Heart Calligraphy: an Abstract Portrait Inside the Body

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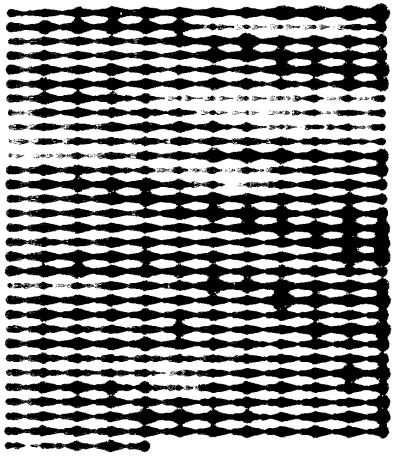

Figure 1: One Drawing by Heart Calligraphy (Pen pressure mapping, Rollerball pen, Inkjet paper)

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Abstract
Heart Calligraphy is a biofeedback installation that creates abstract portraits of participants with their heartbeat data using a pen plotter. The real-time heart rate is mapped to the basic parameters of the pen's behaviors, namely speed, position, pressure and pen-down time. Due to the natural variability in heart rate, every portrait becomes personal and unique graphic, which reflects the natural biorhythm inside human body. The installation explores the role of the body as a channel through which physiology manifests itself in a form of beauty.

Author Keywords
Biofeedback, heart rate variability, artistic visualization, pen plotter

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

Introduction
When experiencing excitement or fear, we feel our hearts beat faster. However, the heart is continually changing the frequency of its beat without us being aware of it. Biofeedback is a technique that measures the physiological processes, and then rapidly 'gives back' the data to the users helping them be aware of

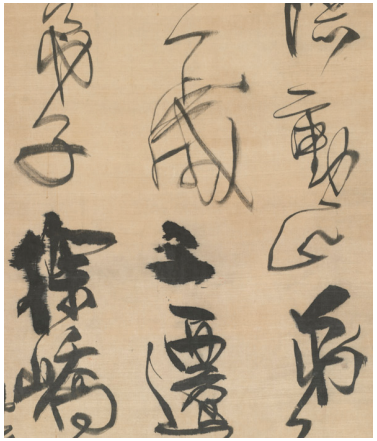

Figure 2: Wang Duo (Chinese, 1592–1652). Free Copy of Xu Jiaozhi's Calligraphy in semicursive script, dated 1635.

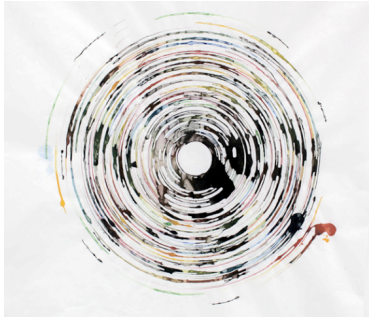

Figure 3: The Spiral painting of Metaphone [7]

their physiological conditions and promote self-regulation on their physiology [1]. In addition to external factors, our physiology is subject to many internal influences such as hormones, breathing patterns and mental states. For example, the heart rate is always influenced by the "fight" and "rest" responses of Autonomic Nervous System [2]. Heart Calligraphy is a participatory live-art installation, which offers the audience a biofeedback experience through the mechanical movement, sound, and artistic visualization.

Heart Calligraphy collects heart rate data from participants and transforms the data into the pen movements creating a unique calligraphy or drawing from the heart. We draw inspiration from Chinese calligraphy. In traditional Chinese culture, calligraphy, like a mirror, is a silent reflection of the mind. In the Han Dynasty, a scholar names Yang Hsiung[1] stated that "Scripts are the Mind Image" [3]. Today, some artists even state that Chinese calligraphy is "the electrocardiogram of the human spirits". A Chinese calligrapher's goal is to vividly and honestly convey his or her mind. This is the reason that the masters often emphasize that "the mind always leads the brush". Once the brush movement hesitates, a black mark is created.

Through this project, we follow a similar idea that " let the heart lead the brush", where each heartbeat triggers one movement, creating a line or a dot. The variation of heart rate is demonstrated by pen's behaviors in real time and the overall heart rate variability (HRV) information is reflected by the visual characteristics of the generated drawings on paper.

[1] http://www.iep.utm.edu/yangxion/

Besides, we are also curious to see how the working of a machine (plotter) could shape a form of biofeedback. As a biofeedback display, we also want to explore how an interactive experience could structure the participant's awareness and exploration of heart rate variability as a psycho-physiological phenomena.

Biofeedback Displays

In essence, biofeedback system is a real-time interactive system; where the input is measured from users' body (bio), and the output is the information (feedback) about their body (bio). Users interact with the system by manipulating their psycho-physiological activities. Biofeedback is not just about presentation of the bio-data; it offers the users a mediated experience of their internal physiological processes. To enhance this experience, many researchers have developed multi-model interfaces beyond a screen-based display. *Sonic Cradle* [4] is designed for a respiration biofeedback meditation practice. It provides an immersive experience where the user is suspended in darkness, controlling sound through the regulation of his respiration. *Cardiomorphologies* [5] is a physiologically responsive artwork, which presents participant's breath and heart rates through a large mandala-like video projection and real-time sonification. It offers the participants a new way of observing and experiencing subtle changes in the body state.

In another direction, some artists and designers who are inspired by the dynamic process inside body, devoted to creating artworks with bio-data. Some of them investigated artistic visualization of biofeedback information by way of "drawing" and "sculpting" data. For instance in [6], the authors proposed a biofeedback system which helps elderly people learn to become

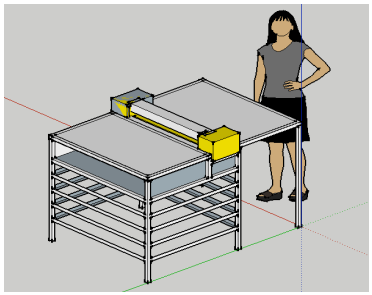

Figure 4: The sketch of the installation

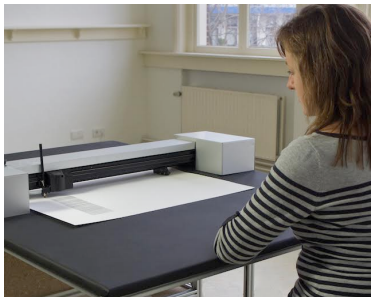

Figure 5: The participants interacting with Heart Calligraphy

aware of their physical state and influence it into a healthier direction. This information is presented to the user as individual artwork (a digital painting), which is created from the measured biosignals and the position of a cursor. *Metaphone* [7] is an interactive installation that transforms the participant's bio-data into colors resulting in aquarelle paintings, as shown in Figure 3.

As a biofeedback display, it is important to balance the clarity of information and artistic/aesthetics expression. In our project, we use a pen plotter both as an interface and as part of a greater 'machinic' system, which can not only provide immediate feedback by its drawing 'behaviors', but also create a calligraphy/drawing as a delayed feedback. The plotter works on the Hewlett-Packard Graphics Language (HPGL-format) commands, which ensures that it can be controlled immediately and accurately. And the effect of actual ink touching paper allows deviations from the visualization in the program, which would contribute to the aesthetics of the graphics on the paper.

Heart Calligraphy

Implementation

Heart Calligraphy consists of a pulse sensor with *Arduino* board for the measurement of heart rate data, a pen plotter and a program based on *Processing* for plotter control. The sketch of the installation is shown in Figure 4. The plotter is integrated into a metal stand. The paper is placed on the plotter's flatbed, which covered with synthetic leather. The pulse sensor is integrated into the flatbed with a 3D printed plastic clip. The participant places the finger into the clip and rests the hand on the table.

A *Processing* sketch is developed to receive the Blood Volume Pulse (BVP) signal measured from the pulse sensor. The BVP signal is filtered by a 3th order Butterworth low pass filter with a cut-off frequency of 2Hz, then the peak of signal (pulse peak) was detected. Each time the system detects a pulse peak value it saves the time accordingly. Then the time difference between two peaks is saved as Inter Beat Interval (IBI). Here, we do not go deep into data analysis; instead, the IBI data is coupled to the parameters of pen's movements in HPGL-format commands. Then through a serial (RS-232C) port, the commands are transmitted to the pen plotter, controlling the pen acting on the surface of the paper.

Mapping Design

During the writing of Chinese calligraphy, it stresses the speed, strength and agility; one example is shown in Figure 2. The variations in strokes are mainly determined by the method of using brushes; for example, the pressure determines the thickness of lines, and the speed influences the texture. The drawing process of Heart Calligraphy follows the similar "pen's action control" drawing process. It involves two transforming processes: from IBI data to the pen movements and from the pen movements to the strokes on the paper. This gives the plotter a good controllability of data representation but also a flexibility and versatility to render the visualization artistically.

As a preliminary exploration with pen plotter, in the design of Heart Calligraphy, we do not intend to draw sophisticated graphics. Instead, we make the plotter draw the basic elements in Chinese calligraphy, namely lines and dots. In this study, four mapping methods

Figure 6: The "input" and "output" of Heart Calligraphy

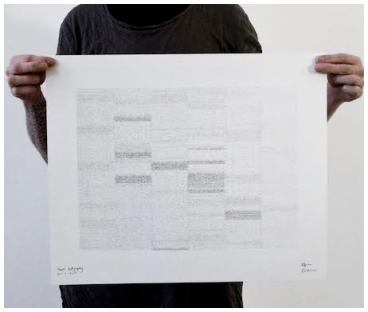

Figure 7: The drawing on a paper of A3 size

have been implemented to discover the possibilities of interaction and the aesthetic impact: (1) position of the pen, (2) pressure of the pen, (3) speed of the pen and (4) the time of pen down. Besides, we experimented with different types of pens and papers such as fiber-tip pen (i.e. black marker), rotring pen, brush pen, tilt-tip brush pen, rollerball pen and charcoal.

Interaction

Heart Calligraphy invites participants to explore how their heart rate increases and decreases through the regulation of their psycho-physiological activities. The participants are introduced to Heart Calligraphy and asked to put on the pulse sensor on the finger. They receive a short introduction on how they can influence the pen's movement by breathing regulation, relaxation and mental/emotional focus. Then we turn on the plotter and left the participant alone. The plotter starts to draw graphics on the paper, as shown in Figure 6. To make the interaction immediate and transparent, we implement a heartbeat-triggered interactive mode for the installation, where the pen will act upon each individual heartbeat, and the IBI data will 'modulate' the pen's movements.

Generated Drawings

During about 10 minutes interaction, as the participant watches and reacts to the installation, his/her physical movements, breathing, and even emotion changes influence the pen's movements and finally reflected on the resulting drawings. Each drawing was created on A4 size paper as shown in figure 7. And based on different mappings, the strokes were drawn in rows or columns.

Figure 8 to 13 show a set of drawings. The drawings feature the rhythm of heart rate variability, indicated by the changes on the length, thickness, and shape of lines or the size of dots. Especially when participants were managing to relax and regulate their breathing into a slow and smooth pattern, the visual characteristics of the drawing might be obvious.

Figure 1, 8 and 9 show the drawings that were produced by mapping from IBI data to pressure of the pen. The drawing in figure 8 was produced on white paper with a rollerball marker. The pen drew lines of equal length in rows but the pen pressure was adjusted according to the updated IBI data. The main visual characteristic of this drawing is a repeating size change of dots that mirror the natural oscillation of heart rate caused by deep breathing.

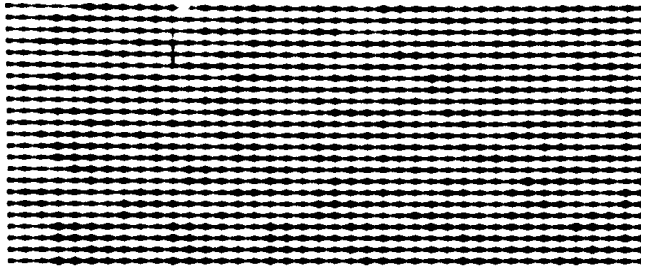

Figure 8: The drawing by pressure-mapping (Rollerball pen)

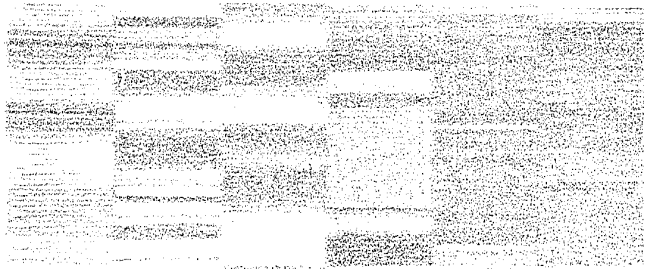

Figure 9: The drawing pen pressure-mapping (Charcoal)

Similar to figure 8, the drawing in figure 9 was also produced by pressure mapping, but with a charcoal. The drawing shows large grey blocks different in size and shade.

Figures 10 and 11 show the drawings that were produced by mapping the data to the position of the pen, resulting in lines of different length. The drawing in figure 10 was created with brush and inkjet ink. The pen was put down on the paper at each heartbeat and drew a line with a new length. Compared to figure 10, in drawing of figure 11, there was a equal-length space between adjacent lines.

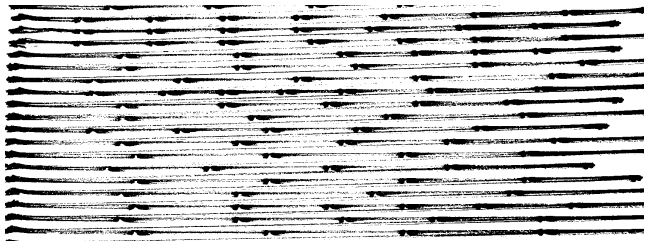

Figure 10: The drawing by position-mapping (Brush)

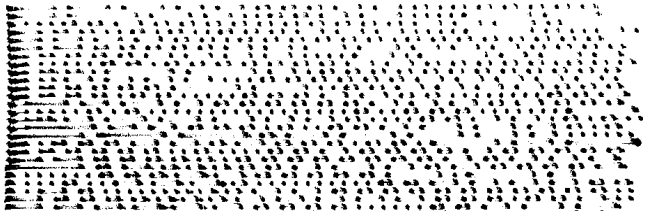

Figure 11: The drawing by position-mapping (Brush)

The figure 12 shows the drawing of speed mapping. The speed of pen movement is adjusted by IBI data. Compared to other works, in this drawing, the thickness and texture of lines seems to have more complicated detailed change. The fast movement results in a thin pale line. If the space between lines is reduced, the lines could form an area with a transition of texture.

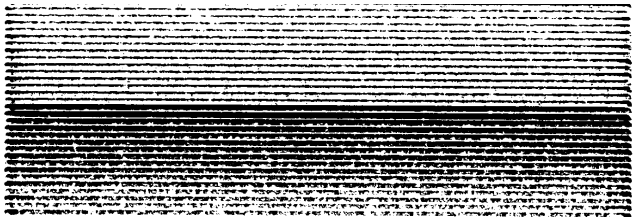

Figure 12: The drawing by speed-mapping (Brush)

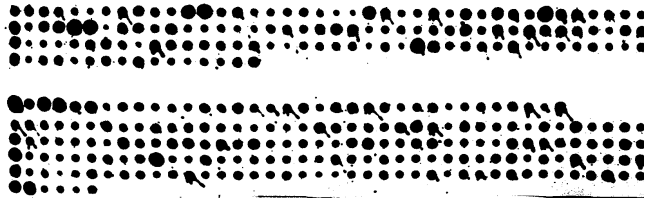

Figure 13: The drawing by pen-down time mapping (Pipet)

The figure 13 features round ink spots in different size. It was generated by a pipet with inkjet ink. The ink spots result from the pen staying on the paper for a relatively long time. At each heartbeat, the pen was moved to next location and placed on the paper. The pen-down time was determined by IBI data. The slower heart rate is, for a longer time the pen would be touching the paper, leaving a larger spot.

Discussion and Future work

Through Heart Calligraphy, we explored the aesthetics/ artistic visualization of heart rate variability in the context of biofeedback. As shown in above figures, four basic mapping methods have been explored. We found that the pen plotter has a great, untapped potential as

an interactive visualization tool. In term of information clarity, the details of data can be clearly expressed by using length-mapping visualization. The pressure mapping and speed mapping mainly influence the thickness and texture of each single stroke and visualize the overall results. The pen-down timing control results in various spots of different size at different location. This enriches the artistic expressiveness of the plotter. From another direction, Heart Calligraphy is part of an interactive arts installation exploring bio-data as materials in art creation. It created a new artistic form of "inside out".

As a HRV biofeedback display, Heart Calligraphy present feedback in a physically based audiovisual modality. It enables the participants to be aware of the natural oscillation in the heart rate through mechanical movement, sound, and visualization. It leaves the participants much space to explore how activities and psychology influence his or her physiology. These explorations contribute to their self-awareness and self-regulation on their physiology– for instance when we realize the impact of stress/relaxation and breathing on the heartbeat. Besides, we think the multi-modal feedback of Heart Calligraphy offers an enriched the participatory user experience. Some audience even reported a relaxing atmosphere induced by the plotter while listening to the machine responds to their heartbeat.

In the future, it will be interesting to explore more graphic patterns of drawings as the output and to introduce more bio-signals as the input, such as breathing signal and Galvanic skin resistance (GSR). We would also like to find out that what experience of the participant received during the interaction could contribute to a biofeedback practice.

Acknowledgements

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TEI 16

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TEI'16 Chairs' Welcome

Welcome to ACM TEI'16, the 10th-anniversary edition of the International Conference on Tangible, Embedded and Embodied Interaction, hosted at Eindhoven University of Technology, the Netherlands from February 14th to February 17th, 2016.

This year's conference marks TEI's tenth anniversary. We see this as a perfect opportunity for recalling some of our founding values and complementing these with contemporary values, for reemphasizing the relationship between interactive products and systems and the body, and for learning from each other's approaches and rationales. To do this, we have established the theme '**Our Body Is Our Manual**': As the interactions we propose in our products and systems are aimed to inform our embodied selves, we should also allow ourselves to be informed by our bodies when designing and researching these interactions. Through a wide palette of work ranging from highly technical to highly artistic, and from highly applied to highly conceptual or theoretical, we wish to trigger discussion and reflection, with the aim of emphasizing what binds us.

TEI'16 hosts a four-day program, starting out with the **Graduate Student Consortium** and a series of **Studio-Workshops** that embody the essence of our community by offering intellectual and practical experiences to conference attendees with diverse skills and backgrounds. The main program is kicked off by **Takeo Igarashi**, who in his opening keynote discusses computer tools that allow end users control over the design of artifacts in their lives. After the opening keynote, the Papers track commences, in a slightly different set up than before. This year we do not include Q&As in the presentations but instead wrap up each session with a reflective discussion between the presenters. The day concludes with the **Demos, Posters** and **Work-In-Progress** exhibition. From day two until day four the **Art Exhibition** questions and frames the impact of new technologies on our lives and proposes new modes of embodiment. Following day three's Papers sessions we host a full afternoon of **Studio-Workshops**, engaging all TEI attendees in active, hands-on discussions. Day four includes three Papers sessions, a lunch lecture and panel discussion, and the closing keynote by **Tom Djajadiningrat**, who reconsiders tangible interaction by discussing new technologies, illustrated through examples by Philips Design.

This year we received 178 submissions to the Papers track, which were all equally subjected to a double-blind peer review process of at least three reviewers and a meta-reviewer. A total of 45 accepted papers makes for an acceptance rate of 25%. For the Work-in-Progress track we received 100 submissions, which were subjected to a double-blind peer review process of two reviewers each. This resulted in 40 accepted submissions, making for an acceptance rate of 40%.

Of course, organizing this conference could not have been possible without the energy and commitment of many, many people. We would like to thank everyone who contributed to TEI'16: the authors for submitting their quality work to the conference, all the organizing committee chairs for managing their part of the conference, the program committee and external reviewers for safeguarding the quality of the conference, the local organizing committee, the sponsors, supporters and partners, and the TEI steering committee.

We wish you a great conference!

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