

2018 Untitled, Horizont Gallery, Budapest, Hungary - upcoming
Parallel Realities,**EchoSynthesis**, Deák17 Gallery – upcoming
Sensorium, Kolorado Festival, Budapest, Hungary
Brain Bar Budapest, Corvinus University of Budapest, Hungary

2017 **Cuatro Tiempos**, Trafó House of Contemporary Arts, Hungary
Sensorium, Trafó House of Contemporary Arts, Hungary
Sound and Matter in Design, Design Museum Holon, Tel-Aviv, Israel
Packet 1, Ex Post, Prague, Czech Republic
All Around Us, Budapest Kunsthalle, Hungary
Brain Bar Budapest, Akvarium Klub, Budapest, Hungary
YouFab Global Creative Awards, Tokyo, Japan

2016 **New Ways of Viscosity**, Collegium Hungaricum Berlin, Germany
Talking Textiles, Wanted Design, New York, USA
Előtérben a háttér, Omnivore Gallery, Budapest, Hungary
FISE Design 2016, Hefter Üveggaléria, Pannonhalma, Hungary

2015 **Sensescapes**, FISE Gallery, Budapest, Hungary
smART!XTRA, Trafo House of Contemporary Arts, Budapest, Hungary
The Garden Sound, Budapest Design Week, The Garden Studio, Hungary
E-textile Summer Camp, Paillard Centre d'Art Contemporain & Résidence d'Artistes, Poncé Sur Le Loir, France
Pillow 2.0., Palmetta Design and Textile Art Gallery, Budapest, Hungary
ARTplacc, Contemporary Art and Design Festival, Tihany, Hungary
Ungheria – Artigianato tra tradizione, design e arte del saper fare, Monza, Italy
FISE Textile, Bartók32 Gallery, Budapest, Hungary
Techtextile - Textile Structure for New Building, Frankfurt, Germany

2014 **E-textile Summer Camp**, Paillard Centre d'Art Contemporain & Résidence d'Artistes, Poncé Sur Le Loir, France
Smart Fashion, Budapest Design Week, Design Terminal, Hungary
Design2014 – Designers of FISE, Tatabánya, Hungary
Budapest Design Film Festival, Budapest Design Week, Hungary
Demo Day, Kitchen Budapest, Hungary
Velux International Design Award, Design Academy Eindhoven, Netherlands
Pecha Kucha X Budapest New Tech Meetup, Trafo House of Contemporary Arts, Budapest, Hungary
Dobbantó, Polish Institute, Budapest, Hungary
Graduation Project - best graduation projects in Central Europe, Polish Institute, Budapest, Hungary
Fresh Fishes, FISE Gallery, Budapest, Hungary

2013 **Graduation Project** - best graduation projects in Central Europe, Poland
Pick Up the Thread! Path of senses in the thicket of finnish ryijy carpets, Museum of Ethnography, MOME Transfer Lab, Design Week Budapest, Hungary
MOME Master's Degree, Ponton Gallery, Budapest, Hungary
Pentatonia, Palazzo Morando, Palazzo Isimbardi, Milan, Italy
Heimtextil, Frankfurt, Germany
Rethink/Re-button!, Design Terminal, Budapest, Hungary

2012 **XXI. Winter Exhibition**, Miskolc Gallery
Pentatonia, Brussels, Belgium

2011 **Rethink/Re-button!**, Museum of Fine Arts, Budapest, Hungary
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Heimtextil, Frankfurt, Germany

PRIZES, SCHOLARSHIPS

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2016 **Hungarian State Eötvös Scholarship**, WeMake makerspace, Milan, Italy
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Spanish	intermediate 'C'
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