Towards the BioFeedback Game

--- with Interoception and Rehabilitation ---

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***Abstract*—This paper reports some experimental developments of serious games with bio-sensing system and multimedia environments. The key idea is the biofeedback system with a combination of interoception and rehabilitation. In the area of rehabilitation therapy, it has been attracting attention that the client themself recovers better on a voluntary basis by the biofeedback technique. I have been developing some bio-sensing / bio-feedback systems with sketching (physical computing) technique and multimedia art. I will report on some cases which can be seen as the serious games in rehabilitation in cooperating with specialists in the medical field.**

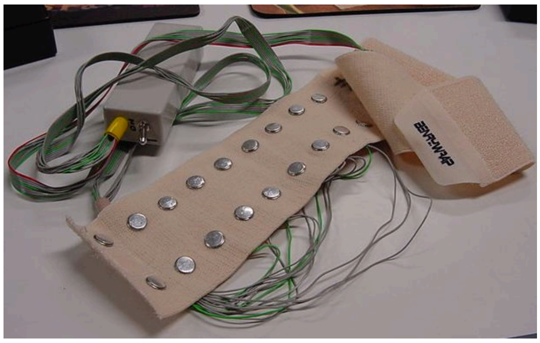
Keywords—biofeedback; bio-sensing; interoception; rehabilitation;

I. INTRODUCTION

As a composer of computer music, the author has been developing many new musical instruments as a part of his composition. Inspired by the BioMuse [1] developed by Atau Tanaka (Figure 1), three generations of EMG sensors were developed - called the "MiniBioMuse" series. The 1st "MiniBioMuse-I" was a single channel EMG sensor with both outputs: MIDI sensor and raw EMG sound [2-3]. The 2nd "MiniBioMuse-II" was a two channel EMG sensor for wrist electrodes with both outputs: MIDI sensor and raw EMG sound [4-7].

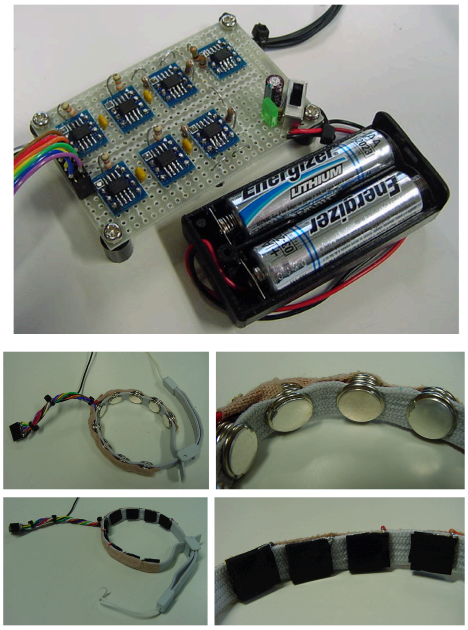
1. Atau Tanaka performs the "BioMuse".

The 3rd "MiniBioMuse-III" was a double eight channel EMG sensor for near the elbow electrodes with both outputs: MIDI sensor and raw EMG sound [8-14] (Figure 2).



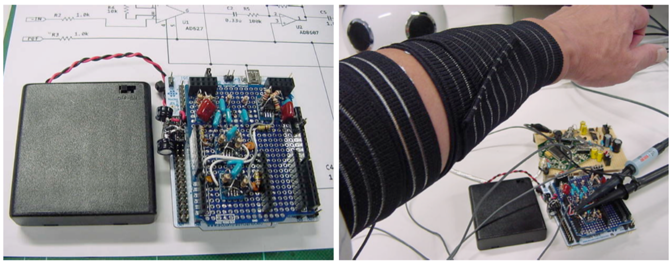
2. New EMG Instruments "MiniBioMuse-III".

The 4th generation of EMG sensor was not developed as a musical instrument. It was developed as a gesture sensor of the palm and fingers based on an offer from a game-related company. The sensing circuit was improved by new front-end IC "AD627", and two types of electrodes were tested - silver plate and the conductive rubber (Figure 3). The gesture recognition algorithm with this sensor [15] will be described at section 3.



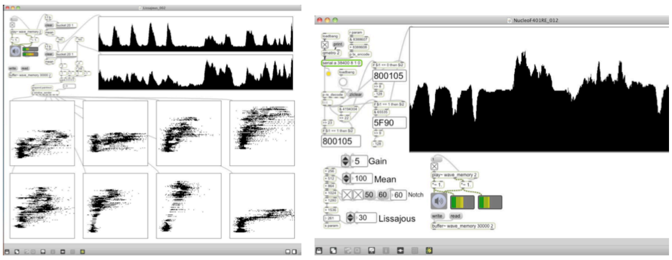
3. The 4th EMG sensor and electrodes bands.

Recently, in collaboration with medical specialists in the field of rehabilitation, we aim to develop / research the applications of bio-sensing techniques. For example, Figure 4 shows the newest (5th generation) EMG sensor system that we developed [16]. To avoid noise, this system contains the WiFi (XBee) interface.



4. The 5th EMG sensor system with WiFi interface.

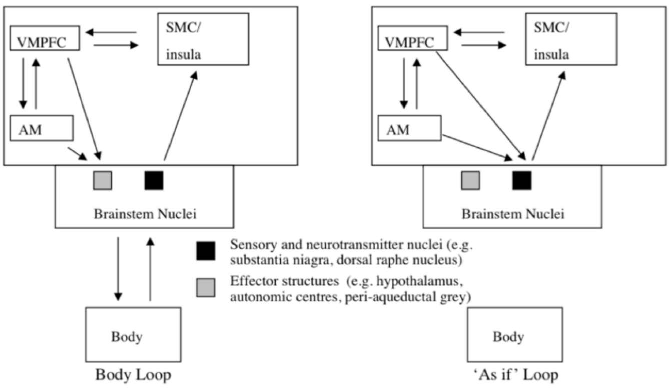
In addition, the new algorithm called "Lissajous Analysis" was developed which works efficiently to extract features in a small amount of processing (Figure 5).



5. Testing the "Lissajous Analysis".

II. SMH AND INTEROCEPTION

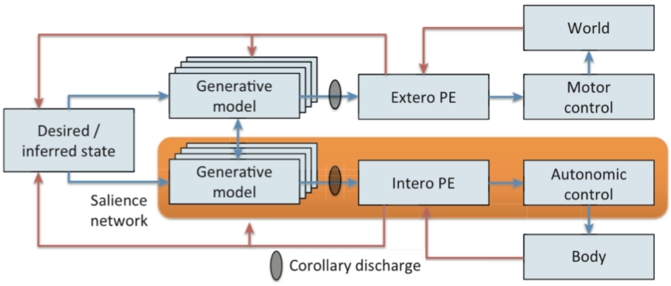
Damasio proposed the "Somatic Marker Hypothesis" in brain science with the "as if loop" for the fast response in the brain (Figure 6) [17-21]. The "Somatic Marker Hypothesis" is pointed out to be the background of affective decision-making [22], or to be the background of interoception and emotion [23]. The interoceptive is a contrasting concept to the external senses (five senses). Each external sense has a specialized sensory organ. However, the interoception is organized from internal organs and the nervous system.



6. The somatic marker hypothesis and the "as if" loop.

As Figure 7 shows, Seth et al. proposed the interoception and biofeedback model as the background of the decision-making and feeling/emotion [24-25]. For example, the origin of the exciting or dynamic emotion is from endocrine substances and hormones which is the result of human activity. The reaction time from this chemical object is long, but the "as if loop" works quickly as a short-cut in the brain. The differences between the result of the "as if loop" and the real result from the chemical response route are real-time compared, and the prediction model is adjusted in real-time. With this bio-feedback mechanism, the "adjusted difference" occurs in emotion and in decision-making.

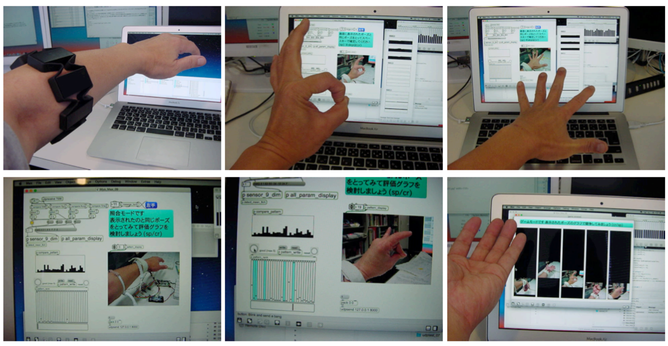
As Nacke et al. pointed out, bio-feedback is very important in the interaction design field [26]. There are many reports and papers on this topic, and I also reported on a EMG biofeedback game with gesture recognition system [27-28]. The subjects in the experiment do not know how to control/trim the muscle to replay the gesture with EMG sensors - this is of the interoception. However, most of the subjects can exercise subtle control to realize the past-recorded gesture by unconscious trial and error [15]. When the replay is successful by the bio-feedback graphical report, all the subjects feel happy/relax and positive emotions. I will introduce some experimental results with BioFeedback systems as a test-case of the serious game in this paper.



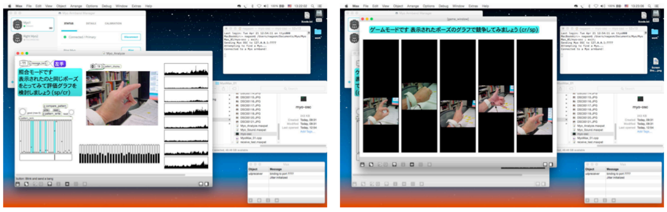
7. Seth's interoception and bio-feedback system.

III. THE MYO GESTURE RECOGNITION SYSTEM

In 2015, the smart biosensor system "Myo" appeared. It has 8 channels of EMG, 3-d direction sensors, 3-d gyro sensors and 3-d acceleration sensors. The interface with the host is Bluetooth, so it is very easy to use. The author developed the specially arranged system of "Myo" to detect the gestures of the palm by the "Lissajous Analysis" algorithm. Figure 8/9 shows the experiment with the subject, with three steps - (1) pattern registration step, (2) pattern reproduction and matching step, and (3) pattern controlling game step. Interestingly, the final "pattern controlling" stage is very affective in noticing "unconscious herself/himself". Everyone can enjoy extending the graph by a subtle adjustment of the unconscious.



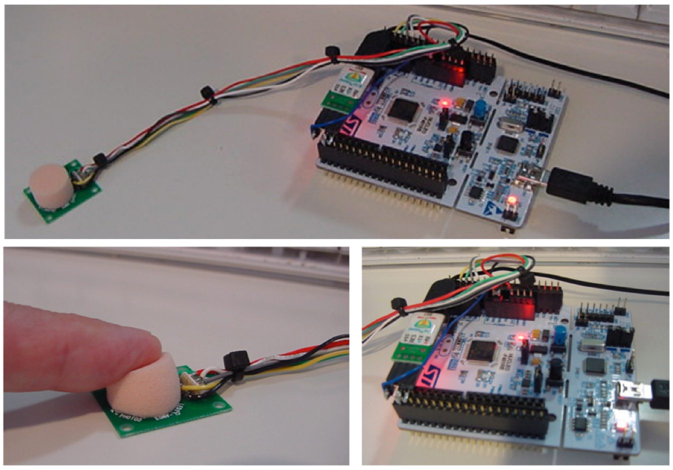
8. The "Myo" gesture pattern recognition/game system. (1)



9. The "Myo" gesture pattern recognition/game system. (2)

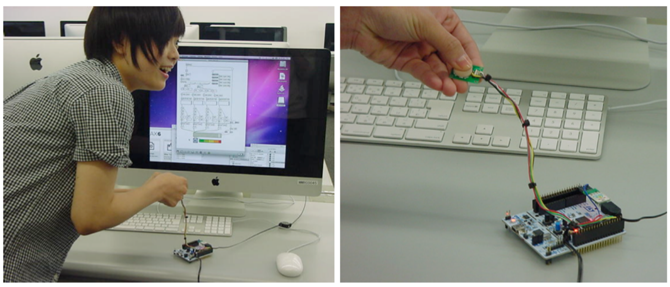
IV. The Tactile Interface

Even though not dealing the direct bio-signals, the tactile sensor is very interesting / important for human sensing. Of course, the bending / acceleration sensors can detect the human conscious / active behavior. However, a strange tactile sensor - which I introduce here - can detect human delicate / unconscious control. The "RT corporation" in Japan released the "PAW sensor" in 2014. The "PAW sensor" is a small PCB (size 21.5mm * 25.0mm, weight 1.5g) with a large cylinder of urethane foam on it. The output information of this sensor is four channel voltages which is time-shared conversion, which means the nuances of rubbing / touching the urethane foam by fingers.



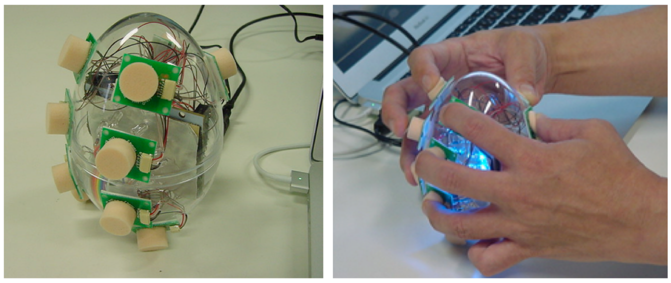
10. The "PAW sensor" and its interface (mbed NucleoF401RE).

At first, the author developed the 1st prototype system using the PAW sensor interface [29-30] (Figure 10), and lent it to my student to produce an installation work whose concept was "sexy touch generates sexy voice". The final work was cute (not sexy) - she produced a fantastic installation work - with her voices in many styles [31] (Figure 11).



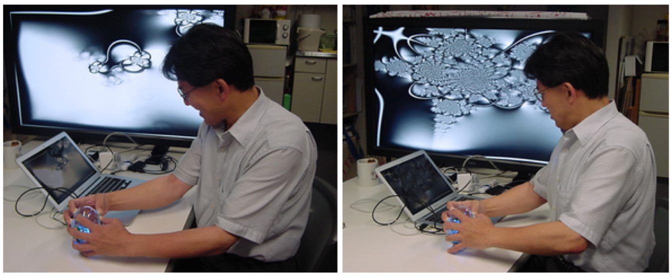
11. Mao Miyamoto's installation work - "touch to voices".

After lending the 1st prototype to the student Mao Miyamoto, I started developing a system to use 10 "PAW sensors" with ten fingers. If all sensors are placed on the same plane like a keyboard, the style of musical performance seems unnatural, because all finger tips must not move like as on a piano or organ. A cube or mechanical shape is also unnatural for the fingers/hands to grasp. Finally I found an egg-shaped plastic container (Figure 12).



12. The new instrument "MRTI2015".

After developing this "MRTI2015" (multi rubbing tactile instrument), I produced a prototype of demo-performance as a multimedia installation work [32-34] (Figure 13). With this system, people can control ten fingers by rubbing tactile action, and a total of 16 parameters from the PAW sensors are realtime mapped - to generate four voices by formant synthesis algorithm and - to generate realtime Open-GL graphics by fractal algorithm.



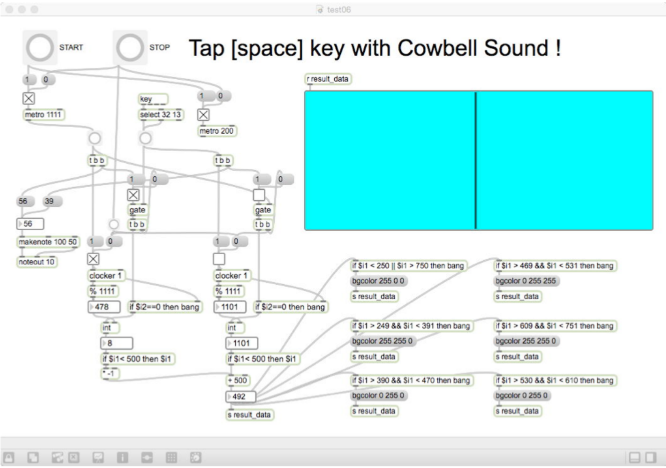
13. Demonstration system for MRTI2015.

This demonstration system for MRTI2015 was opened for two conferences in 2015: Sketching2015 (Arizona) and SI2015 (Singapore). The attendees at the demonstration all enjoyed this system [35-36].

V. Interactive Rhythm Game

I will introduce two topics in this section and next section, but these were not completed as games. Both works are collaboration with my students, and this report is an educational and technological test case.

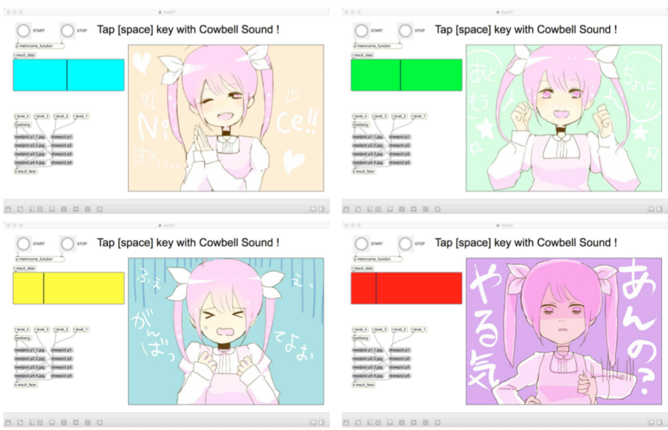
From a collaboration with a biofeedback therapist, I learned about the "Interactive Metronome" [37] which is a game-like exercises system. This is a neuro-motor therapy tool that can be used with all patients across the therapy spectrum due to cognitive and/or physical impairments. However, this system is not well-known in the Japanese therapeutic field and this system is very expensive as medical systems. This era, the sketching (physical computing) and the open-source culture supports developing these multimedia system easily. After some discussions, I developed a new system working just the same as the "Interactive Metronome", with a different name "Interactive Rhythm Game". Figure 14 shows the 1st prototype of the "Interactive Metronome" only with an non-elegant gauge and uninteresting screen design.



14. Prototype of the "Interactive Rhythm Game".

We have many students who are good at drawing pictures. After a discussion with a biofeedback therapist, I requested a student in my seminar to draw pictures of a cute girl who supports the tapping of exercise. She loved drawing cute boys and girls, and finally she easily finished drawing four pictures to display 4 levels of the result in the "Interactive Rhythm Game" (Figure 15).

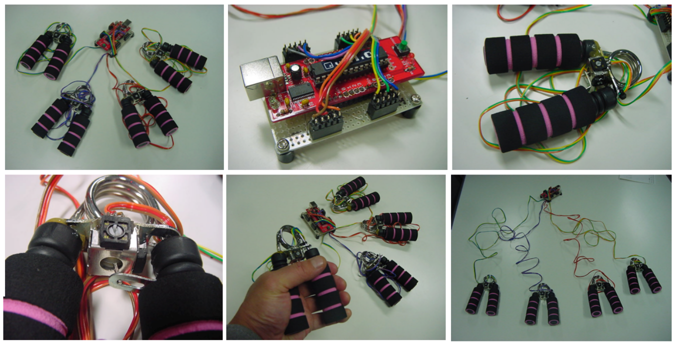
The biofeedback therapist said that this friendly improvement is very effective for the clients/patients and he will test this system in the real field in therapy. This test case shows that collaboration of medical/therapy people and media artists can realize effective bio-feedback systems.



15. The final screenshots of "Interactive Rhythm Game".

VI. Muscles Gymnastics

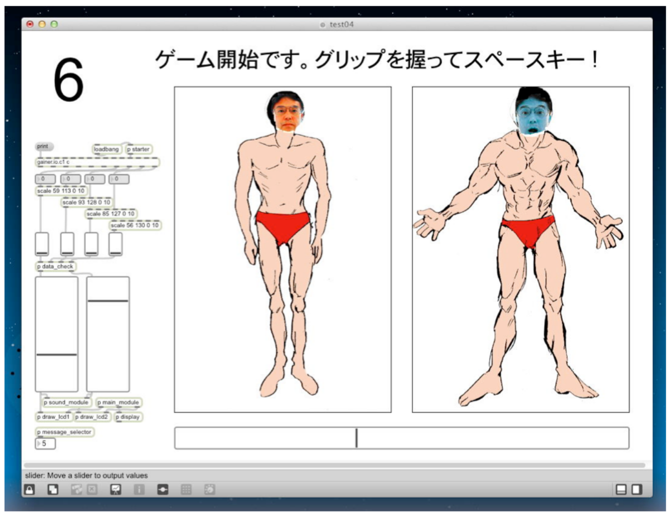
This topic is with "seeds-oriented" design, not with "needs-oriented" design. A few years ago, a student in my seminar developed an interesting interface for muscles / sports (Figure 16). The system has four hand-grips which has a potentiometer to detect the angle of the grip. A total of four outputs of the potentiometers are connected to Gainer which is a universal interface for computers. Originally, this system was designed for a kind of group performance in order to play musical phrases by gripping timing.



16. The 4 channels "hand-grip" interface system.

A few years later, some students and the author developed a new biofeedback game called "Muscles Gymnastics" (Figure 17). At first, the participant captures the face of herself/himself with the webcam. Next, the two participants grip 2 hand-grips in both hands. The game starts by tapping the space key and the pistol sound of the start signal appears, and an image of a whole body appears on the screen. The game duration is only 15 seconds.

When the participant grips the hand-grip many times, the indicator rises on the screen, and the body (whose face is the captured face of the participant) grows into skinny body. In addition, the participant grips the hand-grip more times, the skinny body changes to more macho and brawny body. Finally if the body grows into a perfect body-builder, the result is "Good !". Otherwise if the growing is not completed, the body returns to the original body image after 15 seconds.



17. The screenshot of "Muscles Gymnastics".

At a workshop for doctoral nurses, I presented this system to the attendees. They showed great interes in this system. They commented that the traditional rehabilitation system is boring due to a simple graphical representation, and this game-like system is good to continue. This system is not bio-feedback, but this idea of entertainment will be effective in the designing human interaction systems in rehabilitation field.

VII. CONCLUSION

In this paper, I have reported on some experimental development of serious games with bio-sensing system and multimedia environments. The key idea is the biofeedback system with a combination of interoception and rehabilitation. In the area of rehabilitation therapy, it has been attracting attention because the client themself recovers better on a voluntary basis by the biofeedback technique. My recent interest is the wide meaning of "entertainment". I hope to continue to research the possibility of media arts to expand human emotion and feelings in the field of serious games.

REFERENCES

1. Atau Tanaka, Musical Technical Issues in Using Interactive Instrument Technology with Application to the BioMuse, http://quod.lib.umich.edu/i/icmc/bbp2372.1993.023
2. MiniBioMuse-I demo. http://www.youtube.com/watch?v=n6acfgCrYN4
3. "Brikish Heart Rock" using MiniBioMuse-I. http://www.youtube.com/watch?v=60QeshlDQy4
4. Yoichi Nagashima, BioSensorFusion:New Interfaces for Interactive Multimedia Art, Proceedings of 1998 International Computer Music Conference, International Computer Music Association, 1998
5. Yoichi Nagashima, Real-Time Interactive Performance with Computer Graphics and Computer Music, Proceedings of the 7th IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Man-Machina Systems, International Federation of Automatic Control, 1998
6. "Bio-Cosmic Storm" using MiniBioMuse-II. http://www.youtube.com/watch?v=GMU102byjVc
7. "Bio-Cosmic Storm" using MiniBioMuse-II. http://www.youtube.com/watch?v=_03t6pBhZ9o
8. Yoichi Nagashima, Interactive Multi-Media Performance with Bio-Sensing and Bio-Feedback, Proceedings of International Conference on Audible Display, 2002
9. Yoichi Nagashima, Interactive Multimedia Art with Biological Interfaces, Proceedings of 17th Congress of the International Association of Empirical Aesthetics, 2002
10. Yoichi Nagashima, Bio-Sensing Systems and Bio-Feedback Systems for Interactive Media Arts, Proceedings of 3rd International Conference on New Interfaces for Musical Expression, 2003
11. Yoichi Nagashima, Combined Force Display System of EMG Sensor for Interactive Performance, Proceedings of 2003 International Computer Music Conference, International Computer Music Association, 2003
12. "BioCosmicStorm-II"using MiniBioMuse-III. http://www.youtube.com/watch?v=7dKa4jI2J5w
13. "Wriggle Screamer II"using MiniBioMuse-III. http://www.youtube.com/watch?v=Rd-mPax3hS8
14. "Ural Power" using MiniBioMuse-III. http://www.youtube.com/watch?v=32FLFkgZYKk
15. Gesture recognition experiment with the 4th generation ENG sensor. http://www.youtube.com/watch?v=dgPGZfmboNQ
16. Experiment with the 5th generation ENG sensor. http://www.youtube.com/watch?v=k54kqQHBTvc
17. Antonio R.Damasio. The Feeling of What Happens: Body and Emotion in the Making of Consciousness, Mariner Books,2000
18. Antonio R.Damasio,. Looking for Spinoza: Joy, Sorrow, and the Feeling Brain, Harvest, 2003
19. Antonio R.Damasio. Descartes' Error: Emotion, Reason, and the Human Brain, Penguin Books, 2005
20. Antonio R.Damasio. Self Comes to Mind: Constructing the Conscious Brain, Pantheon, 2010
21. B.D.Dunn, T. Dalgleish, A.D. Lawrence. The somatic marker hypothesis: A critical evaluation, Neuroscience and Biobehavioral Reviews 30 (2006) 239–271
22. Y.Terasawa and S.Umeda. Psychological and neural mechanisms of interoception and emotions, Japanese Psychological Review, 2014,Vol. 57, No.1, 49-66 (in Japanese)
23. H.Ohira. Functional association of brain and body underlying affective decision-making, Japanese Psychological Review, 2014,Vol.57, No.1, 98-123 (in Japanese)
24. Anil K. Seth. Interoceptive inference, emotion, and the embodied self. Trends of Cognitive Science, 17, 565-573. 2013
25. L.F.Barrett and A.B.Satpute. Large-scale brain networks in affective and social neuroscience: towards an integrative functional architecture of the brain, Current Opinion in Neurobiology 2013, 23:1– 12
26. Nacke, L.E. et al. Biofeedback Game Design - Using Direct and Indirect Physiological Control to Enhance Game Interaction. Proceedings of the 2011 Annual Conference on Human Factors in Computing Systems. 103-112. 2011
27. Yoichi Nagashima. EMG Instruments as Controllers of Interoception --- for Healing Entertainment ---, Reports of Japanese Society for Music Perception and Cognition, 2015 (in Japanese)
28. Yoichi Nagashima. A study of interoceptive entertainment with bio-feedback, Proceedings of Entertainment Computing 2015 (in Japanese)
29. 1st test of PAW sensor (1). http://www.youtube.com/watch?v=n7K7x0_2dD8
30. 1st test of PAW sensor (2). http://www.youtube.com/watch?v=Nxiiz5F9TQ0
31. Mao Miyamoto's installation work with the PAW sensor. http://www.youtube.com/watch?v=8rwjmhaiNzs
32. Demo of MRTI2015 (1). http://www.youtube.com/watch?v=LF7KojKRP2Y
33. Demo of MRTI2015 (2). http://www.youtube.com/watch?v=2SD84alrN1A
34. Demo of MRTI2015 (3). http://www.youtube.com/watch?v=FM1Af3TyXNk
35. http://nagasm.org/1106/Sketch2015/Happy.html
36. http://nagasm.org/1106/SI2015/Happy.html
37. http://www.interactivemetronome.com/