Biosignal Augmented Embodied Performance

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ABSTRACT

We explore the phenomenology of embodiment based on research through design and reflection on the design of artefacts for augmenting embodied performance. We present three designs for musicians and a dancer; the designs rely on the artists' mastery acquired from years of practice. Through the knowledge of the living body, their instruments —cello, flute and dance —are extensions of themselves; thus, we can explore technology with rich nuances and precision in corporeal schemas. With the help of Merleau-Ponty's phenomenology of embodiment we present two perspectives for augmented embodied performance: *the interactively enacted teacher*, and *the humanisation of technology*.

CCS CONCEPTS

• **Applied computing** → **Sound and music computing**; • **Human-centered computing** → *Interaction design theory, concepts and paradigms*;

KEYWORDS

Embodiment, Performance, Biosignals, Music, Dance, Interaction Design

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1 INTRODUCTION

The *new materialism* of the fine arts suggests that the subject centre of the socially constructed world no longer exclusively humanistic[1], this allows technology to have a subject position. In post-digital art and embodied interaction we can explore the interplay between the analogue and the digital, between the body and the machine [3]. The 1990s' brought ubiquitous computing (UbiComp) [23] and tangible user interfaces (TUI) [10]. Both these fields are still vital and reinvent themselves. The technology focus of UbiComp and TUI was founded in a notion that the computer interface ought to be richer than mouse-keyboard-screen. Dourish put this in a more intellectual and sociologically grounded perspective [5]. He brought the interaction design community's attention to Dreyfus [6], who shows that the Merleau-Ponty's [16] Phenomenology of Embodiment is relevant to the world of computing. Embodied interaction has remained a current focus in design research [9]. The embodied interaction focuses on the being-in-the-world where presence in time and in space matters, and that the actual shape and innate capacities of the human make the conditions for a design.

In this paper, we explore embodied interaction with two classically trained musicians and a classically trained dancer. We focus on performance, the rich actions of our bodies, and that physical actions are both faster and more nuanced than symbolic cognition in interaction design [12]. Merleau-Ponty illustrates how we internalize external devices with an example of an organist who has to play an unfamiliar organ. An hour before a concert the organist manages to get acquainted with the instrument. Here, learning occurs through interaction with instruments. Through obtaining skills and use of tools, we change our physical space, and our way of being in the world; we can say that we are changing our world. Moreover, Merleau-Ponty distinguishes between concrete and abstract movement, where the later refer to unfamiliar motion schemes. We introduced designs for the musicians that relied on their acquired skills and their repertoire of concrete movements. New designs may introduce unfamiliarity to a familiar situation; thus, as with Merleau-Ponty's example with the organ player, adjusting the world for the musicians. The intimate incorporation of an artifact —for instance a flute or a cello— into bodily practice to the point where artists perceive that artifact as an extension of themselves. Their relationship with the music is intimately mediated through their bodies where trained patterns of muscle movements —corporeal schemas— constitutes a repertoire of musical

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gestalts. We used this intimacy to augment the performance, visually and musically explored the the aesthetic, kinaesthetic, and meaning dimensions of the user experience and designs.

2 RELATED PROJECTS

We introduce three designs —Whirlpool Bach, Critical Digitalism, and The Noise from the Rift —to explore embedded interaction. The first project visually augments the performance of a solo cellist using biosignals of muscles, the second project utilises live sampling to augment a performance musically based on control-rate biosignals of muscles, and the third project uses the audio-rate biosignal as sound source. The use of biosignals in interactive art is not particularly widespread; albeit there is a tradition in a small community of interactive art artist to use biosignals that goes back since the early 1960s. A growing number of artists have since then collaborated with neuroscientists and engineers to design methods that enable the acquisition of minimal electrical signals of the living body. This has enabled direct manifestations of embodiment into interactive artworks. There are many related projects in the last decade that use biosignal sensors. Visi et al. [22] designed a gesture mapping system based on embodied music cognition for performance to be used in performance to enhance the expressiveness and the liveness that provides an extra layer of possible motions and musical expressions over the instrument. Beside visual and aural technologies, Donnarumma [4] explored gesture control using mechanical myography (MMG) audio signals. The aim of the design was to make biological signals the main audio and control source. Donnarumma also aimed at making a perceivable connection between the performer's kinesthetic expressions and the sound for both the audience and the performer. Application of techniques for acoustic feedback controllers (AFCS) to different contexts, such as musical performance, sound installations, and product design, presents a unique insight into the research embodied audio interfaces and environments. Van Troyer [21] illustrates with three prototypes novel designs for AFCS used in different sonically augmented environments based on users' audible actions. Besides extending performance and musical expression via gestures embodied interaction is also used for novel interfaces. Yamaguchi et al. [24] designed a wireless music interface in the form of a ball. The performers' movements and grip pressure control various parameters in a musical process. The design is loosening the link between the physical object and how it sounds and thus provides freedom in the physical performance, for instance allowing the performers to play the instrument through dance. Whereas, Tahiroglu et al. [20] designed an instrument —Network of Intelligent Sonic Agents (NOISA)— with a tight coupling between appearance and sound to explore physical interaction in performance with emphasis on engagement. Their focus was on a novel design where they increased their performance skills with the instrument through rehearsal and training. The novel design implies that it will take time and practice before the users acquire embodied artist skills. Another approach is to augment traditional instruments relying on the trained movement schema of the artists. For instance, McPherson [14] augmented the piano with a portable optical measurement system designed for capturing continuous key motion. The design enables the pianist to be more expressive and adjust a broader and continuous range of parameters of the played note. This increases the world of the instrument; the performers need to expand their abilities and their embodied knowledge for this augmented piano. Capturing the motions of the artist can also be used for training purposes. Menzies and McPherson [15] created a digital bagpipe chanter system to assist in one-to-one piping tuition. The system allows students to record and see a visualisation of their performances. They designed the hardware to accurately and quickly detect continuous finger movements of the player to allow a nuanced input. Various forms of sensors can be used for input in novel designs. Donnarumma [4], above, developed a sensor to measure and sonify mechanical vibration of muscles. Jaimovich [11] presented the work of Emovere: an interactive real-time performance that uses physiological signals from dancers to propel a piece that explores and reflects on the relations between biology and emotions. Jaimovich focuses on the design of collaborative tools and materials, he contributes to the creation of artistic projects working with dancers and physiological signals. The design uses muscle sensors electromyogram (EMG) and electrocardiogram (ECG) that measures the heart activity.

3 METHODOLOGICAL NOTE

Our method for the work in this paper is based on designing or supervising the design of artefacts through a "conversation with the materials of a situation" that intervene in the practice of train artists. We relied on Schön's [18] reflection—on—action to formulate our perspectives on embodied interaction grounded in the design process and experiences of the designs. We have used research through design [25], presenting examples of designs [8]. We have used code and technology as a design material [13] for sketching and prototyping [2]. We have conceptualised the works through reflexive reflections on the designs and the view of Merleau-Ponty's phenomenology of embodiment [6, 16].

Whirlpool Bach

In Whirlpool Bach we explored the interplay between visuals and the performance of a trained musician. We created a

visual augmentation of a cello player performance via controlling the framerate of a video displaying water whirlpools in a stream (Figure 1). The stream is part of a channel used in the eighteenth and nineteenth centuries to ship iron, then the most important export of Sweden. Today, all the mines and mills are closed. Using the electromyography (EMG) signal to reverse the whirlpools of the stream while playing Bach's cello suites symbolising transience of industry and nostalgia for what has been. When the player relaxes the stream start to flow forward, washing away the past.

Figure 1: Performance at the Norberg festival 2014

We used a custom build EMG sensor connected via a data acquisition (DAQ) device to a computer programmed with the data flow programming language LabVIEW (Figure 2). Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is an electronics system-design platform development environment. The LabVIEW program sends open sound control (OSC) messages with the muscle signal amplitude values from the 20 - 50 Hz band to another computer running a QuartzComposer program. QuartzComposer is a data flow programming language designed to manipulate multimedia. This program manipulates the video frame rate based on the muscle amplitude.

The artist described an increased awareness of her movement while playing. She was consciously reflecting in action on her body "not just the cello." This is making subconscious movement conscious thus deprecating the embodied presence, but makes the artist reflecting on her actions. The interplay between the in action and on action is what Schön [18] describes as learning and expanding one's repertoire. Metaphorically, the technology acts as a teacher.

4 CRITICAL DIGITALISM

Critical Digitalism explores embodied interaction and augmented acoustic performance utilising biometric signals (Figure 3). The music was performed on a flute, an analogue synthesizer, and computer running a custom built live sampling

Figure 2: Custom build EMG sensor

and loop player software. The software samples four seconds of audio from the flute and the synthesizer and played back twelve seconds completing sixteen seconds cycles of sampling and playback, four bars in common time based on the larghetto tempo, 60 beats per minute. The music loops are field samples of ventilation fans in academic institution buildings and a time stretched reversed piano chord. Thus, all sound sources originate either acoustic or analogue.

Figure 3: Critical Digitalism, flute, synthesiser and computer performance 2016

In this design, an electromyography (EMG) signal, measuring the muscle signal amplitude, affects the grain size of a live sampled acoustic and analog performance utilising granular synthesis. The digital signal processing and music programming is based on the Beads Audio Processing library [17]. The Beads' granular synthesis manipulates the time-domain

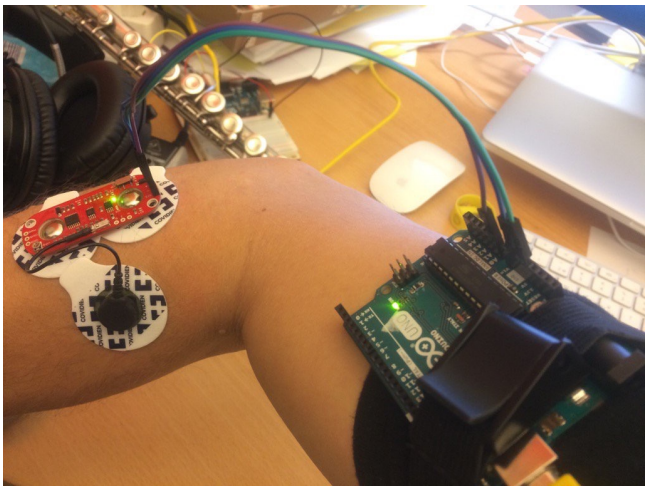

Figure 4: EMG Sensor connected to Arduino

of the time—frequency space of a signal. The MyoWare Muscle Sensor [7] is connected to an Arduino micro controller running Firmata allowing the Arduino to be programmed via Processing (Figure 4). The sound of the acoustic flute and the analogue synthesiser is reversed and stuttered like an old pin printer or disc-drive. High muscle tension calms the lengthens the grains and relax the signal; this mapping implies constant tension in the muscles of the performer or in the ears of the audience. Touching the MacBook trackpad moves a virtual microphone in rectangular virtual space of the sample loops positioned in the corners. The trackpad is played with light swipe gestures.

5 THE NOISE FROM THE RIFT

In the Noise from the Rift (Between Human and Machine) we explored the musical expressiveness of the electromyography (EMG) signal. In the previous project we used the control-rate signal of the MyoWare Muscle Sensor [7], whereas in this project we used the raw audio-rate signal. We attached the EMG sensor to the back of the dancer's shoulder allowing her to generate audio through arm motion and head motion. We present here the initial discovery and sketching phase, for a dance and electro acoustic piece (Figure 5). We did both technology and music sketching with the EMG raw signal amplified through the built in pre-amps of a Behringer 12 channel mixer, and processed through plug-ins (equaliser, delay, noise gate) of Logic Pro X running on a MacBook Pro. We also patched the Moog Mother-32 and MakeNoise 0-Coast semi-modular synthesisers. We began the sketching by listening and dancing with only the raw audio and adding audio processing iteratively. The EMG-signal sounds like pink noise that contains a hum. The signal from the body sounds soft without transients. To make the performance richer we introduced electric props, a lamp, a synthesiser, and the power supply of the synthesiser. The sound from the EMG-senor became hard and sparking when dancer touched these props. By introducing this element we created an electric interplay between the human and the technology. The dancer reflects on her experience: "Hearing technology that otherwise is so omnipresent made me aware of technology's presence and that it interacts with the body's own signals. The body is much more conductive than I thought. Different sounds from technology and from the body. It became clear to me what is my body and what is technology. I think this can be related to all the talk today about artificial intelligence and what is human." Between technology and human, where there is friction and divergence, and where we have not been before. There, we create a new understanding that complement and expand our existing knowledge.

We found it interesting that turning on a lamp, or touching the patch sockets of an analogue synthesiser generated such a loud interferences of the signal. This indicates that our nervous system is affected by and can handle our technological environment although electricity is a recent invention from an ecological perspective.

6 DISCUSSION

We can formulate two perspectives of embodied interaction on the basis of Merleau-Ponty's phenomenology of embodiment and exploration of augmented embodied performance: the interactively enacted teacher, and the humanization of technology.

The Interactively Enacted Teacher

According to Merleau-Ponty the key to the embodied subject or the lived body is habit. But here we must refrain from the idea that habits are more or less mechanical responses to the environment. They are learned ways to perceive and act that works intentionally but on a pre-reflective level. There are always habits in everything we do in every part of our lives. Habits can be described on three levels. They are the concrete habits that I am at this moment, the lived body as it is right now. But they are also the sedimented habits that I have acquired but lies dormant as a background with a potential meaning to what I am doing now. Finally they are also what I could imagining myself doing as abstract habits that I have the capability to learn.

The habits are collected into corporeal schemas. These are more encompassing attitudes that can be described as my embodied perspective containing both perception and action pertaining to a certain world. The corporeal schema is a whole that is more than the sum of the habits that constitute it. It is an immediate knowing of how my lived body is configured at the moment and of the kind of world I am trying to respond to. It can be changed by incorporating and

Figure 5: The dancer exploring the audio—motion of the EMG sensor in the lab.

letting go of habits. It is rough in the novice and refined in the master. The novice musician can awaken as enthusiastic responses from its parents as the master can do from the concert hall audience. The corporeal schema always admits spontaneous improvisation but in a low degree in the novice and a high degree in the master. It takes a very well developed corporeal schema to master a musical instrument. It is through this development that the instrument eventually becomes a part of the musicians lived body barely noticed.

In Whirlpool Bach we investigated the corporeal schema with the help of a cellist in the later years of her training. With the introduction of the EMG sensor and the visual performance a new element was introduced to her corporeal schema. It had the effect of transforming her concrete habits of playing in the moment to abstract habits open for reflection. In one way this interrupted her performance. She started to reflect on her body as an object rather than living it as a subject and the free flowing movement between the lived body and a world of music could not be upholded. But the interruption on the other hand was relevant to what she was doing. She could use it to reflect on how she actually lived her body while playing the cello enabling adjustments to the corporeal schema. The incentive for reflection and learning was, unlike Menzies and McPherson [15], not an intended design.

One way to conceptualise this is that the cellist used the EMG sensor and the visual performance as cultural objects. She could understand them according to their use as a way to monitor her muscles during her performance. We would rather argue that the cultural objects that advanced technology makes possible takes on a "higher" meaning in this situation. To be aware of another human being as a subject is understood by Merleau-Ponty as the actual perception in the world of another who intentionally perceives and acts in the world. In comparison with this we feel that a lot of today's technology has reached the level of "quasi-subjectness". A lot of the devices that surrounds us are not really possible to conceive as mere cultural objects calling us to be used (albeit possibly creatively). We all feel that they in some sense also perceive us and we can perceive them perceiving us. It is in this meaning that we would not conceptualise the EMG sensor and the visual performance as mere biofeedback through cultural objects but as an interactively enacted teacher.

The Humanisation of Technology

There is no real distinction between humanity and technology. Technology has always been "humane" in one way or another. According the Merleua-Ponty it is simply an extension and empowerment of the capacities of perceiving and acting that are already there in our embodiment. But technology is "inhumane" in the sense that it has most often actualised delimited parts of the human potential to be put in service to interests directed by production and consumption and ultimately profit. The human is a producer and consumer for sure but we are so many other things. Among a range of things we feel, love, play, create, socialise and reflect on the mystery of being alive. Today's technology are of course more responsive to this than ever before. For instance our

social capabilities are enlarged by smartphones and internet of things.

Our focus was on concrete movements and learning through interaction with instruments on the basis of acquired skill as described above: the Interactively Enacted Teacher. Jaimovich [11], tried to connect the dancers to sound parameters making them being musicians, playing the instrument. However, this design had to be discarded because of the dancers not being familiarised with a musical-performer motions. The dancers worked with the whole of their bodies and controlling separate parameters with certain muscle was not part of their embodied kinesthetic knowledge. This is an important difference from our work, where we used the knowledge of the living body to augment the performance with appended layers. Using the kinaesthetic creativity in performing with the instrument, the acoustic technology, the analogue synthesizer with its buttons, knobs, and patch cables, and the computer trackpad we designed interactive technology that "sees" the human. Albeit, we can say that the smartphone, the laptop, and the mechanic typewriter before it, sees the human too. However in the strive to not dehumanise users into screen tapping fingers, embodied interaction calls for more rich interaction that can "see" the humans' nuances and precision in their bodily motions. The Noise from the Rift project further deepened the exploration of the intersection between technology and human. Here, we have a distinctive difference between human muscle activity induced EMG noise and the noise induced from touching technology. Electricity as material knows no difference from the synthesizer or the flesh of the human body, thus in the touch between the living body of the dancer and the synthesizer they are one. Whereas, from a human perspective hearing the body and the sound of the interference of technology made us aware of the ubiquitous technology. This relates to Barrett and Bolt [1]: "Whilst humanist thought placed the human subject firmly at the centre of the social and physical world, discoveries in science, particularly around quantum physics and nanotechnology, and the emergence of new human-technological relationships have scented the subject. These movement, in concert with social, political and philosophical theories that question the privilege given to humans in the human/non-human binary, underpin the discourse of new materialism." In this citation, Barrett and Bolt suggest that humans share the centre of our socially constructed world. From our experimentation, we have learnt that sonic augmentation of motions creates abstract awareness of technology and abstract awareness of the living body. Design technology as a subject in the interplay with users allows humanisation of technology at the same time allowing technology to see users as humans. The technologies' more complex and nuanced embodied perception calls for more sophisticated interaction technology to become more humane. We created Critical Digitalism to have a more intimate relationship between the musician and the technology than Whirlpool Bach. The project was inspired by Svanæs' [19] kinaesthetic creativity. He introduced kinaesthetic creativity to enable the body to be part of the design process. "Kinaesthetic creativity makes it possible not only to use the body in the design process as an object to be studied or as a vehicle for acting out proposed solutions, but also to create design processes and environments that will take advantage of the ability of designers and users to explore and enact alternative futures through abstract movements."

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REFERENCES

[1] E. Barrett and B. Bolt. *Carnal knowledge: towards a'new materialism'through the arts.* Ib tauris, 2013.

[2] I. Bergström and A. F. Blackwell. The practices of programming. In *2016 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*, pages 190–198, Sept 2016.

[3] D. M. Berry and M. Dieter. *Thinking Postdigital Aesthetics: Art, Computation and Design*, pages 1–11. Palgrave Macmillan UK, London, 2015.

[4] M. Donnarumma. Xth sense: a study of muscle sounds for an experimental paradigm of musical performance. In *Proceedings of the International Computer Music Conference Proceedings*, volume 2011, pages 316–320, University of Huddersfield, UK, August 2011. International Computer Music Association, Inc.

[5] P. Dourish. *Where the Action is: The Foundations of Embodied Interaction.* MIT Press, Cambridge, MA, USA, 2001.

[6] H. L. Dreyfus. The current relevance of merleau-ponty's phenomenology of embodiment. *Filozofska Istrazivanja*, 15(3):1–20, 1996.

[7] S. Electronics. MyoWare Muscle Sensor development kit. https://www.sparkfun.com/products/13772. Accessed: 2017-03-30.

[8] W. Gaver. What should we expect from research through design? In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, pages 937–946, New York, NY, USA, 2012. ACM.

[9] K. Höök, M. P. Jonsson, A. Ståhl, and J. Mercurio. Somaesthetic appreciation design. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, pages 3131–3142, New York, NY, USA, 2016. ACM.

[10] H. Ishii and B. Ullmer. Tangible bits: Towards seamless interfaces between people, bits and atoms. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, CHI '97, pages 234–241, New York, NY, USA, 1997. ACM.

[11] J. Jaimovich. Emovere: Designing sound interactions for biosignals and dancers. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, volume 16 of *2220-4806*, pages 316–320, Brisbane, Australia, 2016. Queensland Conservatorium Griffith University.

[12] S. R. Klemmer, B. Hartmann, and L. Takayama. How bodies matter: Five themes for interaction design. In *Proceedings of the 6th Conference*

on Designing Interactive Systems, DIS '06, pages 140–149, New York, NY, USA, 2006. ACM.

[13] R. Lindell. Crafting interaction: The epistemology of modern programming. *Personal Ubiquitous Comput.*, 18(3):613–624, Mar. 2014.

[14] A. McPherson. Portable measurement and mapping of continuous piano gesture. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 152–157, Daejeon, Republic of Korea, May 2013. Graduate School of Culture Technology, KAIST.

[15] D. W. H. Menzies and A. McPherson. A digital bagpipe chanter system to assist in one-to-one piping tuition. In *Proceedings of Sound and Music Computing*, 2013.

[16] M. Merleau-Ponty. *Phenomenology of Perception.* Routledge & Kegan Paul, London, UK, 1962.

[17] E. X. Merz. *Sonifying Processing: The Beads Tutorial.* CreateSpace Independent Publishing Platform, 2011.

[18] D. A. Schön. *The Reflective Practitioner: How Professionals Think in Action.* Basic Books, New York, NY, USA, 1983.

[19] D. Svanæs. Interaction design for and with the lived body: Some implications of merleau-ponty's phenomenology. *ACM Trans. Comput.-Hum. Interact.*, 20(1):8:1–8:30, Apr. 2013.

[20] K. Tahiroglu, T. Svedström, and V. Wikström. Musical engagement that is predicated on intentional activity of the performer with noisa instruments. In E. Berdahl and J. Allison, editors, *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 132–135, Baton Rouge, Louisiana, USA, May 2015. Louisiana State University.

[21] A. van Troyer. Composing embodied sonic play experiences: Towards acoustic feedback ecology. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 118–121, London, United Kingdom, June 2014. Goldsmiths, University of London.

[22] F. Visi, R. Schramm, and E. Miranda. Use of body motion to enhance traditional musical instruments. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 601–604, London, United Kingdom, June 2014. Goldsmiths, University of London.

[23] M. Weiser. Some computer science issues in ubiquitous computing. *Commun. ACM*, 36(7):75–84, July 1993.

[24] T. Yamaguchi, T. Kobayashi, A. Ariga, and S. Hashimoto. Twinkleball : A wireless musical interface for embodied sound media. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 116–119, Sydney, Australia, 2010.

[25] J. Zimmerman, J. Forlizzi, and S. Evenson. Research through design as a method for interaction design research in hci. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '07, pages 493–502, New York, NY, USA, 2007. ACM.