Performance, Art, and Cyber-Interoceptive Systems (PACIS)

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ABSTRACT

This paper[1] provides a survey of the research-creation activities of the collaboration, *Performance, Art, and Cyber-Interoceptive Systems* (PACIS). PACIS has been exploring how technology can help us create deeper connections with the world around us, each other, and ourselves by combining bioinformatic sensing technology with physiological awareness techniques found in *The Batdorf Technique (TBT)*. Primary outputs of this research involve the development of new and novel interfaces that integrate complex physiological data in performance and computational art contexts. The focus of this endeavour is on the sharing of knowledge and exchange of ideas across disciplines, the traineeship of students and emerging scholars in the technological as well as somatic techniques and the creation of workshops, articles and performances.

CCS CONCEPTS

• **Applied computing~Performing arts** • **Applied computing~Media arts** • *Human-centered computing~Empirical studies in interaction design* • Human-centered computing~Empirical studies in collaborative and social computing

KEYWORDS

cyber-interoceptive, cybernetics, interoception, valence and arousal, bioinformatic sensing, computational arts, performance, somatic

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1 INTRODUCTION

The human sensory system can be understood as a filtering system. Physical form and activity are perceived by the senses and translated into modulated streams of ionic current, which move through the body, via the nervous system, to the brain. Specialized brain regions receive and decipher these modulated current signals to process them for interpretation by other functionalities operating within the body[1].

There are volitional and non-volitional (autonomic) aspects to our bodies. We can consciously and intentionally stimulate motor neurons, which innervate muscle fibres, to move our bodies. Other processes, like heart rate, digestion and perspiration are primarily mediated through the subconscious. Some actions, like breathing, are subject to both subconscious and conscious control[2]. Our conscious thought rests upon an emotional sea, and our emotions are linked to autonomic processes in our bodies. Our mood, which stimulates our conscious thought, influences our perception because our emotional substrate acts as a neurological filter as well[3,4].

The medium established by our physiological state therefore is pivotally important. The manner in which we generate conscious thought is dependent upon our emotional state. Emotional state is reflected in autonomic processes, within the body, that are related to our physiological state[5]. William James described the mental aspect of emotion, emotional feeling, as subject to underlying physiological state and not vice-versa[6]. Antonio Damasio has described emotion as 'the ever changing landscape of the body'[7]. Significant scientific research has shown that the only way we can consciously access the emotional brain is through interoception[8]. Interoception refers to any internal sense that involves numerous sensory

receptors in internal organs, such as stretch receptors, that are neurologically linked to the brain[9,10].

2 OBJECTIVES

We are exploring how technology can help us expose and augment non-volitional, autonomic processes of the body using performers who have developed advanced interoceptive awareness. The advantage in working with these performers is that they are accustomed to maintaining interoceptive awareness while being observed and have an ability to recreate emotional states. Our desire is to employ bioinformatic sensing technology to create regulatory feedback systems facilitated by bioinformatic sensors.

Bioinformatic sensors are a special class of sensors that track human characteristics such as heart rate, muscular movement, eye movement, skin temperature and breathing[11]. Recent research in bioinformatics suggests that it is possible to generate reasonably solid, actionable vectors to indicate the real-time emotional state of an individual using a layering of complex data sets sourced from physiological variables that contribute to an individual's emotional valence (range of pleasant to unpleasant) and arousal (range of activation and deactivation)[12–17]. Valence and arousal data of a performer can be used to develop co-collaborative applications that help us increase our somatic awareness and help mediate the bi-directional emotive connection of a performer with an audience.

We use the term *Cyber-Interoceptive Systems* to describe a feedback connection between performer, computer, other performers, the audience, and the environment in the pursuit of new forms of *embodied* performance, *embodied* human computer interaction, and *embodied* cognition. The term *Cyber-Interoceptive Systems* derives from the concept of cybernetics. Norbert Wiener, a pioneer in the field of cybernetics, describes cybernetics *as the study of the communication and control of regulatory feedback both in living beings and machines, and in combinations of the two*[18]. PACIS incorporates systems design inspired by cybernetics in order to develop bi-directional feedback experiences between subject and environment in order to create more meaningful connections between the two.

Much of the inspiration for incorporating cybernetics into this work has come from N. Katherine Hayles book, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*[19] where she describes the rise of human-machine integration through the history of *cybernetics*, an interdisciplinary pursuit of a *general science of the workings of the human mind*[20]. Hayles' book provides a critique of technology as moving us culturally away from a *natural* self, to a disembodied self, losing subjectivity as our intelligence is co-produced with intelligent-machines (a.k.a. the *posthuman condition).* The incorporation of *cybernetics* with *interoceptive practices* is done in conscious resistance to this tendency. We seek to develop systems of human-machine integration that enhance interoceptive somatic awareness, drawn from the belief that human intelligence is an embodied intelligence that is not housed in the brain, but is inclusive of the body and the environment. This view is aligned with current trends in psychology and brain science[21,22].

3 THE BATDORF TECHNIQUE

One of the unique aspects about this project is the incorporation of the nuanced interoceptive somatic system known as *The Batdorf Technique* (TBT)[23]. Developed by Erika Batdorf, TBT is a somatic education system that allows performers to access, catalogue and recreate emotional states, and develop heightened presence through physiological awareness. This work relates to literature in embodied cognition, which studies the empathic relationships between the observer and the observed that indicates that *sharing the emotions of others is associated with activation in neural structures that are also active during the first-hand experience of that emotion*[24]. The technique includes a carefully developed approach to the inclusion of emotional discovery during interoceptive awareness training. The technique organizes the practitioner's access to specifically located *awarenesses* related to involuntary systems (breath, blood circulation, temperature, relationship to gravity, skin, etc.) that can eventually be consciously modulated to vary the kinaesthetic state being. The training systematizes the full scope of a performer's work from the early stages of interoceptive awareness to the complicated juggling of this somatic work with layers of external structure (from conscious exteroceptive musculoskeletal movement to choreography and memorized text) in the act of specific kinaesthetic communication with an audience.

TBT belongs to a class of somatic movement education techniques that focus on the re-education of the body to support holistic health, injury recuperation and prevention, and increased dynamic range of expression. The practice of somatics was defined and named in the 1970s by Thomas Hanna and others[25] influenced by forms such as Yoga and Martial Arts and based on practices originating in the early 20th century. somatics practice draws on several fields such as new interoceptive explorations in psychology[26–28], body work[29–31], emotional work in actor training[32–34], and movement education[35–37], with many techniques moving between these sub-areas. TBT is unique in the field of somatic movement practices in that it 1) encourages the full range of human physical and emotional experience and expression; 2) has systematized the process of a performer's development from fundamentals in interoceptive awareness (the ability to feel sensations from multiple involuntary systems simultaneously) to then simultaneously also juggling sensory information, then adding eye contact, eventually spoken text and/or choreography and finally observation (audiences); and 3) has a structured approach to training practitioners to repeat at will various emotional states for performance while being observed.

4 METHODOLOGY

A major aspect of the PACIS collaboration involves an exploration of the technical challenges and implications of the use of bioinformatic sensing to track the emotive inclination of

participants, and then use emotive inclination as a modality of interaction in performance and computational art contexts. Quantitative measures found in bioinformatic sensing applications are applied to the qualitative method of TBT for the development of *cyber-interoceptive systems* in the context of performance and human computer interaction. The approach is to find a corollary between the experience perceived by the performer or audience member and the bioinformatic measures of the individual taken at the time of the experience. When there is a corollary, then several pathways for exploration emerge: *Can the bioinformatic sensing be used as a feedback system to help train performers in TBT? Will it be possible to use somatic control as an interactive interface? Can this system be used to develop new modalities of interaction between the audience and performer?* Much of our current experimentation is happening in this latter arena. TBT trained performers, along with Digby, are assisting Batdorf and acting as participants in our research activities. Hosale and Macy are developing hardware and software solutions in consultation with the performers. Our research to date based on our work as a team including informal interviews that inform an empirical approach to the manipulation of the parametric aspects of audio-visual feedback, resulting in the creation of interactive performance systems that respond to a performer's emotive state.

We explore these questions through an empirical investigation that follows a progression of four parallel layers of activity. First, we are looking primarily at the personal connection between embodiment and physiological data to see if it is possible to confirm the subject's own awareness of various systems of the body. Second, we focus on the connection made between two people and see if there is a way that one can influence the embodiment of the other, and if the experience of embodiment can be shared. Third we will focus on the exploration of psychosocial potential of the combining of embodiment and physiological data by looking at how this technology can be used to explore and augment group experiences, and the ability of the performer to affect the audience. Fourth we will turn to the role of affect and the environment, in particular how the performer can have a biofeedback relationship with the performance environment.

5 TOOLS

5.1 Hardware

For these studies emotional state data is gathered from the multi-channel *BioNomadix* wireless sensing system, and the single-channel *MP40* wired system (see Fig. 1.) developed by *Biopac*[38]. Both systems are capable of reading a variety of physiological measures, such as Blood Volume Pulse (BVP), Electrocardiography (ECG, heart rate), Galvanic Skin Response (GSR), Electromyography (EMG, muscle), Electroencephalography (EEG, brain waves), and Electrooculography (EOG, eye movement). These systems are used to gather physiological data from participants in an immersive performance context. The performance environment provides the ability to control the presentation of stimuli, monitor the physical reaction, and change the scene based on the reaction interpretation as nuanced by emotional state, blurring the line between high resolution auditory and visual virtual content and physical experience[39–43].

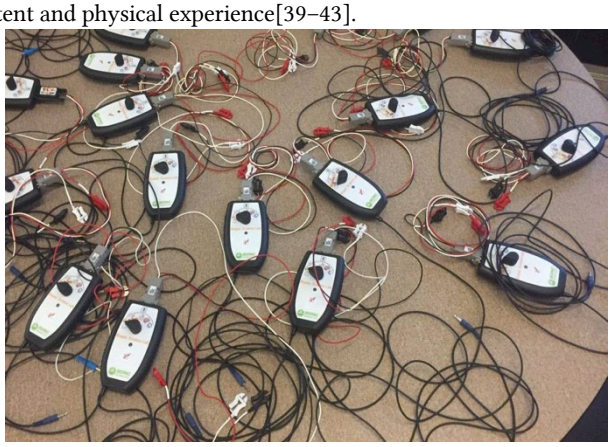

Figure 1: BIOPAC MP40 bioinformatic data acquisition units. ©M.D. Hosale.

In many ways the *BioNomadix* system is an ideal tool for this research. It is lightweight, multi-channel, wireless-system that can be placed locally to the point of measurement. However, the cost of the *BioNomadix* system (hardware and software) is expensive making it unreachable at this time. The only time we had access to this system was on special loan exclusively for the purpose of the *Movement and Emotion as Computational Interfaces Workshop* (MECI) (see section 6).

By contrast the *MP40* is a much more bulky, single channel wired system, but with a much more affordable price point. The upside is that the *MP40* is quite hackable. Signals from the MP40 are sent on 4096Hz carrier wave over a standard 1/8" audio cable allowing them to be processed using commonplace digital audio programming environments such as Max[44] and SuperCollider[45] on any modern computer with an audio interface (for more on this see section 6.3 below). The fact that the MP40's operate in audio range means that they can be also be extended by use off-the-shelf wireless guitar or microphone transmitters to give them wireless capability (see section 8.2).

New developments in the *MP40* include working with a barebones version that is 60%-70% smaller than the original and integrating it with a RaspberryPi[46] running SuperCollider in a system we are calling *PACIS Pak*, as shown in Fig. 2. The advantage is that the entire analysis system is encapsulated into a set of wearable components, making it much cheaper and less cumbersome to implement in performance contexts than the previous system, which required a laptop and standard audio interface. The built-in wireless capability of the RaspberryPi, combined with additional hardware provides the capability of connecting LED's, loudspeakers, and haptic transducers within costumes and objects. The *PACIS Pak* was developed in Hosale's *nD::StudioLab* [47] in collaboration with Macy.

Additional experiments have been conducted working with the Teensy microcontroller[48] with onboard DSP using an extended version of the Teensy Audio Library[49], but with less desirable results and a similar price point as the Raspberry Pi.

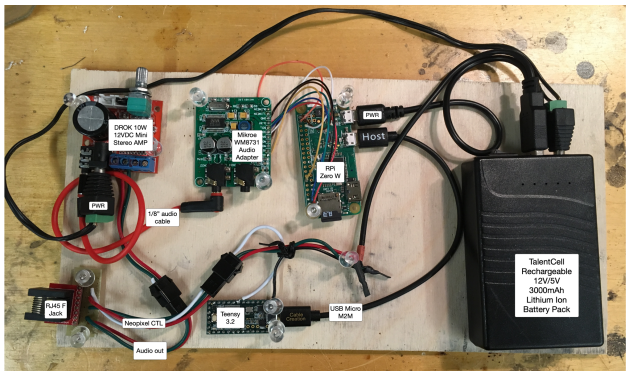

Figure 2: The *PACIS Pak* system. ©M.D. Hosale.

5.2 Software

The *Biopac* system includes software called *AcqKnowledge*[50], which can analyze and export biosensor data for use in custom software solutions. The *Biopac* system can also be used to connect with *Max*, or any software capable of OSC. *AcqKnowledge* is a biomedical research quality data acquisition software that does sophisticated real-time analysis and data logging. The downside is that *AcqKnowledge* is expensive and has not been available in our work, except in special circumstances. *BioNomadix* requires *AcqKnowledge*, whereas with the *MP40 AcqKnowledge* is optional.

While developing custom software for the *MP40* entails a certain amount of redundancy with features already present in *AcqKnowledge*, the upside is that it gives us the flexibility to develop modular, lightweight, cost effective systems that are scalable and deployable on many platforms.

Therefore, as part of our research efforts we have developed templates and strategies for interfacing the MP40 using the *Max* multimedia programming environment, and the *SuperCollider* audio programming environment. Through our efforts we have developed a fairly robust analysis system called the *MECI Filters* (see section 6.3) that is able to capture and clean signals from the MP40. Most recently, most of our attention has been on the analysis of the heart (ECG) signal due to its expressivity, having high potential for determining affect[51]. So far from the heart rate signal we are able to capture heart rate, heart rate variability, and, through the use of wavelet analysis, respiration[52] (see section 8.2).

The focus of the research thus far has been on the acquisition and interpretation of real-time data, but in the future a significant effort will go into the collection of data for non-real-time post-processing of data sets. This will allow us to reflect on how this can point to new directions in the process, which could be used to train a machine learning system such as *Wekinator*[53]. All along this process we are dealing with the practical challenges of technology attached to bodies in motion and the 'noise' that this creates in the data, especially from subtler physiological systems. The incorporation of machine learning will help us identify usable signals, and to recognize patterns within them.

6 MOVEMENT AND EMOTION AS COMPUTATIONAL INTERFACES WORKSHOP

6.1 Overview

In June 2016, the team held an intensive workshop *on Movement and Emotion as Computational Interfaces (MECI 2016)*[54] at York University (Toronto, Ontario Canada). The workshop explored bioinformatic sensing technology with modes of physiological awareness found in somatic performance practice. The workshop targeted a diverse audience and participants included students, academics, and industry professionals from fields such as computational arts, somatic practice, entertainment, gaming, computer science, architecture, virtual reality and other art/science collaborations. The workshop was held early in our collaboration and knowledge gained from this workshop catalyzed our collaboration and helped us establish the first principles of our endeavour.

6.2 Workshop Structure

The structure of the workshop helped us find a balance between somatic work and technological development. It also gave us a means whereby we could structure our inquiry that ranges from individual interoceptive exploration to transference between a performer and other persons:

Solo work focussed on the individual personal connection between embodiment and physiological data. The goal here was to discover awareness with the systems of the body that are normally consciously ignored.

Duets focussed on the connection made between two people and see if there is a way that one can influence the embodiment of the other, and if the experience of embodiment can be shared.

Ensemble work focussed on the exploration of the psychosocial potential of the combining of embodiment and physiological data in the context of group experiences. This includes looking at how technology could be used to explore the ability of the performer to affect the audience.

Audience/environment work looked at how the performer can have a biofeedback relationship with the audience and environment of the performance.

This structure influenced the progression of our research-creation activities, where we have developed solo, duet, and ensemble works in progression and in increasing complexity. For more details see section 8, below.

6.3 Tool Development

Several tools were developed in preparation for the MECI workshop that became the foundation of the PACIS tool-kit in the years to follow. On the hardware-side we used both Biopac

BioNomadix and *MP-40's* (described in section 5) in the acquisition of data. As mentioned above, the *BioNomadix* system requires *AcqKnowledge* data acquisition software that is a proprietary but does provide interfacing via OSC facilitating connections with *Max* and *SuperCollider* for mapping with audio/visual mapping sources. The task here was more or less straightforward in that it involved the creation of appropriate network sockets and then properly interpreting and mapping network protocols to relevant parameters in software, e.g. analyzed ECG signals to light or sound.

Most importantly the workshop saw the significant development of a software tool called the *MECI Filters*, which were specifically designed to obtain clean data from the *MP-40*. The *MP-40* is a single channel device that is capable of capturing a wide variety of biophysical data as described in section 5. This data is captured in the form of microvolts which are digitized and transmitted via an Amplitude Modulated audio signal with a 4096Hz carrier and captured by the computer using standard audio interfaces such as the MOTU Ultralite Mk3[55]. In order to obtain a workable signal, the *MP-40* source signal must be demodulated, then a set of conditioning filters are introduced the eliminate known noise sources, such as AC ground hum, and prepare the signal for further processing. The output of this first set of filters is referred to as the *raw* signal and is analogous to the target biosignal being acquired before the demodulation chain, etc. (e.g. the raw ECG). Following the *raw* signal is a set of filters that are used to provide deeper analysis of a signal, e.g. extracting heart rate variability from an ECG, referred to as the *cooked* signal. For the purpose of the workshop a more general-purpose *cooked* filter set was developed that provided a smoother signal by isolating and low pass filtering in specific frequency ranges relevant to particular signal types (ECG, EMG, GSR, etc.). The development of these filter chains was inspired by the capabilities of *AcqKnowledge* and relied heavily on the expertise of Macy with the assistance of Hosale.

Through these interfaces and tools data collected from the Biopac *BioNomadix* and *MP-40's* used in the workshop to map to sound synthesis, audio sample triggering, real-time video manipulation and generation, real-time computer graphics manipulation and generation, and DMX lighting control.

6.4 Workshop Results

A promising result from the workshop was that we found clear indicators of potential interfaces using Electromyography (EMG), Electrocardiogram (ECG), skin conductance (eccrine/GSV) and breathing (using a Respiratory Measurement Transducer) measurements in our explorations. This was present in performance contexts when measuring both the arousal of the audience and in the arousal of the performer (but not at the same time). Also, in the audience we saw strong indicators of emotive response derived from skin conductance (eccrine/GSV) in response to particular performance while observing practitioners of TBT. In addition, there were several demonstrations where subjects used interoception (both in experienced and non-experienced TBT practitioners) with stimulus to control sounds and lights by altering their emotive state consciously. This was measured using ECG, skin conductance and breathing and comparing them with self-reported experiences.

7 THE *BATDORF INTENSIVE*

Every May, Batdorf and Digby hold a two-week long intensive workshop on *TBT* in Toronto in order to train advanced performers to consciously work with awareness of systems connected to the autonomic nervous system (interoception) as part of their practice. Simultaneous to the advanced workshop, a range of training is provided, including beginning, intermediate, and future teachers of the technique. For example, the workshop in 2016 was used to work on advanced interceptive techniques to prepare for MECI and a presentation made at the 4th annual International Somatics Conference & Performance Festival (SOMA2016) in New York. The *Batdorf Intensive* in 2017, 2018, and 2019 are used to create material specifically for inclusion in a workshop performance of *Simurgh* (described below in section 8.3).

8 PERFORMANCE WORKS

The creative output of the PACIS collaboration has so far resulted in the development of three performance works, *Burnish, The Red Horse Is Leaving* and *Simurgh.*

8.1 *Burnish*

Burnish, , conceived, written and performed by E. Batdorf, installation design M.D. Hosale, with work by S. Bartos and I. Dewi[56]. *Burnish* is a solo performance-based artwork presented in a stand-alone immersive installation environment. Inspired by elements of fire, flooding, and the desire to cleanse the heart, Burnish invites individual audience members to experience an intimate performance contained in a mini-pavilion. Others can observe through eye pieces in the walls of the pavilion, but the views are distorted, with the only clear view of what is happening being presented to an individual audience member. Integrating music, digital technology, poetic text, art objects, and singing the artist attempts to maintain a deeply authentic process that is altered by her interaction with the individual audience member. Changes in the structure and content of the performance are controlled through custom computer interfaces that rely on conscious input from the audience (indirectly) and the performer (directly). Sound and light events dynamically respond to bioinformatic measurements taken from Batdorf's heart (ECG) and muscles (EMG) during the performance using the *MP40* and *MECI Filters* to collect and map biophysical data.

Burnish was presented in the *56th Venice Biennale* in an official collateral event with *9dragonheads*[57]; *The Toronto Theatre Centre*[58]; the *Summerworks Festival Toronto* in 2016[59]; the *Santa Barbara Center for Art, Science, and Technology* (SBCAST)[60] in December 2016; and as part of the *Currents* Festival in Santa Fe, New Mexico in June 2017[61].

8.2 *The Red Horse Is Leaving*

The Red Horse Is Leaving written and performed by E. Batdorf, directed by K. Digby, with work by M.D. Hosale, O. Khan, A. Macy and J. Rigzin Tute[62]. *The Red Horse Is Leaving* is a long poetic monologue written and played by Erika Batdorf inspired by her mother, an artist, Thaya Whitten, in her studio trying to paint a vision she has seen. In writing *The Red Horse is Leaving*, Batdorf has attempted to recreate what she could only imagine was happening in the mind of her mother during delusional, paranoid and ecstatic moments. This is an extrapolation from research based on her mother's journals, paintings and lecture performances, along with Batdorf's own experience of Whitten's struggles as an artist wrestling with schizophrenia; sometimes brilliant, sometimes demented. It moves back and forth from an interactive audience lecture/dialogue to the artist alone in her studio talking to herself in poetic and mad, searching refrains. A 'Gargoyle' representing madness is onstage throughout the piece, silently played by a dancer, represents the inner workings of Whitten's mind.

A major aspect of the remounting of this work is the inclusion of bio-sensing and new media technology. Batdorf wore an *MP40* connected to a wireless microphone transmitter which sent ECG data captured by an audio interface on a computer running *Max*. The computer analyzed the ECG via *MECI filters* using the *raw* and *cooked* signal to control an LED-lit spine woven into the fabric of the costume of the Gargoyle. Using the ECG signal we were also able to estimate Batdorf's breathing by using a wavelet analysis for the interpolation of R-to-R signal components of the ECG, as described in Haddadi, et. al.[63] and Tan[64]. Extensions of this work could later be applied to valence and arousal measurement as described in Agrafioti, et. al. [65] and Chen, et. al. [66].

The Red Horse Is Leaving was workshopped in the Summerworks Festival in Toronto in the August 2018[67]; then shown in the Workman Arts *Rendezvous With Madness* Festival in Toronto in October 2018[68]; *Out of Towner's Performance Series* in Brooklyn, New York in October 2018; *Soaking WET*, West End Theatre, New York, NY May 16-18, 2019[69]; and the *Macy Theater* in Santa Barbara, California on May 25, 2019.

8.3 *Search for Simurgh*

Search for Simurgh, K. Digby in collaboration with E. Batdorf, inspired by the work of R. Movafegh, created collectively by the Simurgh Project Ensemble, A. Dehbonehie, M.D. Hosale, J. Howman, A. Macy, P. Sabet[70]. *Search for Simurgh* is an immersive theatre installation with a mid-sized ensemble cast. *Simurgh* is inspired by the life and work of Roya Movafegh, a Montreal-based multi-media artist who escaped her homeland during the Iranian revolution. *Search for Simurgh* explores the story of a child refugee's escape from her home as metaphor for the search to find our true selves. Themes of the work include identity, displacement, dissociation/re-integration and freedom. The themes of *Search for Simurgh* are highly topical, directly relevant to the experiences of people worldwide, and easily facilitate an exploration of technology's potential to enhance human connectivity. Additionally, the staging of *Search for Simurgh* includes surreal and fantastical imagery that is well-suited to mixed reality technologies, including sculptural elements that move in response to the audience, sonic landscapes, and bio-feedback experiences between performers, participants and each other. *Search for Simurgh's* narrative structure allows for a small core of performers to be joined by local talent for supplementary roles at each site, thereby encouraging deeper dialogue and connection with local communities.

Search for Simurgh, was workshopped at the Toronto Media Arts Centre, Toronto from July 31st -August 2nd 2019. For this workshop the *PACIS Pak* (described in section 5) was developed. The *PACIS Pak* were primarily used to implement a work by Alan Macy, called *Hand-to-Heart*[71], which was integrated into the show. The *Hand-to-Heart* features a 3-D printed model of a heart containing a haptic transducer and an LED light source. The heart model is connected to a *PACIS Pak*, which in turn, is connected to a individual. The heart is then passed around a small group of participants so that the participants can feel and see the heart signal of the connected individual in their hand. The intent of the work is to promote embodied intimacy among the performers and participants in the group.

9 SUMMARY OF THE *PACIS* TIMELINE

The PACIS collaboration began with *Burnish*. Batdorf invited Hosale to work on *Burnish* with the intent of adding technological elements to the piece. It was then that Batdorf and Hosale noticed a synergy around her somatic practice and the bioinformatic sensing work of Macy. Between Batdorf and Macy there was an understanding of emotional affect and cognition as a whole-body experience that was present physiologically as much, if not more, than in the mind. In addition to Macy, Digby, a long-time collaborator of Batdorf's in TBT, was brought into the PACIS collaboration. For Batdorf and Digby this derived from the interoceptive work described in sections 2 and 3 above. For Hosale and Macy this meant the measuring of these physiological states and representing them as sound, light, and haptic events. In the early stages of the work *Burnish* quickly became a proving ground for some of the first principles of the work. Heart (ECG) and muscle (EMG) sensors were included in *Burnish*'s production.

Our first year of collaboration resulted in the MECI workshop. Shortly after the workshop Digby proposed that we work on *Simurgh* with the intent of integrating biosensing and performance from initial concept to production. First discussions around the development of *Simurgh* began in December of 2016.

The scale of the *Simurgh* in terms of scope of the production and size of the ensemble made the leap from *Burnish* to *Simurgh* feel daunting. Therefore, it was decided to mount an interim work, *The Red Horse is Leaving*. This began in the Spring of 2017. The progression from *Burnish* (a solo work), to *Red Horse* (a two hander/duet), to *Simurgh* (an ensemble work with audience interaction) closely followed the strategy of moving from *Solo work*, to *Duets*, to *Ensemble work*, and connection

Audience/environment as described in the MECI workshop in section 6 above.

A remounting of a work by Batdorf from ten years earlier, *Red Horse* was originally a solo work. In the new version it was rewritten as a duet. *Red Horse* was chosen in part because it was quite adaptable to this shift, which facilitated the exploration of the use of technology between two TBT trained performers in an actual performance setting. In addition, the narrative of *Red Horse* has a large emotive range. The production of *Red Horse* gave us insight into the challenges of pressures of theatre production while working across disciplines with novel biosensing technology. In addition to the technological challenges we faced, we had a number of mundane obstacles that included working methods, deliverables, and other workflow hiccups that had to be smoothed out in order to realize the work.

Creative research conducted by PACIS was then organized around realizing the artistic vision of *Simurgh.* The parallel development of *Simurgh* and the ongoing production of *Red Horse* helped to feed the ecology of this endeavour. Having both a piece in production and a piece in development allowed us to address unexpected issues that typically come up in performance contexts, and apply that experience to a new, larger work that has the potential for deeper integration of *cyber-interoceptive systems* in its development. This led to the development of the *PACIS Pak* described in section 5.1 above, which was a primary development tool for the production of *Simurgh.*

10 CONCLUSION

This creative project holds two simultaneous processes. First, we are artists creating an original work intended to inspire and incite. Second, we are researchers developing outcomes that have application far beyond the world of our artistic creation. This is where the work of our art can advance knowledge in the fields of medicine, computational art, human-computer interaction, and mixed reality. Our goal is to have these two processes feeding each other – both in the development of novel interfaces for human computer interaction, and the development of technology-enhanced embodiment training pedagogies – will be shared in educational workshops offered throughout the creation phase and in conjunction with touring of finished work.

Research-creation methodologies ask challenging questions of the technology that push and test its limitations. For example, in a typcial laboratory environment subjects under observation are generally asked to limit their movement in order to reduce noise and artifacts produced by movement. The trade-off for getting a clear signal is that results can often be confounded in laboratory settings, as subjects are being asked to modify their behaviour, influencing the outcome of the results. However, when working in a performance context, limiting the movement of the performers is simply not an option. Therefore, this necessitates the need for the development of signal processing tools that can mitigate noise in situations where extreme movement is present. The demands of performance, including high-quality signal-to-noise ratios, non-invasive and un-inhibiting sensing devices, and low latency real-time signal analysis systems, have the potential to contribute to techniques and instrumentation in traditional laboratory environments implying that there is a high potential for this research-creation activity to contribute to the research activities of disciplines that rely on biosensing and their applications as part of their work.

Beyond instrumentation, research-creation activity provides the opportunity to test questions around the ability of technology to enhance the performance/user experience (such as with the questions stated above: *can the bioinformatic sensing be used as a feedback system to help train performers in TBT? Will it be possible to use somatic control as an interactive interface? Can this system be used to develop new modalities of interaction between the audience and performer?*) in novel circumstances. By combining the methods of performance creation and dissemination with scientific methodologies this work benefits from both worlds. Ultimately, the evaluation of a performance lies in the assessment of the affect on the audience or the performers. Traditional measures such as a show's success can help identify the ability of the tools to facilitate and enhance artmaking; or in the case of traineeship, of the tools ability to enhance the development of a performer's technique. Through additional insight drawn from scientific measurement, surveys and observation, scientific methodologies can give us insight into the effectiveness of the tools being presented.

Another way that research-creation methodologies contribute to the field is by providing a critical lens on the cultural implications of new technology. Positive aspects of ubiquitous biosensing include advances in technology that increase monitoring of the physiology for health benefits, such as fitness[72] and preventative medicine[73]. Negative aspects include the potential to surveil persons in a more invasive manner than previously possible. Fear of increased racial profiling and the use of health profiles in the evaluation of job applicants or employees, to access insurance premiums, or other life affecting barriers being introduced as a result of this technology are a likely and potential hazard. In addition, there is the increasing trend in information technologies to create systems that encourage disassociation. In our work we seek to counter this tendency by exploring and developing experiences that help us create deeper connections with the world around us, each other, and ourselves in meaningful contexts that explore the essence of the human condition.

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REFERENCES

[1] Nicholls, John G. Martin, Paul A. Fuchs, David A. Brown, Mathew E. Diamond, and David A. Weisblat. *From Neuron To Brain.* Fifth edition. Sunderland, MA:

Sinauer Associates, 2012, pp. 69-182
[2] Ibid. pp. 383-528
[3] Lewis, Michael. "The emergence of human emotions." *Handbook of emotions* 2 (2000): 265-280.
[4] Cacciopo, JT, Berntson GG, Larsen JT, Poehlmann KM, Ito, TA (2000) The psychophysiology of emotion. In *Handbook of Emotion, 2nd Edition* (Eds: R Lewis, J M Haviland-Jones), Guilford Press, New York, pp 173-191.
[5] Izard, Carroll E. *The psychology of emotions*. Springer Science & Business Media, 1991.
[6] James, William. 1890. The Principles of Psychology (2 vols). New York Holt.
[7] Damasio, Antonio. Descartes' Error: Emotion, reason and the human brain. Random House, New York: 1994.
[8] van der Kolk, Bessel A. Van Der. The Body Keeps the Score: Brain, Mind, and Body in the Healing of Trauma. New York: Viking, 2014.
[9] Damasio 1994
[10] Craig, A.D., 2003. "Interoception: the sense of the physiological condition of the body." *Current opinion in neurobiology*, *13*(4), pp.500-505.
[11] Picard, Rosalind W. "Affective medicine: Technology with emotional intelligence." Studies in health technology and informatics (2002): 69-84.
[12] Cacciopo 2000
[13] Scherer, Klaus R. "What are emotions? And how can they be measured?." Social science information 44, no. 4 (2005): 695-729.
[14] Chanel, Guillaume, Julien Kronegg, Didier Grandjean, and Thierry Pun. "Emotion assessment: Arousal evaluation using EEG's and peripheral physiological signals." In Multimedia content representation, classification and security, pp. 530-537. Springer Berlin Heidelberg, 2006.
[15] Stickel, Christian, Martin Ebner, Silke Steinbach-Nordmann, Gig Searle, and Andreas Holzinger. "Emotion detection: application of the valence arousal space for rapid biological usability testing to enhance universal access." In Universal Access in Human-Computer Interaction. Addressing Diversity, pp. 615-624. Springer Berlin Heidelberg, 2009.
[16] Nicolaou, Mihalis A., Hatice Gunes, and Maja Pantic. "Continuous prediction of spontaneous affect from multiple cues and modalities in valence-arousal space." Affective Computing, IEEE Transactions on 2, no. 2 (2011): 92-105.
[17] Koelstra, Sander, Christian Muhl, Mohammad Soleymani, Jong-Seok Lee, Ashkan Yazdani, Touradj Ebrahimi, Thierry Pun, Anton Nijholt, and Ioannis Patras. "Deap: A database for emotion analysis; using physiological signals." Affective Computing, IEEE Transactions on 3, no. 1 (2012): 18-31.
[18] Wiener, Norbert. Cybernetics or Control and Communication in the Animal and *the Machine*. Vol. 25. MIT press, 1948, 2nd Rev. Ed. 1961.
[19] Hayles, N. Katherine. How we became posthuman: Virtual bodies in cybernetics, *literature, and informatics*. University of Chicago Press, 2008.
[20] Ibid.
[21] Van der Kolk 2014
[22] Damasio, Antonio. The Feeling of What Happens: Body and Emotion in the Making of Consciousness. Harcourt Brace, New York: 1999.
[23] http://www.batdorf.org/technique (accessed August 5, 2019)
[24] Singer T, & Lamm C (2009). "The social neuroscience of empathy." *Annals of* the New York Academy of Sciences, 1156, 81-96.
[25] Eddy, Martha. "A Brief History of Somatic Practices and Dance: historical Development of the Field of Somatic Education and Its Relationship to Dance." Journal of Dance and Somatic Practices Journal of Dance and Somatic Practices 1, no. 1 (2009): 5-27.
[26] Ogden, Pat, and Kekuni Minton. "Sensorimotor psychotherapy: One method for processing traumatic memory." *Traumatology* 6, no. 3 (2000): 149.
[27] van der Kolk 2014
[28] Payne, P., Levine, P.A. and Crane-Godreau, M.A., 2015. "Somatic experiencing: using interoception and proprioception as core elements of trauma therapy." Frontiers in psychology, 6.
[29] Rolf, Ida P. Rolfing: Reestablishing the natural alignment and structural integration of the human body for vitality and well-being. Inner Traditions/Bear & Co, 1989.
[30] Rywerant, Yochanan, and Moshé Feldenkrais. *The Feldenkrais method: Teaching by handling*. Basic Health Publications, Inc., 2003.
[31] Harer, John B., and Sharon Munden. The Alexander technique resource book: a *reference guide*. Scarecrow Press, 2008.
[32] Rix, Roxane. "Alba Emoting: A Preliminary Experiment with Emotional Effector Patterns." *Theatre Topics* 3, no. 2 (1993): 139-145.
[33] Schechner, Richard. "Rasaesthetics." *TDR/The Drama Review* 45, no. 3 (2001): 27-50.
[34] Adler, Janet. Offering from the conscious body: The discipline of authentic *movement*. Inner Traditions/Bear & Co, 2002.
[35] Hartley, Linda. Wisdom of the body moving: An introduction to body-mind *centering*. North Atlantic Books, 1995.
[36] Hackney, Peggy. Making connections: Total body integration through Bartenieff fundamentals. Routledge, 2003.
[37] Groff, Ed. "Laban movement analysis: Charting the ineffable domain of human movement." Journal of Physical Education, Recreation & Dance 66, no. 2 (1995): 27-30.
[38] http://www.biopac.com (accessed August 5, 2019)
[39] Chu, Chi-Cheng P., Tushar H. Dani, and Rajit Gadh. "Multi-sensory user interface for a virtual-reality- based computeraided design system." *Computer-Aided Design* 29, no. 10 (1997): 709-725.
[40] Dani, Tushar H., and Rajit Gadh. "Creation of concept shape designs via a virtual reality interface." *Computer-Aided Design* 29, no. 8 (1997): 555-563.
[41] Nowak, Kristine L., and Frank Biocca. "The effect of the agency and anthropomorphism on users' sense of telepresence, copresence, and social presence in virtual environments." Presence: Teleoperators and Virtual Environments 12, no. 5 (2003): 481-494.
[42] Västfjäll, Daniel. "The subjective sense of presence, emotion recognition, and experienced emotions in auditory virtual environments." CyberPsychology & Behavior 6, no. 2 (2003): 181-188.
[43] Takatalo, Jari, Göte Nyman, and Leif Laaksonen. "Components of human experience in virtual environments." Computers in Human Behavior 24, no. 1 (2008): 1-15.
[44] http://www.cycling74.com (accessed March 27, 2019)
[45] https://supercollider.github.io/ (accessed March 27, 2019)
[46] http://www.raspberrypi.org (accessed March 27, 2019)
[47] http://ndstudiolab.com/(accessed August 5, 2019)
[48] https://www.pjrc.com/teensy/ (accessed March 27, 2019)
[49] https://www.pjrc.com/teensy/td_libs_Audio.html (accessed March 27, 2019)
[50] https://www.biopac.com/product/acqknowledge-software/ (accessed March 27, 2019)
[51] Agrafioti, Foteini, Dimitris Hatzinakos, and Adam K. Anderson. "ECG pattern analysis for emotion detection." IEEE Transactions on Affective Computing 3, no. 1 (2012): 102-115.
[52] Haddadi, Rachid, Elhassane Abdelmounim, Mustapha El Hanine, and Abdelaziz Belaguid. "Discrete wavelet transform based algorithm for recognition of QRS complexes." In 2014 International Conference on Multimedia Computing and Systems (ICMCS), pp. 375-379. IEEE, 2014.
[53] http://www.wekinator.org/ (accessed August 5, 2019)
[54] http://www.ndstudiolab.com/meci (accessed August 5, 2019)
[55] https://motu.com/products/motuaudio/ultralite-mk3 (accessed August 5, 2019)
[56] http://www.mdhosale.com/burnish/ (accessed August 5, 2019)
[57] Batdorf, E., S. Bartos, M.D. Hosale, I. Garrett, I.Dewi, Burnish, An interactive performance installation 56th Venice Biennale Official Collateral Events, with Nine Dragon Heads, May 6 -10, 2015.
[58] Batdorf, E., S. Bartos, M.D. Hosale, I. Garrett, I.Dewi, Burnish, An interactive performance installation, Theatre Centre, Toronto, May 15-22, 2015.
[59] Batdorf, E., M.D. Hosale, Burnish, An interactive performance installation Summerworks Festival, Toronto, August 2016.
[60] Batdorf, E., M.D. Hosale, Burnish, An interactive performance installation Santa Barbara Center for Art, Science, and Techn*ology*, Santa Barbara, California, December 2016.
[61] Batdorf, E., M.D. Hosale, *Burnish*, An interactive performance installation *Currents Festival*, Santa Fe, New Mexico, June 2017.
[62] http://www.batdorf.org/the-red-horse-is-leaving (accessed August 5, 2019)
[63] Haddadi, R., Abdelmounim, E., El Hanine, M., & Belaguid, A. (2014, April). Discrete wavelet transform based algorithm for recognition of QRS complexes. In 2014 International Conference on Multimedia Computing and Systems (ICMCS) (pp. 375-379). IEEE.
[64] https://medium.com/@andrewtan_36013/electrocardiograms-qrs-detection-using-wavelet-analysis-a1070505efee
[65] Agrafioti, F., Hatzinakos, D., & Anderson, A. K. (2011). ECG pattern analysis for emotion detection. *IEEE Transactions on Affective Computing*, *3*(1), 102-115.
[66] Cheng, Z., Shu, L., Xie, J., & Chen, C. P. (2017, December). A novel ECG-based real-time detection method of negative emotions in wearable applications. In 2017 International Conference on Security, Pattern Analysis, and Cybernetics *(SPAC)* (pp. 296-301). IEEE.
[67] http://summerworks.ca/artists/the-red-horse-is-leaving/ (accessed August 5, 2019)
[68] https://workmanarts.com/event/red-horse-oct-17/ (accessed August 5, 2019)
[69] http://thebanggroup.com/wet.php (accessed August 5, 2019)
[70] https://www.simurghproject.org (accessed August 5, 2019)
[71] https://alanmacy.com/project/hand-to-heart/ (accessed August 5, 2019)
[72] https://www.fitbit.com (accessed March 27, 2019)
[73] https://www.cnn.com/2019/03/16/health/apple-watch-heart-rate-arrhythmia-afib-study/index.html (accessed March 27, 2019)