A collaborative development of an artistic responsive fashion collection

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Abstract

This paper focuses on the merging of technology, media art and fashion design in the creation of an artistic fashion collection titled *Immediate Invisible*.

Immediate Invisible is a collaborative project. It consists of six modular outfits with built-in electronics for displaying physiological responses as audio output. The idea plays with a recurring theme in fashion: revealing and concealing. This is also linked with novel technology and the use of sensors in contemporary everyday life.

This paper describes the process of making *Immediate Invisible* from the point of view of the artist and expert's collaboration, through presenting selected materials and structures, technology, computing and sound, and how they affected one another when merged to create the outcome: 'a hearing device for the body'. *Exquisite Corpse* by Friswell, 2010, is used as a metaphor for the collaborative design method in *Immediate Invisible*, where all disciplines had equal value in creating the outcome. An interaction design approach was necessary in order for the outcome to be a modular, functional collection.

An examination of the tangible outcome is presented as the findings. Technological requirements had an effect as artistic input, which ultimately transformed into statements in the outcome. Similarly, the needs of a mobile body and layered outfits affected the chosen

technology. The presented project differs from other similar wearable projects with its modularity, and from conventional fashion due to the use of responsive sound as an inherent part of its aesthetics.

Keywords

wearable technology, performative fashion, responsive, sensor, audio, modular, Exquisite Corpse, biofeedback, physiology, sonic interaction design

Article Classification

Case study

1. Introduction

This paper focuses on the merging of technology, media art and fashion design by describing the concept and the artistic, interdisciplinary design process of the project *Immediate Invisible*. The growing field at the intersection of art, fashion and technology is also discussed in order to understand the value of the project.

Immediate Invisible is an artistic responsive fashion collection that combines fashion, responsive electronic systems and musical soundscapes. The artwork consists of six outfits with built-in electronics, which display composed soundscapes that evolve based on the wearer's physiology. The outfits are created to function on a mobile body and they work standalone, without the need for external processors, power or amplification of sound.

This paper describes the process of *Immediate Invisible* and the artistic outcome from the point of view of the artist and expert's collaboration. *Immediate Invisible* was created through intensive collaboration between a fashion designer, interaction designer, musician, electrical engineer and many others. The Surrealists' technique *Exquisite Corpse* is used as a metaphor for the collective design method in *Immediate Invisible*. As examples of motives for the project, this paper presents selected materials and structures, technology, computing and sound, how they were chosen, and how they affected one another.

1.1 Sensor technology and fashion: a layered means to communicate

New technologies and ubiquitous internet access enable constant revealing of personal information: attending events, checking in to locations, and even physiological data displayed publicly are a method of building one's identity. Similarly, individual garments can be perceived as a nonverbal mode of communication (Kawamura, 2011). Fashion as such is able to reveal and conceal the wearer's body, sex, cultural values and much more when socialising with others. Yet all this new technology, adapted into the everyday life, enables the exposing of one's self and body to the assessment of others.

> "In an incredibly short space of time, computing technology has become both extremely sophisticated and almost invisible, normalized by daily use and influenced by the daily narrative of film... In reality, life's pace has accelerated to the point that we are no longer aware of the effect of computing on our everyday existence." (Braddock and Harris, 2012.)

As technology seeks to become transparent by looking into intuitive uses and focuses on functional design, the impact of new wearables or other devices towards the social sphere can be left unnoticed (Beloff, 2010).

These layered meanings of new technologies and fashion were a shared interest of the interdisciplinary artistic team behind *Immediate Invisible*. Sensor technology, when brought close to the human body and merged with fashion, adds a new layer of what is possible to reveal. Invisible details beneath the human skin and beyond conscious control can be displayed. Artists can seek to make the technology visible by elevating the interaction into the focus of expression. When the audience is made aware of the technology used, it is possible to improve our understanding of the new technologies, which we have already partly accepted into our lives.

1.2 The growing multifaceted field at the intersection of art, fashion and technology

The field at the intersection of art, design, technology and science has been very active both in literature and in practice. Beloff (2010) categorises different approaches and projects in the growing field of wearable technology by their aims: developing solutions to engineering problems, developments in fashion and design, and conceptual approaches with a playful attitude that reject the requirements of conventional functionality.

In the history of fashion, designers have quickly embraced new technologies and fabrication procedures (Lee, 2005). Fashion designers envisioned a move towards clothing merging with computer-operating systems (Braddock and Harris, 2012) Technology has made its expressive appearances on catwalks, showcasing the results of interdisciplinary collaboration. Alexander McQueen created a collection for Givenchy A/W 1999-2000, which featured photoluminescent inks and battery-powered light emitting diodes, inspired by the film *Tron* (Braddock and Harris, 2012). Hussein Chalayan has collaborated with designer and engineer Moritz Waldemeyer in order to create complex mechanical garments for re-experiencing the metamorphosis of fashion between 1900 and 2007 in his *One Hundred and Eleven S/S 2007* fashion collection (Braddock and Harris, 2012).

Sensors on the human body accompanied with sports applications have become mundane. The use of sensor technology in sports is not only a tool for monitoring, but also a means to communicate. These applications can benefit the wellbeing of people by helping to understand an individual’s health and motivating personal progress through sharing with peers. For example Nike+ and Finnish Sports Tracker are combining their own sensors and programming with existing technology, such as a user's mobile phone and laptop, to process the data and to share it with other users on a global scale. Similarly, Apple Watch does not advertise its technology to measure heart rate as a wellness application, but as a social communication tool to experience intimacy. Sleep products integrated to beds or the user's wrist are able to measure and collect data for identifying deficiencies while trying to enjoy a

good night's sleep (Craig, 2014). At the same time, more traditional fashion labels are also engaging with the field, e.g. Ralph Lauren's biometric t-shirts as used in the US Open (Arthur, 2014).

During the past decade, artistic and conceptual interdisciplinary projects have experimented using sensors and real-time output for revealing the body, other personal data or for sharing moments of intimacy, in opposition to the tool-like use of monitoring. These projects play with themes such as "fear as opposed to the feeling of trust, the unknown against familiar, [and] the public vs. the private/intimate" (Pantouvaki, 2012). Philips Design has facilitated the creation of many already iconic wearable interdisciplinary concepts, such as the emotion-sensing *Bubelle Dress* that was made as part of the *Skin Probe Project* in 2006. Between 2009 and 2011, V2_Lab and Daan Roosegaarde have collaborated with young fashion designers Maartje Dikstra and Anouk Wipprecht, in order to experiment with the relationship between intimacy and technology by creating three garments: *Intimacy White*, *Intimacy Black* and *Intimacy 2.0* (Pantouvaki, 2012). Wearables can also give an intimate response to the user's behaviour directly to the user as in the *Honest Signal Shoes* (Kwack et al., 2011). The shoes employ accelerometers and pressure sensors to detect the apparent nervousness of the wearer. These shoes are primarily used to provide intimate feedback for people who wish to improve their public speaking skills.

2. Immediate Invisible project

The idea behind *Immediate Invisible* was to create an artistic women's fashion collection in order to explore a new type of nudity and bodily display. The idea was to create unique garments merged with built-in audio systems, processors and sensors for reading physiological data beneath the wearer's skin. Sensor technology enabled the harnessing of physiological input data, which modified soundscapes to further expose the body of the wearer. The idea was to make an artwork in the form of a fashion collection that differs from conventional fashion design in its use of sound and biofeedback as part of its aesthetics (Pesonen, 2013). The focus was on the expressive, communicative side of fashion and technology.

The motivation for the project was how responsive wearables can bring about the feeling of nudity without being naked, through displaying real-time sensor data from the wearer to others. This conceptual feeling of nudity is based on Pesonen's previous personal experience with a wearable artwork as an audience member: in Muu Gallery (2011), she tried on the *Brainwise* hat by Wikström and Nordin. *Brainwise* is a hat that visualises the wearer's brain activity - as measured with EEG sensors - on top of the hat itself. When trying on the hat in

front of an audience, Pesonen felt exposed and nude without the connotations or expectations conventionally related to exposing oneself. This led to the idea of celebrating and further investigating that feeling of nudity.

The idea of *Immediate Invisible* plays with a recurring theme in fashion: revealing and concealing. This is also linked with novel technology and the aforementioned use of sensors in contemporary everyday life. Measured physiological changes are not only monitored by wellness applications, but can also function as an active performer when the output of the data engages with art. It is possible to create a new performer by offering control over a defining aesthetic feature to the unconscious activity beneath the skin. Braddock and Harris (2012, 28) welcome evidence of the unexpected, unpredictable and undone, as errors and planned random elements can offer a tangential moment in the digital age.

2.1 Presenting the team, roles and collaboration

From the very beginning, the vision was artistic, philosophical and explorative, rather than a straightforward technological development or product design. Nonetheless, the makers aimed to create a functioning tangible artwork, instead of just a concept. Fashion merging with technology "requires the collaboration between arts and design principles, processes and traditions, with multiple science and technology disciplines" (Pantouvaki, 2012). The artistic team of the project included interaction designer Valtteri Wikström, composer and musician Samuli Tanner, and fashion designer Liisa Pesonen. All members of the artistic team contributed to the creation of the concept and the artistic pre-design phase of the project, and later provided expertise in their respective fields.

Fashion designer Liisa Pesonen initiated the project. She designed and made the collection, and incorporated the chosen technology into the garments. Although the artistic team collaborated in an equal manner, Pesonen managed the project, i.e. its budget and schedule, as it was a major part of her Master of Arts thesis.

Interaction designer Valtteri Wikström planned with Pesonen the interactivity between the wearer and the different technological components in the collection. He was also responsible for the analysis of physiological data and working with the sensors. He implemented most of the software, hardware and electronics, as well as the generative versions of the soundscapes.

Composer and Musician Samuli Tanner composed a full soundscape consisting of six different mutating parts – one for each sensor – based on the artistic pre-design of the project. In the beginning of the project, Tanner offered insight on how to use sound, what kind of

soundscapes could be created, how they could function with such random data, as well as what kind of sound qualities could be achieved.

Laboratory manager Jussi Mikkonen from Aalto ARTS was consulted on the use of different wearable sensors and on the combination of electronics with fashion in the pre-planning phase of the project. He contributed to the project by co-designing 3D-printed enclosures for the speakers with industrial designer Simon Örnberg, and by building an sEMG sensor.

The team also received help in making *Immediate Invisible* from various other people: friends and faculty helped with sewing, soldering and other phases of the project that turned out to be more demanding and time-consuming than planned. In addition, the outcome was documented in action, which engaged a photographer, model, makeup artist and an editor for the demo film.

The artistic collaboration and the conceptual design phase started in the autumn of 2012. Soon after, the necessary technologies were chosen or developed and the designs for the garments were finalised in order to create the collection. Most of the tangible part of *Immediate Invisible* was created during the first half of 2013, as opportunities to showcase the outcome to an audience set deadlines for the project. The compressed schedule forced many parts of designing and building, both for fashion and interaction design, to overlap, and fast decisions were often required. The planned schedule and the time that it actually took to finish building a part often did not match. For example, the time allocated for soldering ended up being doubled and even after that, a mistake in the supply of some of the connectors lead to redoing a significant portion of the work. In the autumn of 2013, *Immediate Invisible* was ready.

2.2 Shared aims and objectives

One of the artistic aims was to produce an appealing and conceptual fusion of fashion and sensor technology. Merging technology with fashion without gimmickry demands conceptual thinking and innate aesthetics (Braddock and Harris, 2012). The artistic team developed the idea by conceptualising the aims, as defined by the artistic objectives. As the artistic team was interdisciplinary, the aims of the project were versatile and further defined the concept for artistic decision-making in the process.

The aim of the project was not to visualise the body underneath the skin, but to keep it invisible. The artistic objective was to create a kind of hearing device for the body: a collection of outfits would play out soundscapes that changed according to the physiology of the wearer, as measured by sensors, thus revealing the body underneath the wearer's skin as if

it could be heard. The aim was to decorate the body with responsive sounds, similar to a garment reshaping itself when worn. The inspiration for many artistic decisions in *Immediate Invisible* came from showcasing the very immediate and invisible fragments of actively functioning bodies *via* responsive sounds (Pesonen, 2013).

An ambitious and demanding objective for the resulting collection was to create a modular outcome on both a technological and fashionable level. The artistic team did not wish to create an artwork that would be a fixed result, but one that allowed rearranging.

2.3 Cutting and rearranging the project as the heads, torsos and legs of an Exquisite Corpse

In this paper, *Exquisite Corpse* by Friswell (2010) is used as a metaphor for the collaborative, creative method in *Immediate Invisible*. *Exquisite Corpse* is a method of creating collective literal or visual art, and it was invented by Surrealists in the 1910s. Usually the task of drawing an *Exquisite Corpse* aims to create a character with a separately drawn head, torso and legs. The first participant draws the head and then folds the paper, leaving only a few traces for the next participant to create a torso and so on. The outcome is unknown to the makers until the final unfolding and revelation of the *Exquisite Corpse* reflecting the collective personality of the makers (Friswell, 2010), resulting in a body of work where all participants of the artistic team have an equally important role in the process and in the result. In *Immediate Invisible*, control over the outcome was shared by all artists.

This approach was not employed as a clear method or dogma in *Immediate Invisible*, but it became a natural part of the creative team's process, and was recognised after the project was completed. The 'heads, torsos and legs' of the project can be represented by the contributions from each member of the interdisciplinary team, or the combination of fashion, technology and sound. It also reflects the modular outcome as the 'heads, torsos and legs' can also be seen as the separate electronic garments: sensor garments, processor garments and audio garments are ultimately connected to expose the wearer's body beneath the skin, and unfold the final outcome of *Immediate Invisible*.

3. The fusion of technology, fashion and sound in *Immediate Invisible*

The practice-led objective of the project was to explore combining fashion and technology within the frame of the artistic idea, resulting in a modular outcome. The interdisciplinary artistic process consisted of the following phases: artistic pre-planning, conceptualising and testing; designing and manufacturing; and finally finishing the work.

Even though the aim of the project was not to develop a clearly usable tool or application, an interaction design approach was necessary for computing, and for the definition of standards on how to wear and combine separate functional pieces. Interaction design is about shaping digital things for people's use; it is not about building technological solutions, but about shaping the technology into something that people can use. The material is the technology, and the design process is about exploring an interactive solution from the user's perspective. The end result is a new application: a possibility provided by the technological medium and envisioned by the designer. (Lowgren, 2013.) The desired interactive system of *Immediate Invisible* can be defined as responsive from the perspective of a wearer:

> "The structure of a responsive work is such that we are made aware that we are responding while we are responding, that we are playing a role in a greater system of responsivity extending beyond our isolated subjective choices. This takes some of the control away from us: we do not control, we respond." (Kozel, 2007.)

3.1 The existing electronic interface as a starting point

As developing new technology from scratch was not one of the project aims, the potential of existing electronic interfaces was used and adapted. Most of the merging of technology and garments was designed and made in a way that allows detaching and replacing individual components. One of the aims of the project was that all the necessary technology should be built into the garments, to allow the wearer to move freely and not depend on external hardware, e.g. external computer systems, power sources, audio systems, or other types of communication operating over a longer distance.

3.1.1 Sensing beneath the skin

The choice of sensors was one of the most artistically important decisions defining the entity. As the aim was to investigate revealing through fashion and technology, the team concentrated on the passive interaction between the wearer and the garments. The objective was not to make new types of musical instruments, as this would give control over the garments to the wearer, but to give the body underneath the skin an opportunity to be heard. This aim ruled out many existing sensors and possible forms of interaction between the wearer and the outfit. Physiological measurements were limited to phenomena that arise from the autonomic nervous system. The autonomic nervous system represents the involuntary activity of the body. It is also related to the psychological and physical state, moods and emotions of the organism. The autonomic nervous system can be further divided into the sympathetic and parasympathetic nervous systems, which represent the fight-or-flight response and the return to balance (or homeostasis). At an early stage, the measurements were limited to the peripheral nervous system, i.e. brain wave measurements were left out. This

was decided because the added complexity and interpretability of brain activity would likely take too central a role in the project.

Due to reasons related to project management – schedule, budget and controlling risks related to fragile technology – the team was limited to self-built, off-the-shelf and sponsored sensors. After various tests, four different sensors were chosen, two of which would be used twice, in different ways in two garments to create a total of six sensor garments:

Self-made skin conductance sensors, which measure the subtle activity of the sweat glands on the wearer's palm. Skin conductance has two components: 1. The tonic response, or skin conductance level, is a slowly evolving value, which has been loosely linked with emotions and moods in literature, but is also influenced by external factors such as temperature; 2. The phasic response, also known as the electrodermal response or startle-response, is a fast reaction, usually occurring due to unexpected stimuli or spontaneously as a reflection of sympathetic nervous system activity. Two skin conductance sensors were included in the collection, one measuring the phasic response and one measuring the tonic response.

The Pulse sensor[1] photoplethysmograph, which measures the amount of red blood cells in the veins of a finger. Two measurements were extracted from the data: the pulse length (heart rate) and more experimentally the size of the pulse representing the oxygen saturation of the wearer. Two of these sensors were also included in the collection and used to measure separate phenomena.

The Sports Tracker electrocardiographic (ECG) band, which measures the electrical activity of the heart. Because ECG is very accurate, a measurement for heart rate variability can be extracted. It represents the small variations between heartbeats, and it has been used successfully for studying many different psychophysiological phenomena, e.g. stress and emotions.

A self-made surface electromyography (sEMG) sensor measuring the electrical activity of the thigh muscle. This was the exception to the rule as it measured the only 'voluntarily controllable' parameter, although it was conceptually curious as a person cannot move without affecting the sound.

[1] www.pulsesensor.com

Simple possibilities for measuring breathing were also considered. For reliable measurements, breathing sensors (respiration inductance plethysmography) proved to be too problematic to make. The prototypes were not really measuring the breathing but the expansion of the chest. Since it is possible to breathe without actively expanding your chest and breathe with excessive expansion, it would have required extensive adjusting on the wearer and calibrating the measurements every time the garment was worn. A prototype that used a stethoscope for direct recording of lungs and heart through sound was also built. This test was abandoned, as the microphone for building this would have needed a significant amount of extra power. It was also very susceptible to external noise, making it impossible to use when layered garments rubbed against each other. Furthermore, using the sound of the body itself in the soundscapes would have given too literal a sonification. The artistic team found it more interesting to mystify and aestheticise the source with otherworldly, composed soundscapes.

3.1.2 Processors and processing

For the processor garments, the Raspberry Pi integrated single-board computer was chosen as the main processing unit, because it is compact, economical, powerful enough for real-time audio processing, and has a reasonable power consumption for use as a wearable processor. This enabled a range of choices for sensors and imposed no limitations on composing the sounds. The Raspberry Pi reads the whole operating system from an SD card, so the different soundscapes and analysis units could be stored on "cartridges", which can be swapped from one processing unit to another. Physiological sensors needed analog inputs, so an analog-digital converter (MCP3208) was added, and a custom printed circuit board was made for the purpose of connecting the analog-digital converter to the Raspberry Pi. For power, 2200 mAh USB power banks were used, providing a battery life of 2 - 4 hours.

The sensor data were interpreted by a system developed by Wikström for the purpose of real-time analysis of physiological responses. The data were collected from a recording module made for the analog-digital converter, and then passed onto different analysis modules depending on the physiological signal. The analysed data were then sent as Open Sound Control messages by the main application to the audio processing software (Wikström, 2014).

3.1.3 Speaker enclosures

The 3D-printed loudspeakers became an essential part of the project both technologically and artistically. 3D-printing made it possible to have the enclosures answer the demands of the fashion design. An important consideration in designing the enclosures was determining their size, in order to achieve the desired sound quality. The process continued with determining other qualities that an enclosure could possess, as their shape could be utilised in shaping the

garments, much like historical undergarments. The first model of an enclosure succeeded well in amplifying the sound and increased the quality of sound, but its shape had limited possibilities when placed around a mobile body. It was also sharp and long, and so it did not offer much volume for the fashion designs in the way that e.g. a pannier would. Furthermore, it was too heavy and lacked the possibility to attach onto and detach from garments; the structures for possible fastening were decided on before the design of the garments was completed.

Many of these issues were fixed in the second model through reducing the thickness of the material, and changing the shape to better inspire the design for audio garments. This model was then used in designing the garments and pattern-making, as well as in testing the technology. The final model – with minimal changes compared to the previous one – was equipped with details for attaching the enclosure inside the folds constructed in the garments.

Figure 1. The enclosures are designed to hang inside folds of fabric.

3.2 Composing sounds and computing sounds

The idea of finding meaningful artistic aesthetics through randomness was utilised in the creation of the soundscapes and their use, as well as in how they created an entity with the garments. The possibilities and limitations of the used audio technology also affected the artistic work, as the sounds were composed directly for this project.

The sound design process was initiated by discussions between Pesonen, Tanner and Wikström on how to communicate the different physiological responses through sound. Based on these discussions, Tanner composed a full soundscape for *Immediate Invisible*,

consisting of six different mutating parts, with one for each sensor. These mutating parts were composed so that they could be played at the same time, resulting in a random harmony as the changes would be 'controlled' by the measured data. The composition consisted of examples of the generative sounds, small samples, and instructions on how the samples were processed to create the examples. Wikström made the responsive generative versions of the sounds in the Pure Data visual programming language.

3.3 Fashion design for 'a hearing device'

The visual character of *Immediate Invisible* was not predefined. Instead, it was created during the designing and manufacturing phase of the process and based on the concept, functional requirements related to technology, and Pesonen's artistic ambitions. In the concept, the collection is seen as a hearing device for the body. For artistic reasons, the silhouettes and materials needed to communicate this peculiar concept, rather than merely appearing as conventional garments. Focusing on sound as a fundamental feature of the aesthetics, it was reasonable to conceive minimal visuality. To contradict the concept of exposing the body with responsive sounds, Pesonen designed a modest concealing look with expanding silhouettes, distracting from observing the visual body. Functional requirements related to technology were used as inspiration for choosing materials and designing structures, while functional sophisticated product design was not one of the aims. Manufacturing methods employed in the project varied from laminating fabrics to hand embroidery. The main visually expressive materials represent functionality, e.g. water-repellency, protection and ventilation. Many of the chosen materials, such as 3D-meshes and nets, were originally designed for functional use, or they were able to offer a functional purpose: e.g. thick wool in the audio garments could be used to direct the sound of the speakers, thus adding an acoustic level to the designs.

"The technical integration needs to be seamless and invisible for the wearer. However the inherently human desire to control and fear of abuse need to be revisited in this process, providing the ability for the user to consciously turn it off." (Seymour, 2010) To create revealing outfits in this project, it was important that the technology would be as inseparable a part of the outfits as their other features, like colour and shape. Thus the outfits were designed to lack control features, achieving a passive relationship between the wearer and the garments. As the concept contradicts the aforementioned requirements for user control, the integration of technology transforms into visual details in the garments. The wearer is made aware of the responsive system, although many electronic components become compact enough for invisible integration into garments. Expanding the size communicated the concept as visual statements and added volume to the silhouette.

3.4 Designing modularity

One of the aims of *Immediate Invisible* was to create a modular outcome and the desired modularity of the collection directed the design process on many levels. To be able to make a modular entity, many parts of the collection required standards. The modularity of the electronic system was designed so that any set of three units – a processor, loudspeaker and a sensor – could be combined to create a functional outfit. Metallic 6.3 mm stereo audio plugs were chosen for connecting the modules, as they provided enough electrical connections, and they were aesthetically interesting, thus adding electronic visuality into the garments through jewellery-like functionality. Using audio connectors also reflects the sonic nature of the entire collection, revealing how details can be utilised to communicate the concept.

The connectors were located between sensor garments, processor garments and audio garments at a chosen point around the left waistline, to enable combining all the garments from the point of view of technology. This also affected the design of the silhouettes: many of the separate garments were designed to be fitted around the waist in order to minimise possible stress on wires around a mobile body. Extension wire garments were added to the collection to answer the needs of sensor placement: the requirements of the sensors to be placed next to the skin defined the sensor garments as more like accessories or undergarments within the collection.

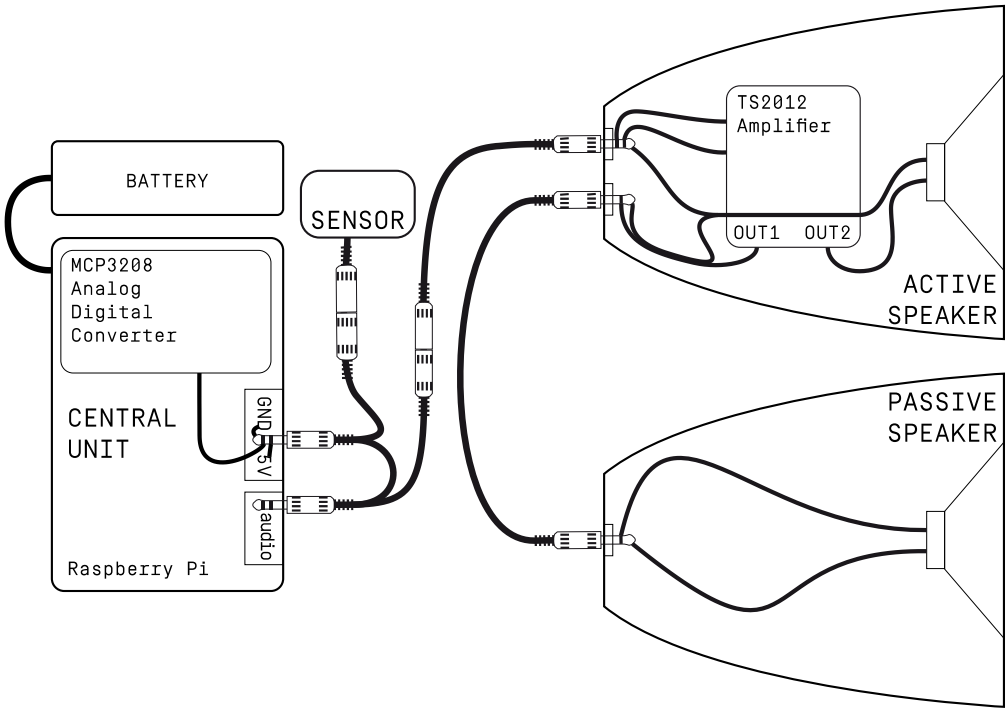

Figure 2. Functional wiring schematic between the different components: sensor, processor and sound system.

Figure 3. *4/6 Sensor garment, 6/6 Processor garment, 1/6 Audio garment* with connectors visible on the left waistline.

4. Unfolding *Immediate Invisible*

Immediate Invisible is an artistic women's fashion collection. The process resulted in an artwork consisting of six rearrangeable outfits that respond to the wearer's physiology with adapting soundscapes. The collection can be divided into sensor, processor and audio garments. Functional responsive outfits are combined by choosing one garment from each category. Following more conventional design, and to enable presenting the artwork in the context of fashion, the collection is created in a size that fits female models.

Figure 4. *4/6 Sensor garment, 6/6 Processing garmen*t and *1/6 Audio garment*.

'Pulse' is the only sound that is directly recognizable as the signal that is driving it. The heart rate is triggering a throbbing sample, representing directly the heartbeat of the wearer.

Figure 5. *3/6 Sensor garment, 2/6 Processor garment* and *5/6 Audio garment*.

A noisy *whooshing* sound is driven by the blood oxygen level, as measured by a photoplethysmogram. The playback speed of a 'burring' noisy sample is controlled by the change in the amplitude of the pulse. The result is a 'whooshing' sound that continuously evolves in a two-octave range.

Figures 6.-7.

Image 6. *5/6 Sensor garment, 5/6 Processor garment* and *3/6 Audio Garment*
A ‘buzzing’ and ‘burring’ drone is driven by the skin conductance level. Two samples, a buzz and a burr, are amplitude-modulated by two inversely frequence-related low-frequency oscillators, creating a tremolo effect.

Image 7. *6/6 Sensor garment, 1/6 Processor garment* and *2/6 Audio garment*
An abrupt sound is triggered by the skin conductance response. The ending and starting points of a small impulse sound is controlled by the length and amplitude of the response.

Figures 8.-9.

Image 8. *2/6 Sensor garment, 4/6 Processor garment* and *6/6 Audio garment.*
A 'transforming melody' is driven by the heart rate variability of the electrocardiogram. Each heartbeat triggers the next note of the melody, and the position within the melody is determined by the heart rate variability.

Image 9. *1/6 Sensor garment, 3/6 Processor Garment* and *6/6 Audio garment.*
A 'springy sound' is controlled by the amplitude of the electromyographic signal. An impulse sample is triggered, and a delay effect connected to a band-pass filter is manipulated to create a spring effect, with tension varying according to the amplitude of the response, or each time a muscle response is detected.

As in *Exquisite Corpses*, the final outcome – the combination of fashion, sensor technology and responsive sounds – was unknown to the artistic team until the final unfolding on a model at the very end of the project, even though previews of the result were to be seen along the process. These moments were points to reflect upon the aims that were related to the performative artistic characteristics.

When first testing the sensors, Wikström and Pesonen played with Pulse sensors and sounds transforming based on pulse and blood saturation. This experimentation resulted in two

completely different soundscapes as the sensor input differed greatly between Wikström and Pesonen. It was possible to evaluate the effect of a unique wearer for processing sound.

In May 2013, Wikström presented the collection by himself at the Sibelius Academy in Helsinki. Not being able to wear the outfits himself, the performance consisted of displaying the garments on mannequins and Wikström using the sensors to read his own body. An interesting feature of this performance was that Wikström combined the activity with physical exercise, directly affecting his heart rate and other physiological features. This was seen as a novel and interesting way to perform by the spectators, who were witnessing a clear connection between his body and mystified sounds.

Photographer Heta Saukkonen wore the entity as she modeled in MediaLab's Demo day, as well as for photographing and filming the outcome. She was able to offer valuable information on the user experience, and she reported feeling exposed in front of the live audience. However, she also felt that the stress about interest towards herself was diminished by the responsive sound of the outfit, similar to the feelings of nudity previously experienced by Pesonen.

At the photoshoot, Saukkonen experienced the entity as she was wearing all of the six outfits. The aesthetics of the fashion designs appealed to her as she considered herself elevated as if dressed in a sculpture or piece of architecture. The variation of sounds resulted in contradicting experiences between separate outfits. An outfit measuring pulse distanced Saukkonen, because of its resemblance with the mediated sound of a pulse. She found the soundscape of another outfit harrowing, and she also spent an extensive amount of time wearing it. Saukkonen felt most in harmony with an outfit measuring heart rate variability. The melodic soundscape appealed to her personally and resulted in an immersive relaxing experience.

5. Reflection

The outcome of *Immediate Invisible* fits within Beloff's (2010) definition of projects with a playful attitude: it has peculiar functional design and exaggerated visuality. The outcome lacks rational user control over technology, in order to enhance the wearer's passive relationship towards what they are exposing, and to have the electronics and sound as an inherent and inseparable characteristic of the outfits. These irrationalities are a means to explore the random, the unexpected, and the experiences of nonverbal communication.

From the point of view of interaction design, the project allowed technological exploration as well as a context for the development of physiological analysis software for interactive purposes. An important aim, and a design challenge, was making the collection modular by creating interchangeable components out of physically very different devices. Creating standards and taking a user-centered approach were necessary when planning the placement of sensors and connectors. This modular approach and standards-focused planning was present in all aspects of the project, in order to reduce risks related to e.g. combining fragile electronics with slow hand-sewing. Detachable and replaceable components allowed alteration and rearrangement of the collection throughout the project.

Immediate Invisible departs from other artistic wearables with similar ideas and aims due to its modular ambitions. As an artwork it is not self-sufficient or an entirely ready-made, fixed set of functioning outfits. It allows exploring different combinations of shapes, colors, materials and responsive sounds. In that sense, even though it is not aiming for conventional use but to be perceived as art, it honours conventional collection design practices. The project result includes 21 functional garments. To achieve more visual variation, as well as to be able to explore placing the audio systems and processors differently around the body, some freedom in designing the garments was allowed at the cost of complete modularity.

As the electronic systems built inside the outfits were designed to be responsive systems, the use of the outfits cannot be compared to musical instruments: they cannot be actively played, and the changes of sound are not consciously controlled by the wearer. As human control is separated from the artistic impact of the worn outfit, there is no possibility of so-called failure while exposing one's body. This leaves the feeling of nudity clean from expectations or connotations traditionally related to observing one's body.

Fashion as such is deeply entwined with wordless communication. In *Immediate Invisible*, responsive sounds planted inside the garments become part of this interaction between the body, the wearer and the audience. Even though some physiological changes can be traced to psychology, the sounds do not offer an interpretation of the wearer's emotions. Instead, the sounds display the invisible activity beneath the skin.

Immediate Invisible began with the aim of creating an artwork in the form of a collection, which could display the wearer's physiological changes with soundscapes. The project developed together with the team, as the aesthetics, technology and functionality were not pre-determined. The collaboration formed from a common interest around the themes of wearable electronics, physiological sensors and involuntary communication. Each member of

the team brought their own expertise and vision into the execution of their core area, while still collaborating and brainstorming with the others, resulting in a functioning responsive outcome. As such, the outcome did not form from the vision of a single creator, but rather as an organic amalgamation of ideas and practices. Even though the project was initiated and managed by Pesonen, each member of the team had an equally important role in the creation of *Immediate Invisible* and in its existence as more than a mere concept. It was necessary that all the members fulfilled their share: a panel of an *Exquisite Corpse*.

High artistic ambitions and equally important artistic goals motivated the team even when problems occurred. Time management, a general problem often encountered in design projects affected parts of this work as well. Compressed schedules and underestimating the time necessary for practical work lead to stress and very long working days when striving to meet deadlines.

6. Concluding remarks

The needs of the different disciplines – technology, sound and fashion design – were recognised by the artistic team members and cherished as inspiration, like the traces seen from under folded panels of an *Exquisite Corpse*. For instance, technological requirements affected the fashion design process from the first sketches, not only as problems to be solved, but also as artistic input. Due to technological development, many of the accessible electronics have become so small that they allow some level of sophisticated attachment into garments. While fashionable wearables are going towards seamless, invisible merging of technology and textiles (Seymour, 2010), *Immediate Invisible* had the opposite goal, and the electronics were used as a visual influence so that the overall look would communicate their existence within the garments. As such, one of the first interests was to increase their size to match with the desired volume of the garments and thickness of materials. Likewise, the needs of a mobile body and layered outfits affected the technological requirements.

In *Immediate Invisible*, technology is not used as a tool to clearly extend the abilities of the wearer. Instead, the technology is used as a means to express and experience in a passive manner, as both technology and fashion share similar features of revealing. The result is a unique artwork that does not attempt to become a product line for fashion markets. In *Immediate Invisible*, no personal biometric is recorded or transmitted outside of the outfits. The measurements are only used for real-time exposure with morphing sounds, to concentrate on revealing the body's physiology and the feeling of nudity without being naked in the moment. Randomness was used as a designed feature of the process and the outcome. The

outfits do not send messages to each other or to any central server, but they receive input from the wearers' physiology, resulting in a random layered soundscape. This in turn is affected by the sounds of the outfits, and creates an interesting network of feedback through the feelings and physiological responses of the wearer.

Although physiological measurements can be traced to psychology, the outcome does not interpret the data for the purpose of expressing emotions. Similarly, the responsive outcome emphasises the passive relationship between the wearer and fashion. User experiences reveal the possible value of an artistic approach for future consideration, regarding designing wearables: an explicit display of sensor-measured data can distance a person from one's body, which contradicts the mystified experimental presentation that ultimately offers an immersive experience.

The opportunity to collaborate in practice offers an important space for artists to test the potential of their ideas as more than concepts. Creating a collection from a novel perspective was valuable experience for the future practice of the artistic team. Similarly to *Exquisite Corpses*, the final outcome of *Immediate Invisible* was partly hidden from the makers until the end, when all the components were put together on a living and breathing model.

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Interview

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Figures 3. -9. Photographer Kerttu Malinen

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