In Forgotten Daydreams:
Performing in Biosignal-Generated Visualizations

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ABSTRACT

This research project is a performance in an interactive installation that projects the live human biological signals into narrative visualizations. It aims to cultivate consciousness of the participants to daydream about the unlimited prospects for their bodies and the world.

The objective of this master thesis is to explore the realm of art and technology in mixed realities by combining craftsmanship and narrative visualizations. It aims to unpack an immersive and interactive hybrid space for daydreaming and to influence everyday life experiences.

The supportive theoretical frameworks examine how info visualizations and performance could merge into the immersive and interactive systems and to empower the boundless daydreams of the participants. This thesis project applies the practice-based research methodology with methods of research examining technology and materiality, literature review, case studies, and iterations of prototypes.

The key findings include the sense of proprioception through interactions with this installation, and the duality, positive and negative sides, of narrations in daydreams.

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During the one-year journey to research on and complete my MFA thesis project, I gained countless inspirations, motivations and precious feedback from my supervisors and the whole IAMD cohort. Thank you everyone.

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Last but not least, to my family, my father Yang Cao and mother Hong Luo, thank you for always being my safe haven. Thank you for being along with me during this journey.

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INTRODUCTION

I had so many dreams that I forgot.
I created one of them,
One of the forgotten daydreams.
As I walked, she followed.
She touched me.I ran away.

Daydreams are the undefined time and space in my body. The forgotten daydreams are the stolen imaginations. For thousands of times, I forgot the nightdreams when I woke up, and forgot the daydreams when I was no longer lost in thoughts. These moments were like floating pieces of illusions that I hesitated to acknowledge their existence. And I could not recall them anymore. But they were haunting me, again and again, silently and imperceptibly. The secret bottom of my heart was disclosed by these forgotten daydreams: allure and absurd, tranquil and uneasy, illuminated and shadowy. I tried to capture my vanished nightdreams and fleeting daydreams, even though I knew that they were so illusory that I could scarcely give them forms.

In this thesis project, I reified the immersive experience in daydreams by using human biological signals as the dream activators. The heartbeat, the breath, and the body movement are used to generate an interactive conversation with the forgotten daydreams in the realm of physical and fictional space.

My interdisciplinary approach was to forge the forgotten daydreams by using digital craftsmanship. As a candidate of MFA, I aimed to utilize my multi-disciplinary knowledge to contribute to the bigger field of creative media.

Figure 1: My previous interdisciplinary works (from up to down, left to right): I Need Air. S. Cao Collaboration with Y. Qian. 2017. Don't you see me cry. S. Cao. 2020. Bride Specimen. S. Cao. 2019. Data Visualization of Aviation Flights. S. Cao. 2020.

Chapter two elucidates my thinking process through Literature Review within the theoretical frameworks of Biosignal Visualization, Daydreams for Artists and Participants, Performance in an Immersive and Interactive Setting, and Hybrid Arts in relation to Body, Object, and Mixed Realities.

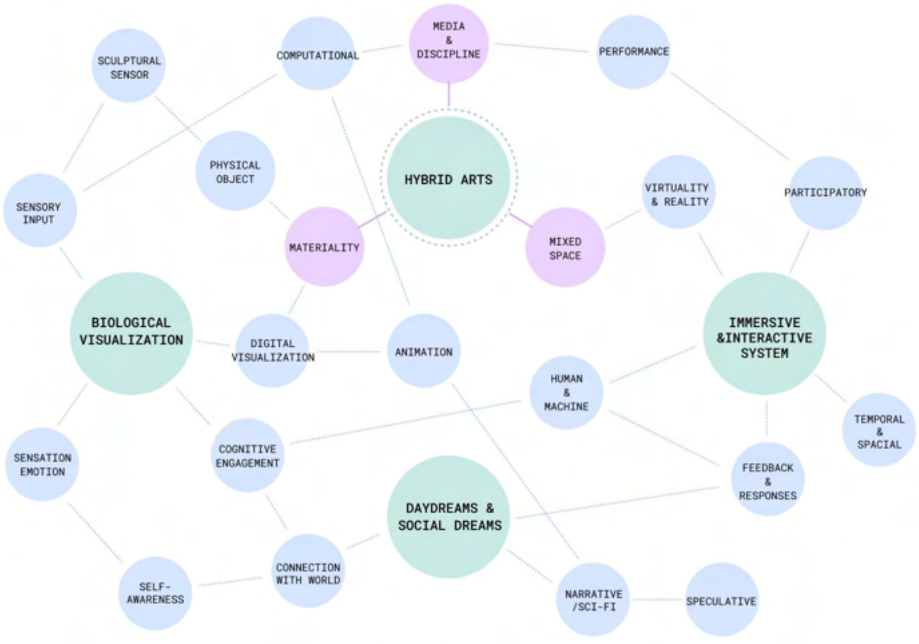

Figure 2: Mind map of the theoretical frameworks. S. Cao. 2020.

In Chapter 3 I explain my research methodology of Practice-based Research as well as the multiple methods including artist research, technology research, materiality research, etc.

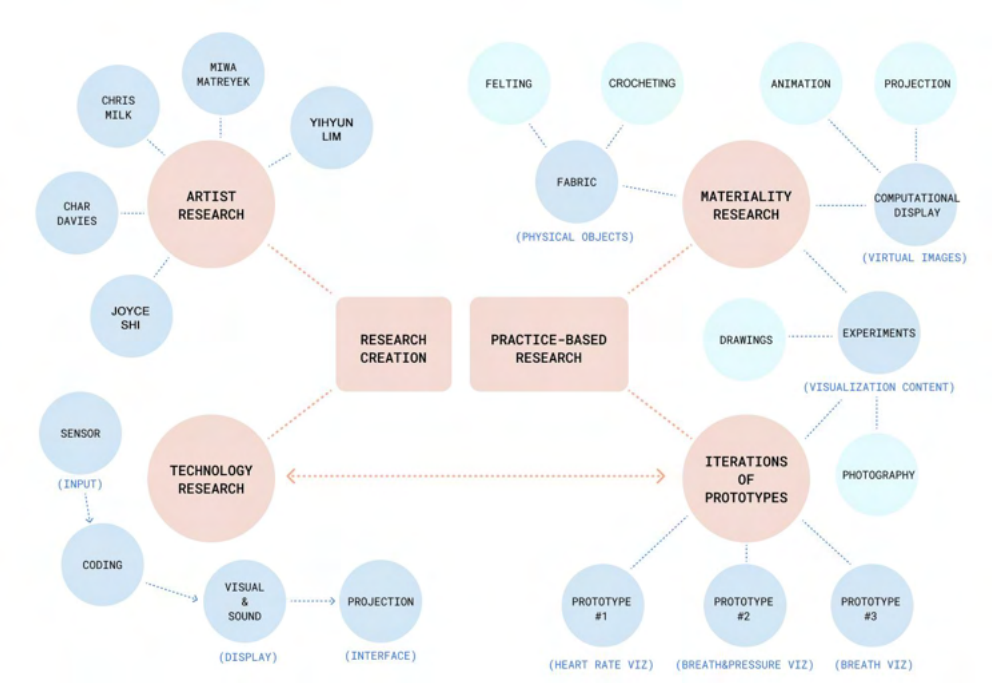

Figure 3: Mind map of the methodology and methods. S. Cao. 2020.

Chapter four documents the prototype iterations and Chapter five presents the final prototype. Last but not least, Chapter six discusses the reflections on this thesis project and the possible future work to be explored further.

My research questions focus on:

How could the use of interdisciplinary approaches effectively form an interactive and immersive space to invite participants experiencing and reflecting on the forgotten daydreams?

How would people respond to the duality (illuminated and shadowy sides) of narrations in daydreams?

While human biological data is often represented as infographics in a medical context, would a narrative way of visualizing engage and provoke people more to think about their bodies?

LITERATURE REVIEW

2.1 Biosignal Visualization

Human biosignal visualization is principal for this project. In this section, Biosignal and Biosensing, context of Data/Info Visualization, and the Rationale of Visualizing Biosignal are discussed.

2.1.1 Biosignal and Biosensing

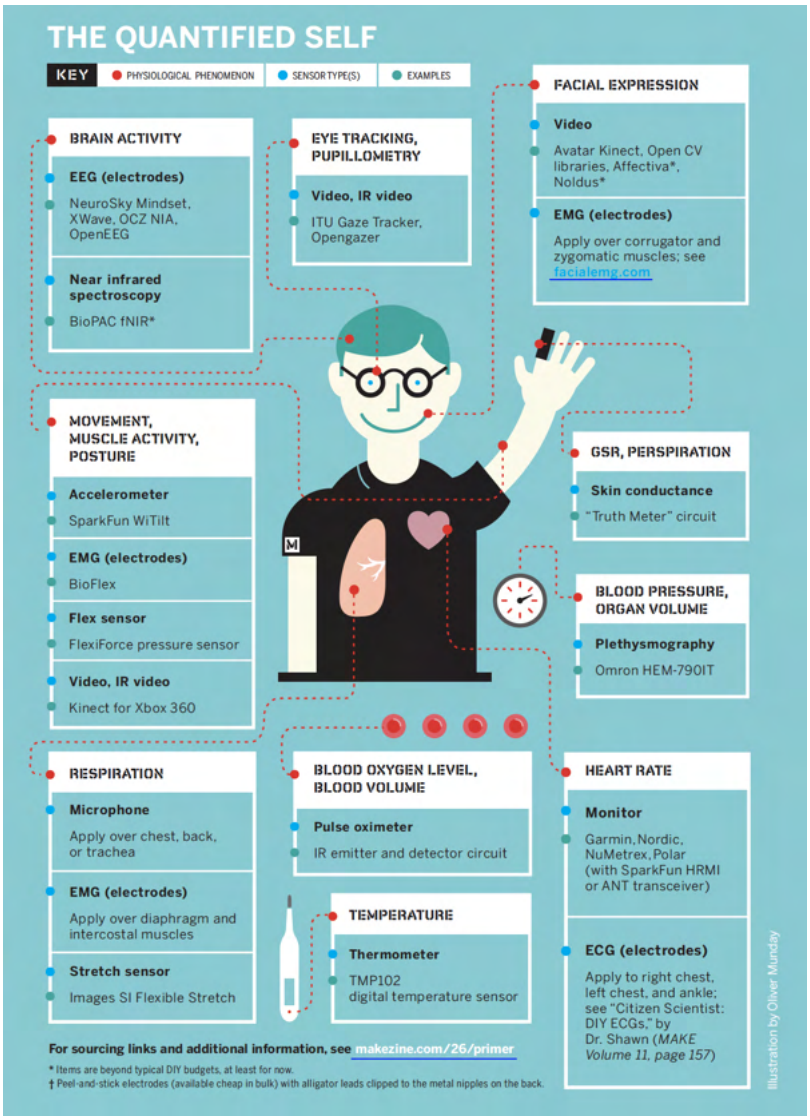

Figure 4: The Quantified Self in Makezine vol.26 pp.104. Illustration by Oliver Munday. 2011.

To understand the data input, it is significant to define the related terminologies.

> **Biosignal** is any signal in living beings that can be continually measured and monitored. The term usually refers to bioelectrical signals, but could also refer to nonelectrical signals (Paul 456). In this thesis project, it particularly refers to the human biosignals such as the heartbeat.
>
> **Biosensing** refers to the detection of biomolecules using an analytical device (i.e., biosensor) that combines a biological component with a physicochemical detector (Sina).
>
> **Biosensors** are analytical devices that convert a biological response into an electrical signal (Mehrotra 153–159).

The bioelectrical signal includes Electroencephalogram (EEG) which is related to brain activity, Electrocardiography (ECG) which is related to heart activity, Electromyography (EMG) which is related to skeletal muscles, and Mechanomyogram (MMG) which detects when muscle is contracted. The non-electrical signal includes Mechanical signals (e.g. the Mechanomyogram or MMG), Acoustic signals (e.g. phonetic and non-phonetic utterances, breathing), Chemical signals (e.g. pH, oxygenation) and Optical signals (e.g. movements) (Singh et al. 175).

In this thesis project, other than biosignal sensors for heart rate (under the category of ECG), I also utilized sensors for detecting body engagement including physical blow breath (under the category of Acoustic signals), and body movements (calculated by pressure).

The use of biosensing and sensors for body engagement has been employed in many fields. For example, the application has been rapidly growing in the medical field, as it is "being used pervasively in the medical field to diagnose infectious diseases" (Mehrotra 153–159). This technology is also applied in the artistic fields because biosensing offers the opportunity for people to interact intuitively with digital systems through biofeedback. People can also share their biosignals within the communities (Montgomery and Laefsky 102).

Since artistic-related practices have been adopting psychophysiological electrical potentials of human subjects, biosignals becomes a strategy to control the creation of interactive content towards adaptive, symbiotic, and immersive experiences. (Aly, et al. 1) However, Miguel Ortiz, a Mexican composer and sound artist, points out that although biosignal sensing in interactive

arts has been applied since the mid 1950's, it remains a relatively little known field of research within the artistic community as compared to other sensing technologies. (Ortiz).
Thus, this thesis project aims to explore the possibilities of using biosensing technology to form a creative interactive media for people to track themselves and to encounter biosignal data stories through artistic visualization.

2.1.2 Data/Info Visualization

Data/Info Visualization refers to the use of interactive visual representations of data or information supported by computational devices to amplify cognition, where cognition is the acquisition or use of knowledge (Card 6). According to Lev Manovich, one of the leading theorists of digital culture, the provisional definition of information visualization is "a mapping between discrete data and a visual representation" in a nutshell (Manovich 2).

There are specific terminologies such as data visualization (dataViz), information visualization (infoViz), scientific visualization, information design, and etc. In this thesis project, dataViz and infoViz are particularly applied. Regardless of certain discrepancies, all visualization types share a similar purpose: to tell the data story and to present the findings. This concept is supported by Isabel Meirelles, an information designer and educator, "whether they serve as a means to communicate stories and research findings or as a platform for data manipulation and exploration" (Meirelles 13).

Visualization is the process of transforming unpacked data or information into packed arrangements, folding and unfolding, to bring it into an ordered, readable, and artistic format.

2.1.3 Rationale of Visualizing Biosignal

- **To make Invisible Visible**

"To visualize is to make certain phenomena and portions of reality visible and understandable; many of these phenomena are not naturally accessible to the bare eye, and many of them are not even of visual nature."

- Costa, Joan 1998

Biosignals are real-time, dynamic and imperceptible under the skin. Thus to visualize the body data is to translate the invisible to the visible, and to bring the seemingly isolated data into a more connected system.

To manipulate the data and create data-driven prototypes, the first step is to gather and quantify the data/info into objective numbers. Once the data are collected, the next step is to transform the biosignal input into visual representations, and to deliver the data story to the audience.

Using visualization as a tool is to record information, to convey meaning, to support perceptual inference, and to provide models of actual and theoretical worlds (Meirelles 13). By utilizing biosignal visualizations to provide prototypes of theoretical and imaginary worlds in this thesis project, I aimed to create space for the audience to experience the unlimited possibilities of phantasmic vision of their bio signals. And similarly to Alberto Cairo's point of view that "data are records of observations; data can be encoded as symbols (numbers and words) that describe and represent reality" (16), the visualization of biosignal is not to illustrate "what's there", but to picture the "what-if" scenarios within the human body by using "what's there". In this project, I applied illustrative elements as encoded symbols that represent both the reality and the unreality from daydreams.

Since the purpose is to engage the audience and to let their data form visual and experiential stories about themselves, the style of delivery of these stories is critical.

- **Live Biosignal and Interactive Biofeedback**

Biosignal is real-time, thus the input data can be used as a live generator to stimulate interactive biofeedback. The interactive process can amplify cognition because the participant cognitively responds to the visualizations through perception of the modifying visualizations. As Meirelles put it, "visual displays of information can be considered cognitive artifacts, in that they can complement and strengthen our mental abilities" (Meirelles 13).

As an example of this argument, in the 1960s, a generation of artists, such as Alvin Lucier and Richard Teitelbaum who applied EEG signals for music composition, reappropriated medical

tools and developed systems to harness the subtle physiological changes of the human body. These pioneers slowly created a movement that sought inspiration in medical science to create works that relate to the human being at a physiological level (Ortiz).

2.1.4 Case Study: *Ephémère by Char Davies*

Ephémère is an interactive and immersive virtual artwork created in 1998 by Char Davies, a Canadian artist who applied pioneering Virtual Reality method into her artwork. This interactive project is based on full-body immersion in 360 degree sphere, and provides the participant a vision of continuously changing landscape according to the intuitive processes of breathing and body balance. “By breathing in, the immersant is able to float upward, by breathing out, to fall, and by subtlety altering the body's centre of balance, to change direction, a method inspired by the scuba diving practice of buoyancy control”(Ephémère).

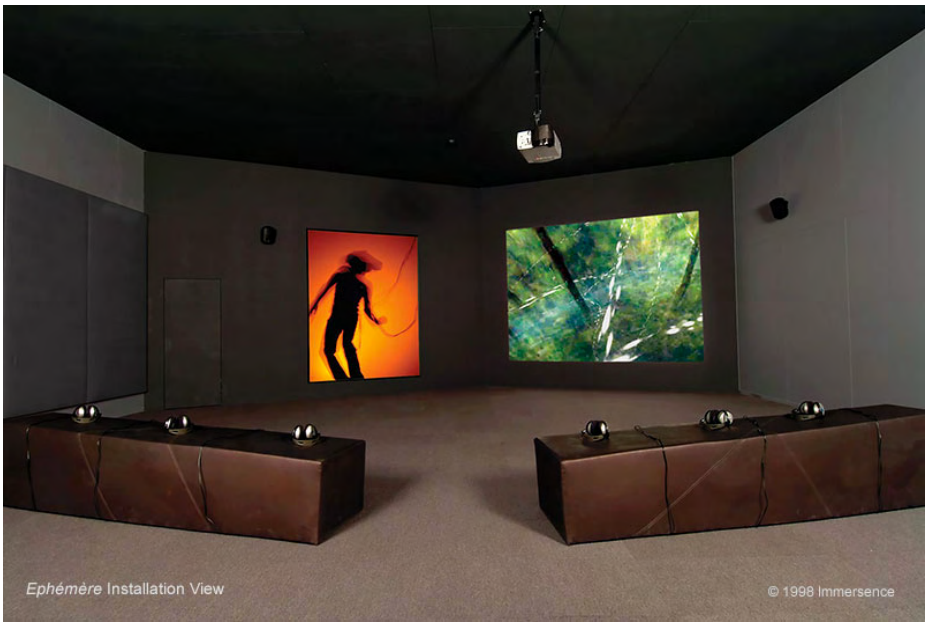

Figure 5: Ephémère Installation. Char Davies. 1998.

Inspired by nature, Davies utilized the seasons (spring, summer, autumn and winter) in the real world to navigate the participant to explore. Elements from nature were converted to abstract, illusive and imaginary visual displays, echoing with the extended body organs, blood vessels and bones. Thus this project generated a unique experience situated in between the real and imaginary world. Davies aimed to depict a natural process from blooming to falling, from

germinating to decaying, and from living to dying by showing “symbolic correspondence between the chthonic presences of the interior body and the subterranean earth” (*Ephémère*). The observers, referred to as “the immersant” by Davies, took control of the navigation inside the virtual reality narrations by wearing the vest equipped with sensors (Grau 198). The breathing and balancing movements were primary interior biosignals used in this project, corresponding with the underlying indications beneath the landscape in real time. By using the human biosignals to generate diverse nature views, *Ephémère* connected the real world with the human body internally, and deepened the intimate relationship between the self and the universe.

> *“Immersion in Ephémère depends on the body's most essential living act, that of breath—not only to navigate, but more importantly—to attain a particular state-of-being within the virtual world. In this state, usually achieved within ten minutes of immersion, most immersants experience a shift of awareness in which the urge for action is replaced by contemplative free-fall. The experience of being spatially enveloped, of floating rather than flying or driving is key to the work. Being supercedes doing. Solitude is a key aspect of the experience, as the artist's goal is to connect the immersant not to others but to the depths of his or her own self”* (Ephémère).

Also, the spatio-temporal structure diagram of *Éphémère* aligned well with my first draft structure for my thesis project. Comparable with *Éphémère*, my visualizations were inspired by nature elements and activated by biosignals. This thesis project also shared a similar purpose to *Éphémère*: it aimed to encourage the participants to reflect on themselves while interacting with this project, and to explore the possible relationships among the inner self, the surroundings, the universe, and the fictional world in daydreams.

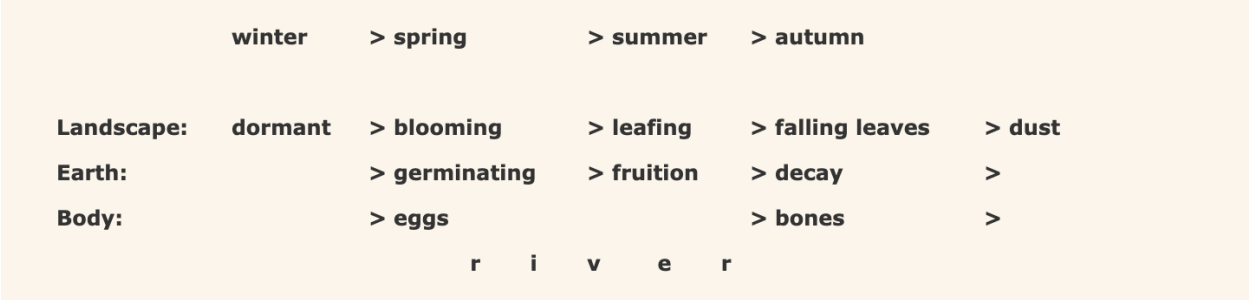

Figure 6: Spatio-Temporal Structure of Ephémère. Char Davies. 1998.

Bio-signals	Representation	Sensor Shape	Visualization elements
Heart Beat	Heart	Stethoscope	Corel-like/...
Finger Pressure	Fingerprints	Hand/Sphere of the earth	Star-like/rain-like
Breathing	Bubble?	Undetermined	Fish-like/...

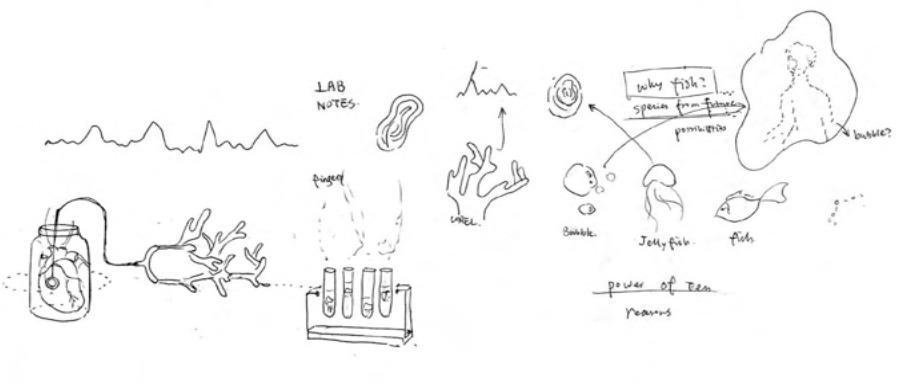

Figure 7: Structure and Elements of this thesis project. S.Cao. 2020.

2.2 Daydreams of an Artist for Participants

"Dreams are powerful. They are repositories of our desire. They animate the entertainment industry and drive consumption. They can blind people to reality and provide cover for political horror. But they can also inspire us to imagine that things could be radically different than they are today, and then believe we can progress toward that imaginary world."

- Dunne and Raby 1

To evoke the daydreams of the viewers is the major purpose and concept of this master research project. In this section, the discussions focus on two streams: why daydreams are important for artists and how daydreams of artists could engage the reflected daydreams for participants and viewers in a broader community.

2.2.1 Daydreams of Artists in the Stream of Consciousness

"For the artist or writer, daydream fantasies may be a source of creative inspiration."

- Farthing 189

Daydreaming constitutes the use of the mind to engage in an imaginative fantasy in order to temporarily escape from daily life in reality. Either memories of existing experiences or prospects for the future are involved (Longe). Based on this understanding, daydreaming serves the function similar to art creations, in either format of self-monologue or visual displays in the brain: to meditate, to imagine, to fantasize, to remember, to forget, to ruin, to bloom, to explode, to revive, to speculate, and capture the thoughts shifting among "silent self-talk, reveries, mind wandering, and flight of ideas" (Löfgren and Ehn 136) which could be self-representational.

Daydreams come from distinct sources and stimulus, and there are various daydreaming styles: positive reactions, frightened reactions, visual imagery, auditory imagery, problem-solving, future-oriented, bizarre-improbable content, sexual, heroic, guilt, hallucinatory vividness, mind wandering, etc. (Singer and Antrobus). In this thesis project, the types of daydreams I hope to provoke are fully open rather than restricted.

According to Freud, daydreaming was a time-wasting activity and there was no reason for the mature person to fantasize (Löfgren and Ehn 150). A contrasting view from Nordisk familjebok, in the standard Swedish encyclopedia of the 1940s, claimed the values of daydreaming as:

> "...inhibited fantasizing about wishes and wish fulfillment in wakeful dream; a form of escape from reality that characterizes introverted personalities. Among writers and artists daydreams are sometimes cultivated as an art form, removing their private nature. But usually daydreams remain purely private fantasies of desire and are regarded by psychiatrists and psychoanalysts as a manifestation of deficient reality adaptation and insufficient willpower."

Daydreaming is the phenomena of thoughts rapidly shifting where irrelevant thoughts get to alternate and one thought leading to another. The terminology for this process could be a stream of thoughts or associations, or a stream of consciousness (Farthing 177). To be more specific, excerpted from tape-recorded stream of consciousness report by participant in thinking-out-loud study (Pope 288), the participant said:

> "I'm looking at that piece of wood down there in the corner. I'm thinking that this is a really, very interesting stream of consciousness. I'm looking at my coat now. I got it from uhm Hadassah. And there's this great Jewish lady there that was un, oh. I'm thinking

> about this tie that I had. Oh, now I'm thinking of a tie of my grandfather's. I'm thinking about the day that my grandfather died. I was at junior high school and [name] walked into the office. I was in the office and I was crying and I didn't really care if he, if he cared that I was crying, uhm. I walked outside. I remember walking down by the football field. It was a long, curvy driveway sort of and I remember looking over through my tears at them playing football… I'm looking at cellophane from a cigarette package… and I'm thinking that I'm smoking too many cigarettes. I should quit because I'm worried that I'm going to wind up like my father…" (Farthing 170-171)

Referring to this example of consciousness description, the stream of consciousness is much like the flow of conversation at a party (Farthing 171). Daydreaming in the stream of consciousness is comparable with a dialogue happening within one's self: a thought directs to another new thought and then continues with or without awareness.

This stream includes the recollection of memory, relatedness of the objects or people, and speculation of the ongoing illusions. Thus as Farthing argues, the practical aspect, daydreams could remind people of their goals and offer the opportunity to reevaluate them. The emotional states can also be impacted by daydreams according to the speculation of the possible outcome. In the other aspect, daydream fantasies enable people to fantasize about fulfilling their desires without any efforts, and these fantasies might be valuable sources of creative inspiration for the artist or writer (Farthing 189).

As an inspiration, daydreaming allows artists to represent themselves in the unspoken language. A daydreamer daydreams about something truly other and in that way represents the true self, and then shares the idiom or aesthetic in the daydreams with the collective (Clare and Zarbafi 30). This thesis project presents the daydreams in my (the artist's) mind and extracts these daydreams to create "alternative realities" (Löfgren and Ehn 142) to guide the audience to start daydreaming.

2.2.2 Guided Daydreams for Participants

In this thesis project, the participants nudge the guided daydreams of the artist (me) to reflect on their own memories and to form a personalized dream dialectic. The memories that are

evoked could be real or unreal: they might exist; they might also have been lost or forgotten before guided daydreaming surfaced new or past daydreams.

Guided daydreams have been incorporated in cognitive psychotherapy to contribute to the modification of goals, attitudes, self-concept, anxiety and behavior (Singer 1975b; Singer & Pope 1978; Starker 1982); (Farthing 189). Although the objective of this thesis project is not to conduct any cognitive psychotherapy, it still aims to encourage the viewers' cognitive responses to their daydreams about body, self and narratives. As a potential for future research, this project could be beneficial for use in work around mental health.

To clarify the term guided daydreams - to guide does not mean to restrict. The guidance operates as a clue, a hint, or an external stimulus, as an activator for the viewers to react to. As argued by Farthing, "daydream thoughts may arise directly from memory, or they may be elicited by distracting physical stimuli or even by stimuli from the task at hand" (Farthing 177). As discussed, this project utilizes the body signals as stimuli for visualization. The displayed visual elements then become the stimuli for the viewers to respond to and to speculate about.

Singer(1975a, 1978) defined daydreaming in terms of stimulus independent mentation, suggesting daydreams are unrelated to the task at hand and independent of current environmental stimuli. However, Eric Klinger (1978) argued that Singer's definition does not capture the richness and variety of waking thoughts and images because though some realistic or fantastic thoughts are not directly related to the task at hand, they might be elicited by current environmental stimuli (Farthing 172).

Opposed to Singer's argument, this thesis project applies the stimuli-dependent method to evoke daydreams. To create the environmental stimuli, in this project I utilized the senses involved in daydreaming such as seeing, hearing and touching
to better "trigger fantasies" (Löfgren and Ehn 102). In this way, the "thoughts change in response to changing external stimuli" (Löfgren and Ehn 170). Similarly, the biofeedback (generated by biosignals) changes in response to the thoughts through cognition, and then the visual stimuli alter according to the biofeedback (generated by updated biosignals), which leads to a continuous loop of daydreaming as illustrated in my diagram "Daydreaming Loop".

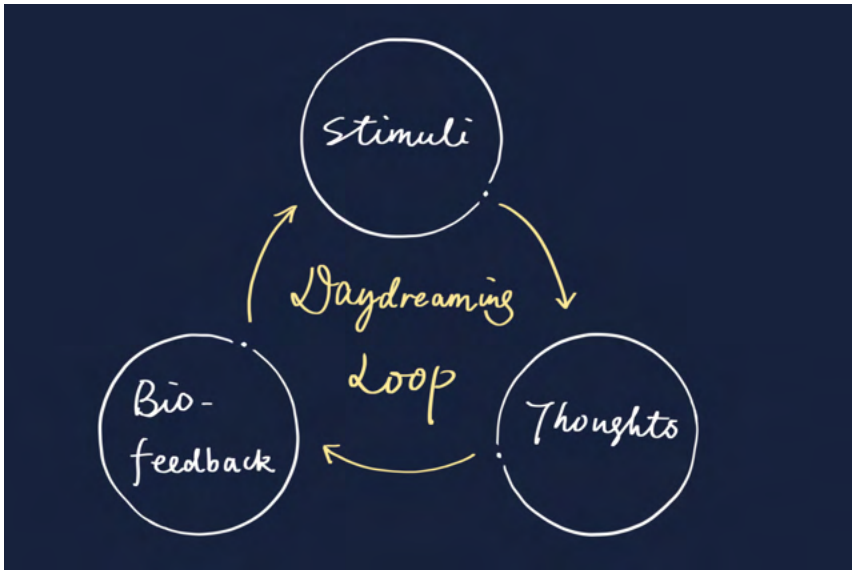

Figure 8: Diagram of Daydreaming loop in guided daydreams. S.Cao. 2021.

The daydreaming experience opens space for the participants to rethink and relocate themselves with the potential to reveal submerged desires or fears possibly more salient than connected actual life experiences (Farthing 180). It allows the hidden minds and emotions to be disclosed or surfaced. Different individuals could generate unique responses to the same environmental stimuli since daydreams are culturally structured by the beliefs and values by which the individual's world is constituted (Caughey 83). The variety of responses adds depth of interactive experience to the research, and thus it is constructive to collectively look at the daydreams in a social context. (will be further discussed in Chapter 6.1)

2.3 Performance in an Immersive and Interactive Setting

This thesis project sits in an immersive and interactive setting. In this section, the rationale of utilizing the immersive and interactive system as well as the application of performative elements are discussed.

2.3.1 Immersive and Interactive System

- **Immersion**

"Immersion can be an intellectually stimulating process; however, in the present as in the past, in most cases immersion is mentally absorbing and a process, a change, a passage from one mental state to another. It is characterized by diminishing critical distance to what is shown and increasing emotional involvement in what is happening."

- Grau 13

According to the research of Oliver Grau, a contemporary German art historian and media theoretician, the immersive image elements could at least be traced back to as early as the late Roman Republic (50–40 B.C.E.), when wall paintings in the Second Style of Pompeii illuminated an expansive vision of space rather than a mere plane surface. (Grau 24-33).

When we think of immersive space, we tend to imagine the space with a body-centered, emotional surrounding environment that drags the viewers into the story, such as the gallery, the cinema, and the dreams. In the immersive space, "virtual imagery proposes 'as-if' worlds" (Grau 252). The idea of immersion corresponds with the process of daydreaming in light of the similar feature that could be described as "a passage from one mental state to another" (Grau 13).

In the book *Visual art: From Illusion to Immersion*, Grau mainly discussed immersion within virtual reality projects, which is non-linear, multi-dimensional, and a space of possibility or impossibility formed by illusionary addresses to the senses (Grau 15). However, this thesis project is based on Mixed Realities (will be further discussed in Chapter 2.4) by applying projections instead of using Virtual Reality equipment. I argue that Mixed Realities offers more freedom for the participants to interact within the installation without wearing a head-mounted display, and provides more technical feasibility for me to discover the intriguing space between real and virtual interfaces.

Without application of virtual reality, however, there are also alternative solutions to amplify the experience of immersion. One example is the TeamLab, an international art organization that gathers a group of contemporary artists and aims to explore the relationship between the self and the world (TeamLab). The project *Tomorrow is the Question* is one of the projects created by Teamlab. By using screens with visual displays that filled the whole room, it effectively created the immersive space which blurred or abolished the differentiation between reality and

"as-if" worlds (Grau 17). In this immersive environment, the participants were also able to interact with the visual displays, and the elements would change accordingly to the participants' positions.

Figure 9: Tomorrow is the Question. Installation by TeamLab. 2019.

To improve the immersive experience, some installations aim to "address as many senses as possible to the highest possible degree with illusionary information via a 'natural', 'intuitive', and 'physically intimate' interface" (Grau 13-14) such as using sonifications, temperatures, smells, or touch senses. And the ubiquitous purpose of addressing these senses is to involve interactivity.

- **Interactivity**

To understand the interactivity in artworks, Erkki Huhtamo, the professor of Media Studies in University of Lapland, well addressed some understandings and misunderstandings of interactive art in her paper *Seven Ways of Misunderstanding Interactive Art*. She pointed out that the experimental interactive technology emerged not recently but could be referred to as early as an artistic experiment with interactivity of Myron Krueger, who is the American computer artist and the pioneer researcher of virtual reality and augmented reality (Erkki 1). Krueger argues, "the video medium has the potential of being more rich and variable in some ways, than reality itself."

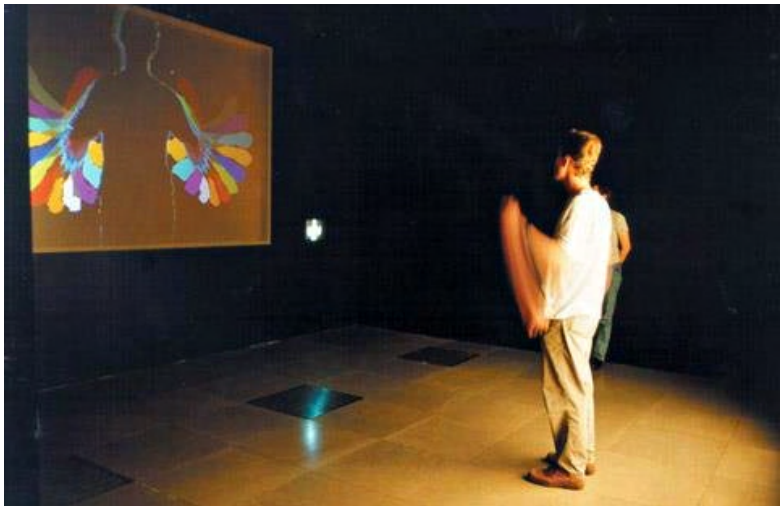

Figure 10: Videoplace. Myron Krueger. 1975

According to author and game programmer Chris Craford's definition, interaction is "an iterative process of listening, thinking, and speaking between two or more actors." In these interactive projects, the"two or more actors" refer to the participant and the "agents" in the virtuality, and the immersive feeling is enhanced when the "agents" in the virtual space navigate in a way that coexists with the real observer (Grau 252). In the time of new technology and new media, human-computer interaction shows up as an adaptive way to explore the cognitive relationships between users and digital interfaces. The computers could interact in similar ways to human beings in three stages: listening, thinking, and speaking. Interaction in computational terms has three stages: input, processing, and output (Igoe and Sullivan xx). Thus, the computational agents in the virtual images have the potential to interact with participants like in a natural conversation.

In this thesis project, this conversation is stimulated by the interaction between the participant, the sensors, and the visualizations. The sensors that detect the body engagement are the input devices *listening* to the audience, while the digital display of visualization is the output tool *speaking* to the viewers. The computational translation of visualization is the pre-programmed and simplified process of *thinking*. The participant interacts with the device to provide the biological data, and after receiving and perceiving the according response from the computer, the participant then digests, reflects on, and further interacts with the visualizations which could be seen as a response from the computer in a dialogue. Some might assume that interactive art should create a monologic loop between the users and their self-representations by technology instead of real interactivity among real human beings, as mentioned by Erkki. She then

challenged this assumption arguing that the interactions between the human and the computer are valid because the self-reflective situation should be one of the "conversational" options embedded in an interactive system, and should be a "polylogue" rather than a monologue (Erkki 3-4).

Such interactive media art allows the participants to lead the narratives in the given context, and to open up the personal interpretations. In the paper *The Imaginary worlds of sustainability: observations from an interactive art installation* by Bendor, Roy, et al. in 2017, the interactive project discussed exemplifies this argument. Within the installation, there are four interactive rooms with participants, partially guided by a narrative through-line, yet at the same time left to make sense of larger meanings on their own. Indeed, there is a main concept and narrative flow of this project for participants to better understand sustainability, to explore imaginary living habitats, to consider possible futures and to rethink who they are and what is important to them (Bendor et al. 1). However, the purpose of applying interactivity is to challenge the participants to consider and go beyond the original concept of their project. As the authors argued, "we were not interested in informing or educating but in provoking" (Bendor et al. 7).

Similarly, the interactions involved in this thesis project aims to cultivate the desire for participants to relocate themselves, rethink about the relationships to the world through daydreaming. Instead of telling a traditional linear narrative - a story without interactivity, involving one's body in a really good sci-fi could provoke unknown responses: fluid, dynamic, shifting, drifting, unseparated, undefined, unconceivable, unpredictable, unstable, and infinite.

Case Study: *The Treachery of Sanctuary by* Chris Milk (Participants as the Agent)

Created by Chris Milk, an American immersive artist contributing to the intersection of technology and art, *The Treachery of Sanctuary* is one of his immersive and interactive projects that tells a story of birth, death, and transfiguration that uses Kinect-powered motion tracking of the participant's body to unlock a new artistic language (Milk). The digital interface, the screen that displays the representations of the human body, is essential in his projects. Kate Mondloch, professor of Contemporary Art at the University of Oregon, claimed the importance of interface in such artwork: "the interface 'matters' for media installation art… Installation artworks are participatory sculptural environments in which the viewer's spatial and temporal experience with the exhibition space and the various objects within it forms part of the work itself".

As to Milk's previous experience of being a photographer and a music video director, he was inspired by the frames in filmmaking and used three triptychs as the interfaces in this project. It is valuable to refer to Milk's application of frames: narratives could also be happening in other frames such as windows, cameras, polaroids, mirrors, etc.

Figure 11: The Treachery of Sanctuary. Chris Milk, 2012.

Despite the interface, the participant's body becomes the central element, and the movement of the body becomes the activator of the visualizations. As Milk states, "our bodies are the most potent and universal of human languages, and in this piece, participants create something eerie and self-empowering, something both human and avian, with their own forms" (Milk). In this project, Milk and his team utilized Microsoft Software Development Kit and the Kinect motion controller for skeleton tracking, so that the computer can capture the body movements of the participants. The representations on the screen are surreal images generated from reality: not a silhouette of the participant but a vivid simulation. Based on that avatar, more visual effects happen and change accordingly to the participant's action: in the first triptych, feathers align with the arms so the mirroring of arms becomes wings. In this way, the participant is able to flap the "wings". Although the outcome is not so different to everybody, the participants still provided different reactions. For instance, some solely flapped arms, some jumped and flapped, and some began dancing. Diverse understanding of this project generates diverse responses and personal conversations with the work. To reflect on this project, Milk wrote:

"What is interesting to me is the two-way conversation between the work and the viewer. The participant is an active character in the content and concept of the piece, and while the technology allows that interactivity, the emphasis is on the experience, on transcending past the enabling innovation to the spiritual immersion. It's a universal, but personal, journey of self-expression, elation, transfiguration, and transcendence.
And it changes every time. So each participation is a new spiritual experience, a new dance. Just as humans have always responded to live, improvisational music by finding a freedom in their own expression, so the piece will be defined for and by each of them, each time: a journey that breaks apart and celebrates emotional existence with a new physical language."

- Milk, Chris

"Can you use technology to produce real human emotion in people?"Milk asks, to explore the relationship between technology and human experience. This relationship seems distant but is indeed intimate. To blur the boundaries between technology and human experience, interactions between these two should be amplified: not only the physical interactions in space but also the immediate personal responses in the silent conversation. The visual stories generated by technology should be related to real human experience or imaginative thoughts to arouse the receivers' emotions, and these emotions should be reflected back on the visualization, creating an infinite loop between the human and machine. The participant is perceiving how the machine is creating visual feedback, and the machine is perceiving how the participant is perceiving. It is a similar situation of how humans interact with the world - in a never ending loop.

2.3.2 Application of Performative Elements

In each example discussed in Chapter 2.3.1, there are always performative elements in an immersive and interactive setting: in most cases the participants are the agents who perform, and in some cases the artist is the performer. In a reversed perspective, immersion and interaction are always involved in a performance - the performer is within the immersive surroundings, interacting with either the objects or the humans.
An example of the interaction with objects is *Step Piece* by Vito Acconci, an influential performance and installation artist. In this project, Acconci used the stool as his exercise tool to step up and down without stopping every morning for four months in 1970 (Acconci 760). He

recorded the time he did this exercise for each morning and sent out a report to the public every month. Acconci stated, this is “performance” only in the sense of: the act or process of carrying out something: the execution of an action (Acconci 762).

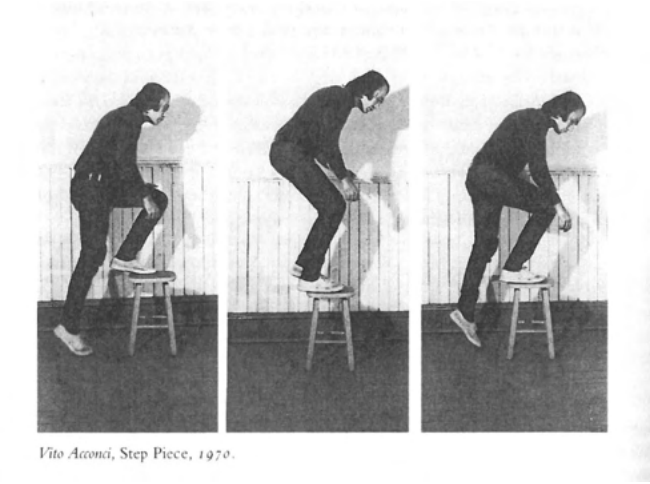

Figure 12: Step Piece. Vito Acconci. 1970

An example of interactive performance with humans is *The Artist Is Present* by Marina Abramović at Museum of Modern Art (MoMA). In this project, Abramović aimed to deepen the engagement with another person through mutual gazes without any other physical or language interactions. As to MoMA’s statement, Abramović’s performative art practice is:

> *A pioneer of performance art, Marina Abramović (born Yugoslavia, 1946) began using her own body as the subject, object, and medium of her work in the early 1970s. For the exhibition Marina Abramović: The Artist is Present, The Museum of Modern Art's first performance retrospective, Abramovic performed in the Donald B. and Catherine C. Marron Atrium every day the Museum was open between 14 March and 31 May 2010. Visitors were encouraged to sit silently across from the artist for a duration of their choosing, becoming participants in the artwork* (MoMA).

Figure 13: The Artist Is Present. Marina Abramović. 2010.

In such live performances, the artist and the visitors are the subjects, and the interaction between them is the soul of the project. In these works the interaction is not only referring to physical interactivity, but also the mutual minds and emotions in an immersive spiritual conversation. Thus performance and interactivity are always closely related.

Case Study: *Myth and Infrastructure* by Miwa Matreyek (Artist as the Agent)

Different from Chris Milk who invites participants as agents in his works, Miwa Matreyek, a Los Angeles based artist, uses her own silhouette as the agent to interact with projected pre-made animations in live performances. Matreyek's project *Myth and Infrastructure* in 2010 elucidates how humans could be connected and conflicted with nature. Her performance was well integrated into the whole visual narrative, and the audience's experience of watching her interactive performance is immersive, within both narrative and the cinematic experiences.

Figure 14: Myth and Infrastructure. Miwa Matreyek. 2010.

In an Interview through email with McCallum Theatre Institute, Matreyek stated that "there is something interesting in the slippage/uncanniness of combining live and pre-made, theatrical and cinematic, and for the audience to know that the piece is only happening because they are there along with me"(Matreyek 6). Inspired by Matreyek, I also utilized the live and pre-made visual elements in this thesis project, and used myself (the artist) as the performing agent. The combination of live and pre-made seeks to combine fictional and actual space to arouse the audience's curiosity to question whether they are experiencing a real or virtual performance.

One of the objectives of my thesis project is to present the invisible as visible in the intersection of real and virtual space, as in Matreyek's work where "dreamlike visual space makes invisible worlds visible, often weaving surreal and poetic narratives of conflict between man and nature"(Matreyek 5). To be more specific in this thesis project, the invisibles are the internal biosignals and the visibles are the alternative visualizations as representations of the biosignals.

I was also inspired by the approach that Matreyek applied. She used mixed methods to create interactive performance layering multiple visual projections, recorded music and the silhouette of her own body moving through the projected animations (Matreyek 4). Her approach offers a fresh perspective to the New Media art field. In this thesis project I also applied multiple layers including digital visualizations, sculptural objects with sensors embedded, and interactive performance, "existing both in the realm of the hand-made and tech" (Matreyek 5). I would

define the usage of multiple media as a hybrid form of art, which will be discussed in the next chapter.

Although in this thesis project I (the artist) will be the only performer because of Covid-19, the next step is to involve other participants as performing agents for future research because "integrating a representation of the observer's body into the image sphere can augment the immersive function of virtual image spaces" (Grau 25).

2.4 Hybrid Arts: Body and Objects in Mixed Realities

This thesis project could be summarized as a hybrid arts research project. Hybrid arts include a combination of various art forms such as sculptures, performances and stage projects, media architectures, media based interventions in public spaces, location based and geospatial storytelling, annotation software tools, artificial life, transgenic art, software art, generative art, etc. (Ajani 37).

This thesis project is hybrid for the following reasons.

The art media and discipline is hybrid: it blurs the boundaries between traditional art (eg. performance, sculpture) and digital art (eg. data/info visualization).

The use of hybrid art media is an interdisciplinary practice. Multiple layers of art media improve the art experience for both the artist and the audience.

For artists, when the artwork itself is extended, the artist's experience and practice are extended as well. The role of the artist intersects with that of the engineer, and the artworks' production entails a multidisciplinary collaboration. The artist is no longer merely an artist but becomes an extended artist" (Laskari et al. 33).

It is the same for the participants/audience. When the participants/audience are interacting with/perceiving hybrid artworks, they are observing and reflecting on the extended art experience, thus they become 'extended participants/audience'.

The materiality is hybrid: it involves physical objects in real space and virtual elements in digital projections.

In the collective autobiography *Evocative Objects: Things We Think With*, the editor Sherry Turkle offers an innovative way and variety of perspectives from different people to consider how objects are associated with their experience. She demonstrates that objects help us make our minds, reaching out to us to form active partnerships (Turkle 308). According to her experience, she was obsessed with looking at the objects in her memory closet as a child, and formed new understandings of those people who owned these objects. Turkle claimed, "for every object they spun a world" (Turkle 10).

Through my background as a jeweler, I found it imperative to construct the connections between the objects and the body. Fabricated objects become the repositories for artists' voices through their materials and shapes. Like jewelry, the role of physical objects is also significant in this thesis project. I embedded the sensors into sculptural objects to construct tangible interfaces to communicate with the participants. Although the physical objects lead the navigation of the immersive experience, the concept is no longer embodied in these objects as in jewelry. Instead, the digital visual elements become the repository that embodies the concepts and narrations.

The space is hybrid: the body and objects are in a physical space while the narrations dwell in a virtual space, thus mixed realities are layered.

In these days, Mixed-reality technology is under tremendous development benefitting from the evolution of computer vision, sensor application, and display technologies (Guzman). Mixed realities offer the opportunity for people to see the physical objects and the possibly responsive virtual objects spontaneously. It is the format that combines both features of Augmented Reality and Virtual Reality (Hoy and Brigham).

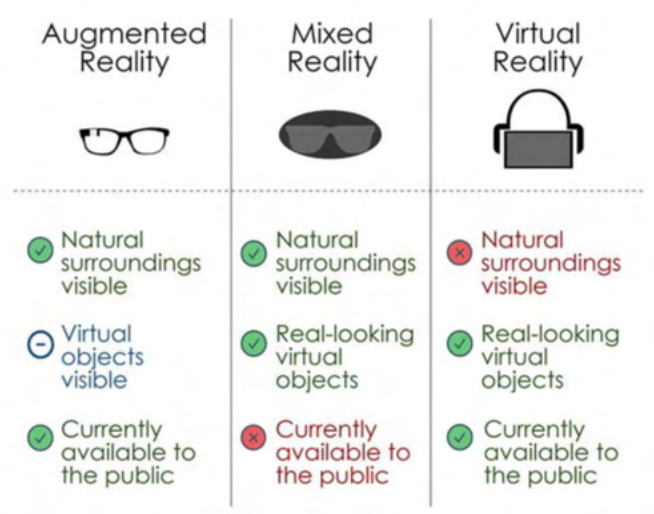

Figure 15: Comparisons of AR, MR and VR. Matthew Hoy and Tara Brigham. 2017.

Mixed Realities can build up intimate connections of physical spaces and media-based image worlds (Grau 89), where most of the settings would contain a large-scale screen of digital displays within a darkened space. The information in virtual space is activated, revealed, reorganized and recombined, and is transformed as to the user's navigations and actions in the real space (Grau 245-247). An early project *Murmuring Fields* by Fleischmann and Strauss in 1998-2000 exemplifies a mixed-reality artwork. This project was set up the interactive acoustic space where the performers could navigate their bodies in the spatial structure and interact with the virtual-acoustic interface by their tracked movements (Fleischmann and Strauss).

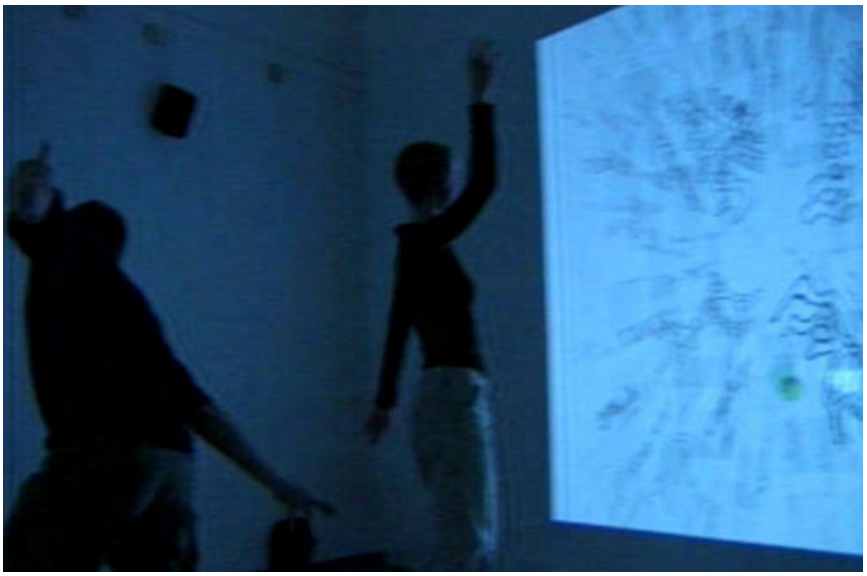

Figure 16: *Murmuring Fields*. Monica Fleischmann. 1998-2000.

Although there is little evidence that the mixed-reality environment efficiently raises the participants' awareness of their bodies, the major purpose of mixed-reality application is to ameliorate the interactivity of movements and gestures in the suggestive image space, so that the awareness of one's self could be enhanced (Grau 247).

- **Why is hybrid strategy applied in this thesis project?**

Grau comments that "the combining of elements of physical and virtual spaces is leading to the emergence of a new cultural technique" (Grau 247). I used hybrid strategy in this thesis project to challenge the role as an artist, to erase the boundaries between physical fabrications and digital media, and to explore different degrees of possible complexity and to enhance the immersive experience (Grau 248).

This thesis project aims to contribute to creative media and new forms of art and to enhance the immersive and interactive experience of the participants/audience, so that they are intuitive to respond to the possible narrations of their biological signals, to relocate and re-understand themselves in the suggestive scenarios, and thus to experience new forms of daydreaming.

Methodology and Methods

I applied a Practice-Based Research Methodology in this thesis project as I utilized my experiments of creating physical and digital artifacts as the central source for new knowledge. The process was part of my final artwork. Referring to Candy and Edmonds's discussion of what is Practice-Based Research, "the making process provides opportunities for exploration, reflection and evaluation" (Candy and Edmonds 66). They also argue that "practice" connotes doing something that extends beyond everyday thinking into actions that may lead to new outcomes (Candy and Edmonds 64).

My practice process helped me to frame and shape my work, and each prototype constituted iterative thinking which illuminated and surfaced improved ideas. For example, I considered creating three separate frames for my projections at first, but after creating three prototypes, I decided to weave these scenarios as a whole in order to reach a higher level of immersion.

In this chapter, I discuss how I built up the work through a Practice-Based Research methodology. I elucidate my methods in this multi-layered thesis project including artist research, materiality research, technology research and prototype examinations. As well, there are applied methods of sketch and photography as inspirations, records of daydreams, speculative poetry, as well as crafting methods including crocheting, felting, generative pattern design, etc.

3.1 Narrative Visualization

The objective of visualization in this thesis project was to translate invisible human biological signals into visual indications. To visualize the heartbeat, breath and body movement, I researched visual representations for these human biosignals. However, most of the cases barely involved engaging visualizations and merely data-driven infographics. To fill this gap, I considered representing these biological inputs by using metaphors: coral growth as a representation of heartbeat, fish growth as a representation of blow, and trace of rain drop as a representation of movement.

However, rather than merely representing human biological data, the visualizations should also form an immersive environment for participants to situate themselves in and to respond to. The space should be familiar enough to the participants to be immersed in, yet still consist of uncanny elements and narratives. Considering this fact, I decided to use natural forms as the basic elements in my visualizations to quickly invite the participants to wander in the hypothetical world. On the other hand, a significant number of the natural forms are organ-like, echoing the signals that human organs generate. Furthermore, according to Edward O. Wilson, a highly regarded biologist, humans have an innate tendency to focus on life attracted to life and lifelike processes. This tendency, he summarized as biophilia (Wilson 1). Referring to this hypothesis, employing natural forms in the visualizations could help the participants effectively daydream in my immersive space.

After producing and experiencing the three prototypes as a participant, I found that the visualizations as signifiers of the biosignal shifted. It was more interesting to speculate on the "what-if scenarios". This allowed me as the researcher and artist to strip narrative down to basics in order to explore my idea (Dunne and Raby 86). During my creative experiment, I would challenge myself with "what-if" questions.

What if my footsteps are magical for plant growth?
What if the pressure is too high?
What if I can blow out my daydreams?
What if the heartbeat is freaking me out?
What if the daydreams are not beautiful but overwhelming?
What if I'm not creating the daydreams but the daydreams are chasing me without escape exit?

These questions continually happening in my practice process are essential to my final concept. Thinking through the making process surfaced new inspirations as well as motivations to create the new artifacts.

As a method to compose the story consisting of the visual elements, I recorded my own daydreams and nightdreams during the thesis exploration phase. Recorded as phone memos, I interpreted these stories with illustrations (see Appendix). While weaving together the separate stories, I found that there was a ubiquitous property in my dreamy illusions: duality. I dreamed of two parallel worlds that were at the same time speaking of fortune and misfortune. I dreamed

of bird cages that could replace the birds with human observers. I dreamed that it was not me who generated the dreams but all the dreams were chasing behind me and I was trying to escape. Dreams were mirrors and reflections of reality whether exaggerated, distorted or totally reversed. Then as an aggregation of all my dreams, I wrote this short poem:

In that sunset, you stood in the ocean with bare feet.
“Is there another world?” You asked.
“Yes.” I said. “There is.”
“Why?”
I did not know.
The sun was the same one that I had always seen.
The ebbs and flows, the sunrise and sunset,
that changed the shape of my shadow.
But my presence is still the same.
My breath, my heartbeat, my footprint.
I engraved on the sand with my toes:

I am scared of burning.
I am burnt by the sun.
I am scared of suffocation.
I am drowning in the ocean of rain.
I am scared of forgetting.
I am caught by forgotten daydreams. Feet by feet.
Like a ghost.

By applying the method of recording dreams in the format of poems and illustrations, I employed the final poem as the major resource for narrative visualizations.

In my experimental prototypes, I used a tablet to illustrate all the visual elements digitally. Although the visualizations served the functions well to present the possible stories of biosignals, they were still confined and limited under my control. To make it more organic and unbound, I replaced some of the digital illustrations with drawings on paper. As the elements are inspired from nature, instead of artificial pigments I made my own organic pigments.

I collected a variety of vegetables and fruits as my paint sources including tomatoes, grapes, oranges, tangerines and avocados. For each kind of vegetable or fruit, I used a different method to extract the juice or pulp. For example, I boiled a box of tomatoes and filtered their orange red juice; I peeled off the grapeskin to squeeze out the purple juice; and I directly used a spoon to mash the avocados to get the mud-like green and yellow pigments. As a result, I successfully collected and categorized the homemade organic pigments into a set of labeled containers.

Figure 17: Process of making organic pigments. S. Cao. 2021.

Figure 18: Collection of organic pigments. S. Cao. 2021.

However, after I applied these pigments on paper sheets and other materials, the outcome did not reach my expectations. Surprisingly, among these pigments, the avocado paint worked the most extraordinarily because of its mixed color and rich texture for forming potential patterns.

Figure 19: Collection of organic pigments made of avocado. S. Cao. 2021.

By using a set of oil paint palette knives, I ground six avocados in the shape of a circle on sixteen pieces of cards, each with a distinct mixed color of green and yellow. The textures were distinguished in three sorts: mud-like, strip-like and flake-like. They looked very similar to the sun in my daydreams. The proportion of green and yellow pigments changes according to different phases of sunrise and sunset.

Figure 20: Collection of cards with avocado pigments. S. Cao. 2021.

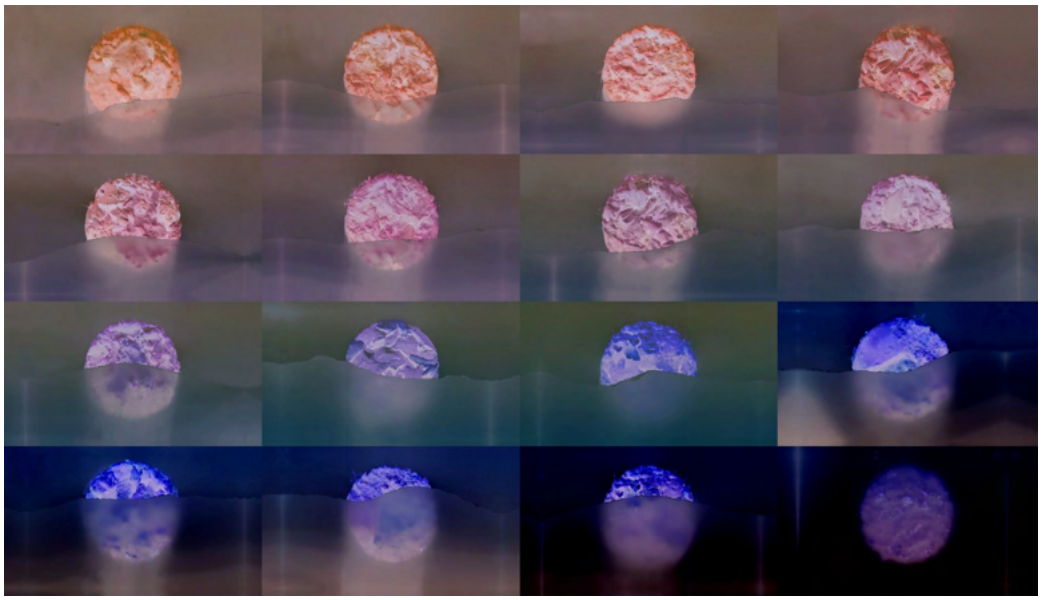

Figure 21: Photoshopped frames from Collection of avocado pigments. S. Cao. 2021.

My photographs of blurred views of objects inspired me to illustrate the ebbs and flows in my poem in a blurry, shadowy, and dreamy way. I was also inspired by *SURFACE / EMOTION* created by Joyce Shi, a graphic designer based in New York. Her project is an interactive web design that allows the users to freely explore by adjusting the input, and the visualizations interpret the users' mood, mathematics and visuals intersectly into abstract and poetic graphs (Shi). This project echoes with my photographs and offers an interesting way to arrange the clear space and the blurry space. The Bézier curve used in Shi's project, which refers to the parametric curve used in computer graphics and related fields (Mortenson 264), reminds me of representations of the turbulent ocean waves.

Figure 22: Daily photographs as inspiration. S. Cao. 2021.

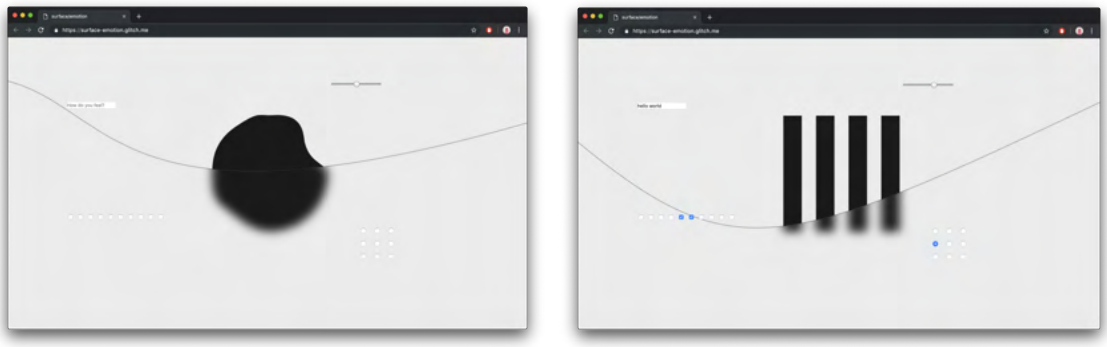

Figure 23: SURFACE / EMOTION. Joyce Shi. 2019.

My photograph records and the artist research inspired me to use tracing paper as the medium to blur the avocado-made sun. I tore down pieces of tracing paper into curved strips. The strips were then put on the top of the sun shapes in order to create different levels of the waves.

To smoothly deliver the animated visualizations according to the changing biosignals, I broke down my work into a number of keyframes to create a coherent flow of a narration. The study of motion by Eadweard J. Muybridge, a leading figure of nineteenth-century photography, offered me an opportunity to learn from his photo frames capturing animals in motion (Shimamura). Despite the fact that Muybridge never made films, filmmakers have transformed Muybridge's serial photographs into short animated films since the early 1970s (Lawrence 15). To take his work *The Horse In Motion* as a reference, I also arranged my sixteen cards in a natural timeline from sunrise to sunset. After I did some editing in Adobe Photoshop, these frames then became the keyframes of motions for my user-responsive animated narration (see Figure 21).

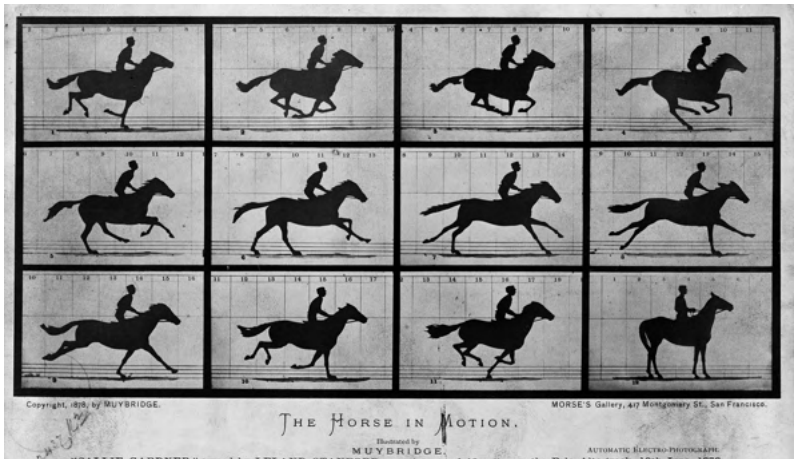

Figure 24: The Horse In Motion. Eadweard J. Muybridge. 1878.

I also added other elements based on these key frames, such as birds and growing plants. In this scenario, a visual sequence connecting to the participants' interactions emerged. The changes of the participants' biosignals activated all the scenes and elements in the daydreams. After it reached the last frame in this scenario, the sequence continued to the second scenario echoing "I am caught by forgotten daydreams" in my poem, as I queried, since not all the dreams were beautiful and healing, what if I couldn't get rid of the nightmare-like daydreams? Thus, the first scene was designed to illustrate poetic visuals generated by the breath pressures and body movements, while the second scene was to stimulate anxious feelings by sonifying a beating heart and visualizing the fear. These two scenarios together formed the duality of daydreams (see Chapter 5.2).

During the practice of constructing visual narrations by using both digital and physical art techniques, I challenged the boundary between artificiality and nature: the natural organisms could live in digital space, and the artificiality did not always have to consist of digital elements. Similarly, I also questioned how traditional art creation existed in digital designs, and how digital media embraced the involvement of handcrafts.

3.2 Sculptural Object as Interface

"Physical objects, which used to be mute, are now starting to talk."

- Han 56

The textile interfaces are referred to as the sensor-embedded sculptural objects in this thesis project. The sensors I used in this project are specifically for heartbeat, blow breath and pressures. As an instrument to connect the participant with the virtual world, the textile interface could be seen as the messenger to transmit human behaviors to the computer. These objects are considered as media for the audience to talk to, to encourage the impromptu interactions by the participants, and to ignite the daydreams.

For artist research, I mainly focused on the project *Felted Terrain* created by Yihyun Lim who is director of the MIT Design Lab. Inspired by the mossy terrain of Iceland, she knitted the main textile interface to mimic the terrain appearance. My attempt for my project was similar to Lim:

she aimed at subverting the notion of primitive handcraft in knitted/felted textile through its integration of soft electronics, computation design, and fabrication method. She explored two aspects of "craft research": the generative craft process of textile and creation of spatial experience through "reflective-on-action" installations (Lim 253-255). The material used was a hybrid where electronics and smart materials are embedded in traditional ones (Lim et al. 403). The knitted conductive yarns (smart materials) are embedded within the non-conductive yarns. Then she used felting to transform the woven texture into a non-woven surface materiality (Lim 257). The tactility and materiality of the final piece led to a soft feeling that invites the audience to interact with the bumps. With the support of sound system design, this knitted terrain became a musical textile interface that generated real time sound when people pinch on the bumps - the possibility of composing unique tunes emerged.

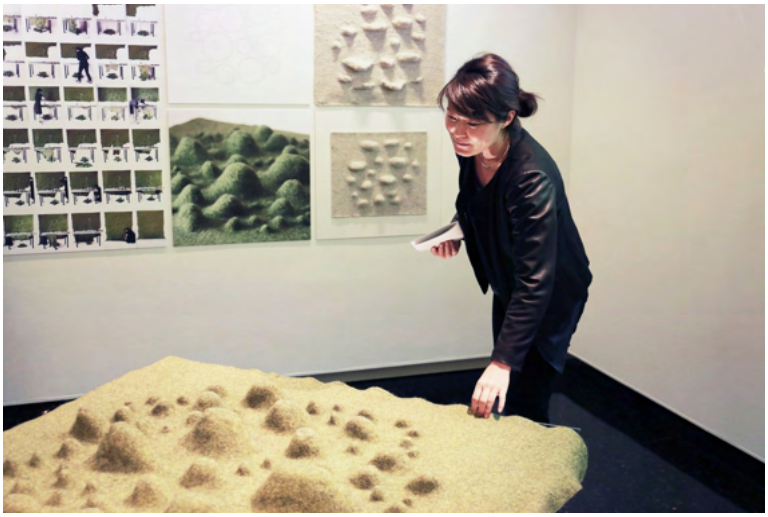

Figure 25: Felted Terrain. Yihyun Lim. 2017.

Similarly and differently, I chose to use the felt and terylene yarns to create three sculptural objects: a blanket with three sensors underneath detecting pressure caused by body movements, a bubble blower with a sensor, and a pocket holding the sensor to input heart data. I chose these materials because both felt and terylene yarns are soft enough to engage the participants through touch. It was a technical decision as well. Take the pressure of body movements as an example, I needed to use squishy materials on top of the sensor to quantify the pressure because they could distribute the pressure into multiple levels.

3.2.1 Blanket

To form an interactive landscape for the participants to step on and wander, I crocheted 9 circle pads with various sizes using the terylene yarns. All these pads were of different colors from the center to the outer edges to mimic a ripple: light green, light blue, lake blue, and dark blue. The craft of crocheting was laborious work. However, it was not just laborious work because each crochet was a continuation and variation of the last one. Each crochet was unique - it was a new decision, a new rhythm, and "not just repetition but differences within repetition" (Lefebvre 90). The crocheting process was driven by generative design methods, where "the rules are at the heart" (Boden and Edmonds 24). I applied unified rules for the crocheting stitches, and the results were different by means of distinct rhythms for each round. The making process allowed me to concentrate on the underlying rules themselves: "the structures that define the artwork, as against the surface" (Boden and Edmonds 26). The generative design method echoed the argument of Tim Ingold, professor of Social Anthropology in the University of Aberdeen, that sawing had "a rhythm quality" (Ingold 98).

I was also inspired by textile artist Mary Worwood who applied threads and fabrics to interpret how she perceived the world, and Vanessa Barragao who used waste materials in her textile works. To enrich the texture of the blanket, I sew pearls and beads in between the stitches, hence the organic sense could be enhanced.

Figure 26: Crocheting Process. S. Cao. 2021.

3.2.2 Pocket

The pocket was also made of terylene yarns although the type of crochet was slightly different from that of the blanket. This pocket served the function to measure the participant's heartbeat with a pulse sensor in it. As the participant needs to cover his/her fingertip on the sensor to transfer biosignals to generate constant visualizations while freely moving through the interactive space, I made this pocket portable in the form of an embellished necklace.

I always involved the *body* as a central subject in my projects due to my jewelry making background. I would define this knitted pocket as a wearable sculpture because it was similar to what Glenn Adamson stated that postwar contemporary studio jewelry was routinely described as "wearable sculpture" (Adamson 27). As a curator, writer and historian, he also claimed that wearing the ornaments was a means of expressing character (Adamson 21). In this project, the pocket was not merely the repository for the pulse sensor, but also helped to situate the participants into the stories. Once wearing it, the participant became the character of this daydream narration, and the daydreams got activated after the "act of wearing" (Adamson 24).

3.2.3 Blower

Different from the crocheting method used for the blanket and the knitwear, I utilized the felting technique to fabricate the blower.

I began with considering how the sensor would fit in the shape of the blower to be inconspicuous. The first step was to create a 3D sketch in Rhinoceros which provided a clear view for me to refer to. The initial plan was to print this model in nylon as a basic structure, yet due to the thinness that I needed, I was suggested not to print it out or it would break easily. So I decided to do the felting directly on a metal ring and embedded four strips of yarns through the felt to hang the sensor. Also, I left the handle as a hollow structure to later set the cables (connected to the sensor and computer) inside.

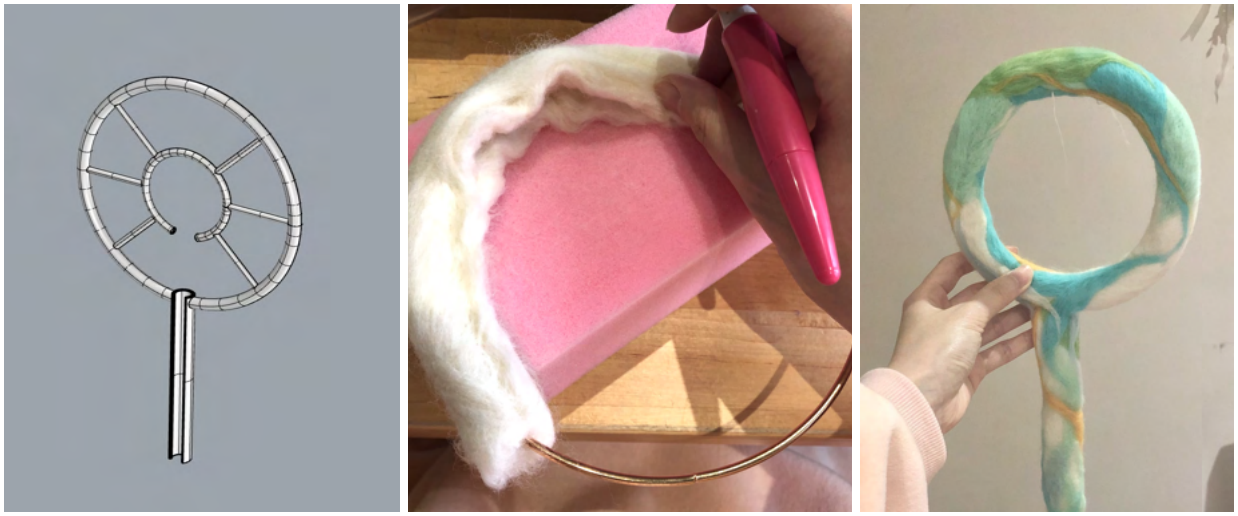

Figure 27: Blower making Process. S. Cao. 2021.

Apart from the priority on materiality and textility of the object making, I also gravitated to the solution of embedding the sensors into these objects in a genuine way. The electronic elements should smoothly merge with the traditional materials, thus I had to take care of the sensors and the cables. As examples, the sensors were supposed to be hidden subtly underneath the blanket, in the pocket, and in the center of the blower. Respectively, the cables were covered with yarns or felts to simulate an extended landscape, an adorned cloth, and a lengthened handle. The next step for me is to better integrate the sensors into objects instead of combining them.

By creating the sculptural objects as textile interfaces, I aimed at seeking a balance of functionality and aesthetic, as well as a reconciling of "craftsmanship and technology" (Lim et al. 413) in united spatial dynamics. These objects around the human body became "planets whirling on their dervishes" (Rose Slivka) in a galaxy installed in the exhibition space, a space that was "a place to start a relationship" (Acconci 764) between the participant and the narrations.

What's more important, as Yihyun Lim stated, was to look for "new possibilities offered by these new hybrid materials both for artisans and users and new perspectives for interaction design" (Lim et al. 403).

3.3 Interactive System Design

With the digital narrative visualizations(see Figure 28) and the physical objects with sensors embedded for sensing body engagement(see Figure 29), I needed to weave them together.

Figure 28: Narrative visualizations projected. S.Cao. 2021.

Figure 29: Sensors embedded in the sculptural objects. S.Cao. 2021.

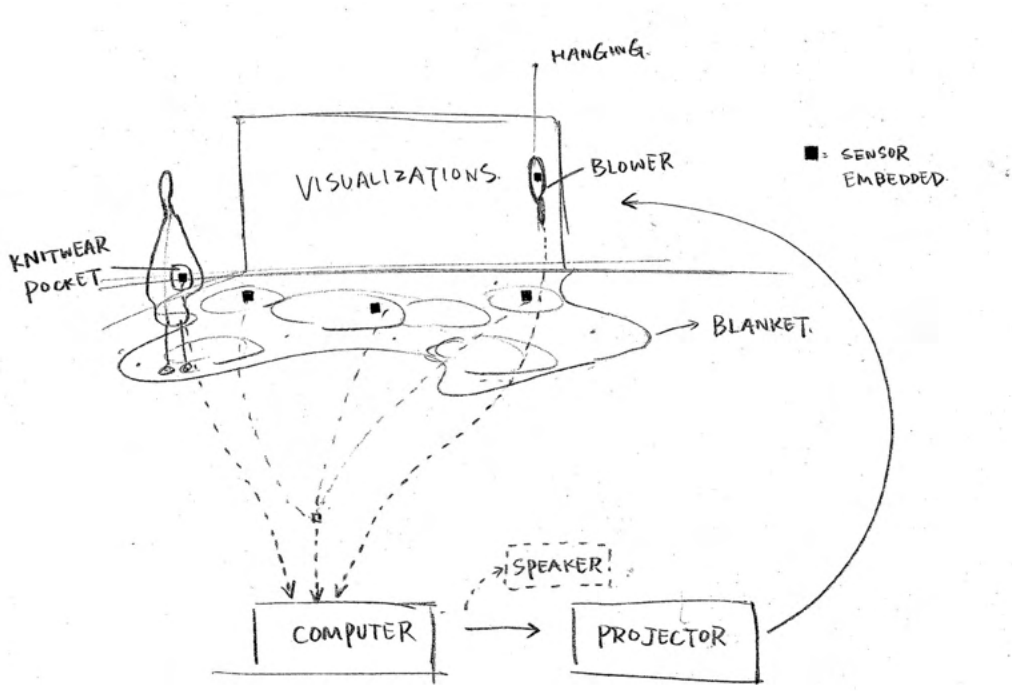

Figure 30: Sketch for interactive system design. S.Cao. 2021.

Figure 30 elucidates the sketch of how I designed the interactive system. There is a wall with projected narrative visualizations. The performer/participant should put on the pocket with a pulse sensor inside to start the journey. On the right side of the installation, a hanging blower with the blowing pressure sensor is fixed. In front of this wall, there is a blanket with pressure sensors underneath for the participant to step on. While the participant begins to interact with these objects, the biosignal data will be collected by the sensor and transmitted to the computer. The computer will then respond to the input and send visualizations and sounds accordingly to the projector and speaker.

PROTOTYPES ITERATIONS

An imperative property of this thesis project was the balance between art and technology, hand craftsmanship and digital visualizations. And to balance these multi-disciplinary components in a hybrid space, the iteration of prototypes became the essential practice. Before starting the final prototype, I created three prototypes to test the feasibility of my concepts and to learn from each experiment. It was imperative for me to think about my project as a whole to foresee the possible challenges.

In this chapter, I elucidate the three prototypes in a chronological timeline. I explored how to visualize the human biosignals, how to employ sensors on Adafruit Circuit Playground Express, and how to use software of Arduino IDE and Processing.

4.1 Prototype I: Heartbeat Visualization

Video link: https://youtu.be/qwKkiNYH6Ls

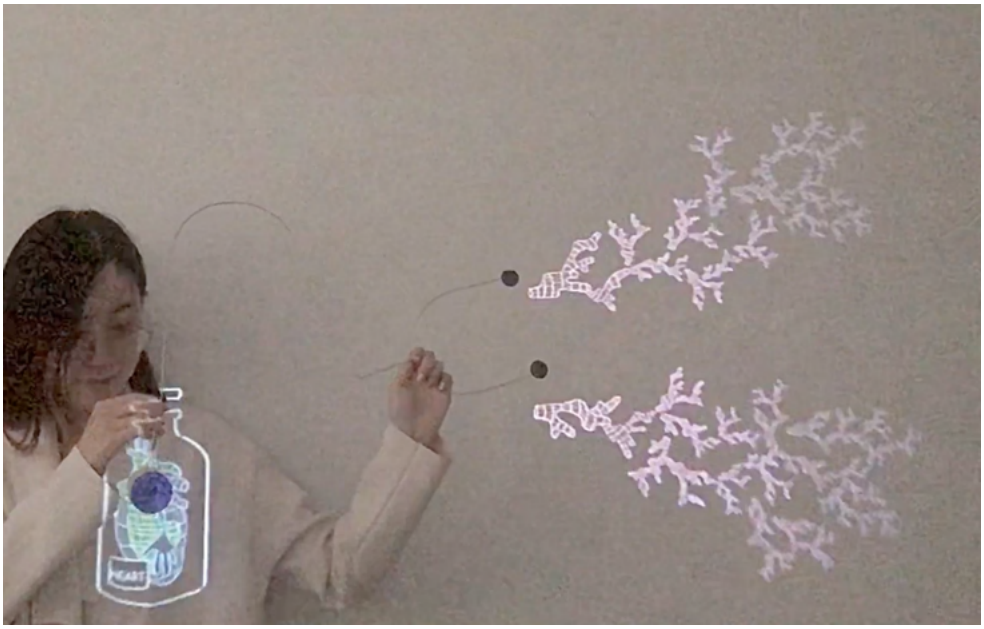

Figure 31: First Prototype. S. Cao. 2020.

The idea of my first prototype was to visualize the participant's heartbeat. The speed of projected animation changes according to the heart rate. In this prototype, I speculated about a clinical

setting where a beating heart and the corel-like visualizations worked as illustrative representations. I also fabricated a rough model of a stethoscope to detect the heartbeat.

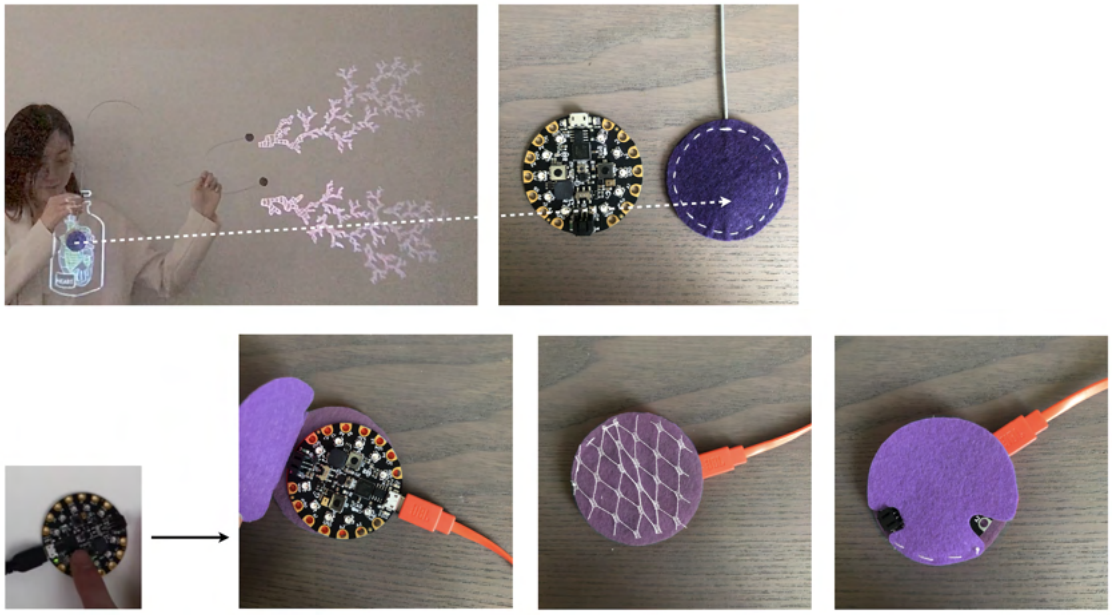

Figure 32: Embedding Sensor into the sculptural object. S. Cao. 2020.

Then I embedded the sensor into the sculptural object - the mimicked stethoscope. The round shape of the sensor fits properly in the fabricated stethoscope made of metal and felt. I use Adafruit Circuit Playground Express to measure my heartbeat by covering the light sensor with my finger, following a guide from the Adafruit Learning System:

> *"When designing the Circuit Playground Express, Ladyada purposely placed the light sensor near the NeoPixel LEDs so that the light from the LED may illuminate a finger and the sensor measure the minute changes in light signalling someone's pulse."*
> (Adafruit Learning System)

The combination of different components worked well in this prototype. However, a problem arose: as a participant and performer, I could not directly see the visualizations to interact freely with this prototype. The participant would be merely passively under detections, but unable to react to the changing visualizations. As a result, the heartbeat would not change accordingly to the visualizations to build up an effective response system.

To solve this problem, I came up with three solutions. Firstly, I could use a large mirror to provide a reflection of body movements. The second solution was that I could set up two opposite walls with contrasting stories going on: perfect and imperfect, positive and negative. In this way, I aimed to explore which side of walls the participants would choose to interact with while perceiving the respective narrations on the other wall. Another solution was that the participant could project his/her shadow as the representation of the body onto the wall with visualizations.

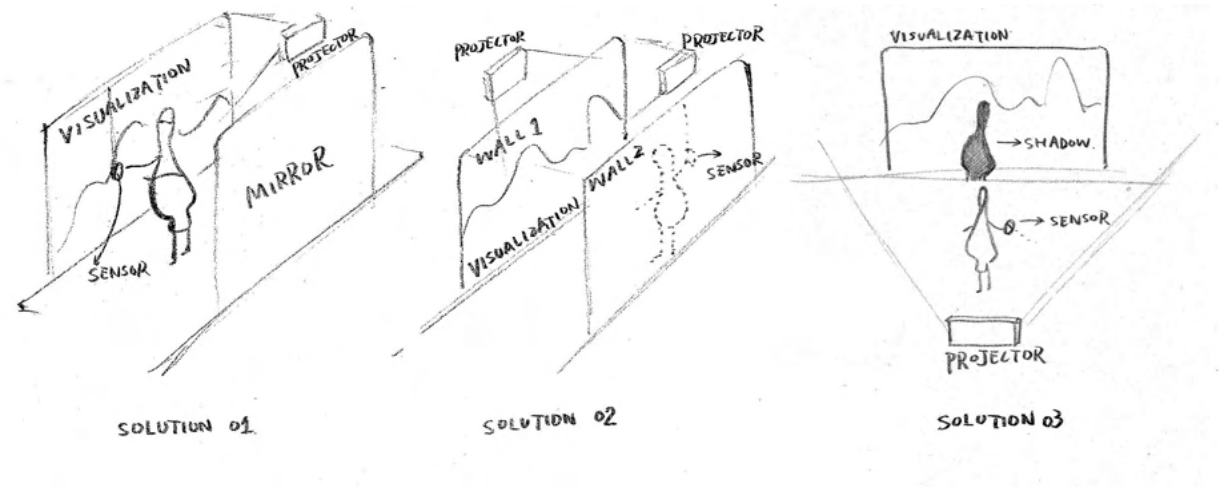

Figure 33: Diagram of three solutions. S. Cao. 2020.

And interestingly, I found that duality as a keyword showed up in these solutions: there are dual sides of a person (physical body and mirrored body/silhouette), dual sides of a story (illuminated and shadowy), and possible opposite responses to different stories (to embrace or to run away).

4.2 Prototype II: Breath Visualization and Pressure Sensor Experiment

Video link: https://youtu.be/xSFaqMvzEPA

In my second prototype, I examined the approach of using shadow to represent the participant's body. The main idea was to visualize the breath. Then the breath became a controller to increase or to lower the level of the water in the "flask", and correspondingly to light up or to dispel the shiny particles. As in return, the updated visualizations impacted the participant's choice of breathing in or out as well as the speed of breathing.

Figure 34: Second Prototype. S. Cao. 2020.
(left1, left2) Animated digital visualization with reference to the shadow of the participant, (right) Actual Projections with my shadow.

For example, the mechanism would be: if the participant breathed in, the water level would increase with the shiny particles gradually lighting up. But as the water increases, its level gets higher than the shadow of the participant. This made the shadow look like drowning in the water. In reverse, if the participant breathed out, then the water level would go down, while at the same time the shiny particles would disappear. This interactivity aimed to examine the reaction of the participants when their shadows are drowned: how they would interact with the story based on what they saw.

In this prototype, the “shadow” became “the other self”, and the interaction became dual states to choose from: drowning with lights or breathing in darkness.

There was also one salient finding in the second prototype: the sound/music added richness to the immersive narrative visualizations, where the emotions could be evoked quickly. This finding motivated me to explore how sound elements could fit in my thesis project, such as the sonification for heartbeat as an ambience tune.

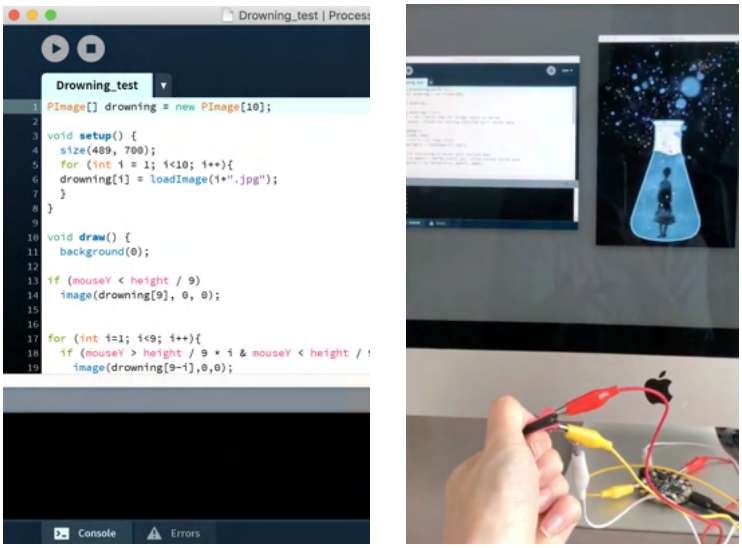

Figure 35: Pressure Sensor Test with Processing and Arduino IDE. S. Cao. 2020.

To examine the procedure of interactions, the first step was to use my mouse as the controller to increase or lower the water level. Due to lack of knowledge on the sensor usage and the computer programs, I did some experiments by employing the ultrasonic sensor and the Arduino Uno to understand how the computer receives and presents the input data. In light of the fact that I failed to find a proper breath sensor, I involved a velostat pressure sensor as a controller instead. The next step was to follow the guides in the book *Make: Wearable Electronics* written by Kate Hartman, the Digital Futures graduate program director at OCAD University and also the director of Social Body Lab. As instructed, I used the materials of two pieces of foam (squishy material), and two pieces of conductive fabric and a piece of velostat (resistive material) to connect with the Adafruit Circuit Playground Express.

This was how it worked: if the participant pressed on the velostat sensor, the generated pressure would be measured and transported from the sensor to the computer, and then the pre-made visualizations would be activated and keep changing due to the pressure. Thus, the water increased when the pressure increased, and vice versa. When perceiving the visualizations, the participant would be influenced by it and then reacted intuitively to decide if they wanted to increase or lower the pressure.

The velostat pressure sensor was successfully created and was a solid support for my further work. By employing the same principles, I could easily create another pressure sensor for the *blanket* part in my final prototype.

4.3 Prototype III: Breath Visualization

Video link: https://youtu.be/qjXrKJpUtPw

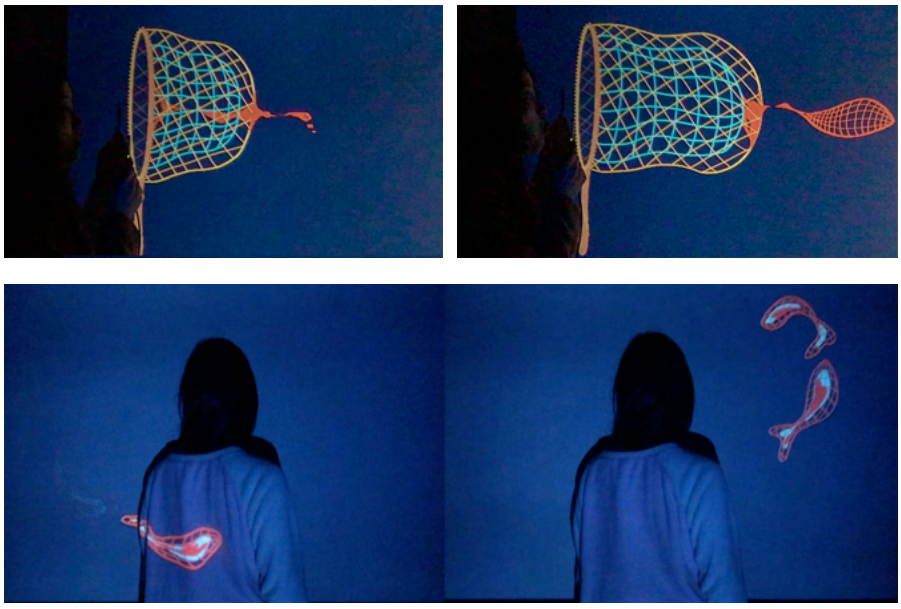

Figure 36: Third Prototype of Breath and Blow. S.Cao. 2020.

The third prototype was an experiment of using breath to generate visualizations. The purpose was to test if the sensor could properly detect the blowing pressure, and how the elements fit in the context.

Instead of visualizing the breath in and out, I decided to visualize the blowing breath based on two reasons. One was that the Adafruit Circuit Playground Express could measure the blows conveniently, and the other reason was that the action of blowing out could be referred to as "giving birth", where I gave birth to the fishes in this prototype.

With the metaphor of fishing nets, when the participant blew to the sensor, the fish grew up and swam out of the expanding fishing nets. After the blowing pressure reached a certain level, a fish was then finally born and began to swim around the participant. Apart from the fishing net or dreamcatcher representation, the blowing action could also be represented as blowing out bubbles that initiated the memory and dreams of childhood, or blowing out the candles that enlightened the daydreams. The final prototype was greatly inspired by these concepts. Therefore, the visualization in the final prototype initiated with the bubble blowing and ended with the candle extinguishing.

FINAL PROTOTYPE

5.1 Installation/Exhibition Design

I used clinical references in the first two prototypes as to the fact that human biosignals related to the medical field. As a result, my initial design for the installation involved a series of medical elements. The arrangement was inspired by the installation project *Mecaniques Discursives* created by Fred Penelle and Yannick Jacquet. Their installation was based on an organized visual diagram that effectively guided the participants.

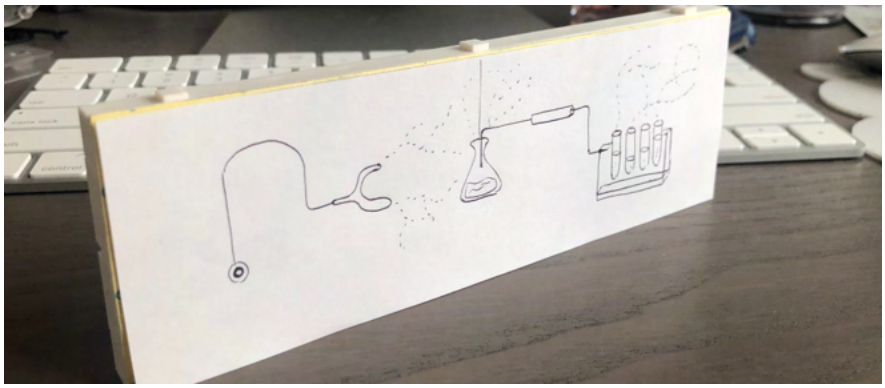

Figure 37: First sketch for the installation / exhibition. S.Cao. 2020.

Figure 38: Mecaniques Discursives by Fred Penelle & Legoman. 2011.

However, after making three prototypes, I started questioning the rationale of arranging the visualizations in such a way for my project. Instead of separating the stories of heartbeat, breath and movement, I determined to reconcile the individual visualizations into a unified scenario

because these biosignals mutually exist in the human body. These stories were supposed to be in the same context. Figure 39 and Figure 40 present my sketch of the first and second installation scenarios for the exhibition.

Figure 39: Installation Sketch of First Scenario. S. Cao. 2020.

Figure 40: Installation Sketch of Second Scenario. S. Cao. 2020.

Due to the situation of Covid-19, it was impossible to invite any participants to experience a public exhibition, so as a performer I would be the only agent to interact with this project. Yet the plans for exhibitions in the future to engage public audiences were under consideration.

Figure 41 presents the instruction for participants to look at before interacting in this installation.

Figure 41: Pop-up instruction for participants. S. Cao. 2021.
Video Link: https://youtu.be/osa-yZjcOlw

5.2 Final Prototype: *A Voyage Within Forgotten Daydreams*

Video link: https://youtu.be/8FnfR9TvkMQ

To deliver a combined narration, I situated all the components in one unified installation, spatially situating the physical objects and the digital visualizations in a balanced way. As mentioned in Chapter 3.1, the final prototype is based on my poem of daydream. I wrote it in Mandarin which is my mother tongue, and translated it into English.

In that sunset,
you stood in the ocean with bare feet.
"Is there another world?" You asked.
"Yes." I said. "There is."
"Why?"
I did not know.

The sun was the same one that I had always seen.
The ebbs and flows, the sunrise and sunset,
that changed the shape of my shadow.
But my presence is still the same.
My breath, my heartbeat, my footprint.
I engraved on the sand with my toes:

I am scared of burning.
I am burnt by the sun.
I am scared of suffocation.
I am drowning in the ocean of rain.
I am scared of forgetting.
I am caught by forgotten daydreams.
Like a ghost.

那天的夕阳下，你光着雪白的脚踩在海里，
问我，
"你觉得会有其它的世界吗？"
我说，会的，会有的。
你又问："为什么？
我只是希望如此，我也没有答案。

我看到过的太阳，始终只是那一个。
潮起潮落，东升西下，
在我的皮肤烙下变化。
我却还是我，
我的呼吸，我的心跳，我的脚印。
我用脚趾在沙土上写下：

我害怕燃烧，
我渴望化为灰烬。
我害怕缺氧，
我渴望溺水而亡。
我害怕遗忘，
我渴望将梦刺杀，
然后被梦追逐。

This prototype consists of two scenarios. The first scenario depicts the illuminated view of the ebbs and flows as well as the sunrise and sunset, and the biosignals of breath and body movement are used. The participant needs to initiate the visualizations by blowing to the bubble blower. According to the pressure of blowing, the illustrative bubbles would appear and become

larger until it bursts. Then an entire view of the sun and waves emerges. At this moment, the participant is guided to step on the blanket to generate body pressures on the embedded sensors. As the foot touches the blanket's surface, there would be a sound of water drop (that I recorded with a spoon and a water bowl), imitating the feeling of stepping into ripples. Since there are three embedded pressure sensors positioned left, middle, and right under the blanket side, the participant can choose which one to step on. When the pressure increases on one of the sensors, the natural-form organisms will grow in the corresponding position, right next to the participant's feet. After some point, the visualization is no longer brightened. Instead, the background gets darker and flying birds are born from the organic-looking elements. After the visualization is totally darkened, it comes to the second scenario.

Figure 42: First Scenario in the final prototype. S.Cao. 2021.

The second scenario is set in a different aura. Instead of poetically dreaming in a daydream, the participant will be trapped in and chased by daydreams. The daydreams are visualized as countless hands trying to catch the participant. The experience would possibly generate disturbed and turbulent feelings. The pulse sensor in the pocket sonificates the heartbeat with my recorded wheeze. The more the participant is scared, the faster his/her heart beats; and the faster the heart beats, the intenser the wheeze is. To run away from this uneasy dream, the participant has to step on one of the pressure sensors to construct a safe space - in this space, a beating heart in a container works as a candle to light up the surroundings. After a certain time,

the hands will gradually disappear, and the participant can walk to the blower and blow it again. The candle light will be blown out and the participant can escape from this daydream.

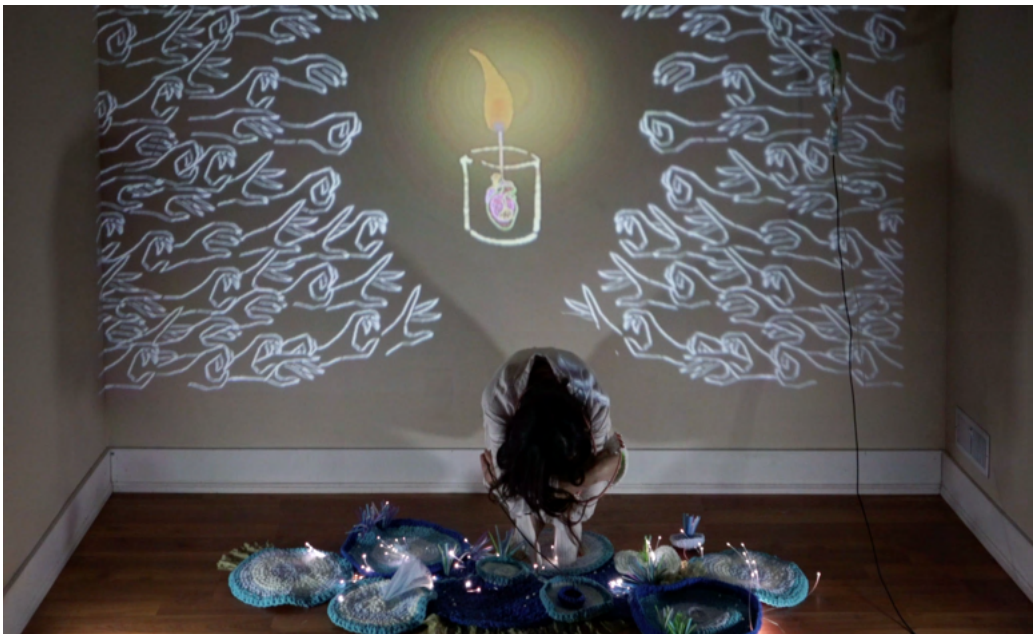

Figure 43: Second Scenario in the final prototype. S.Cao. 2021.

A significant takeaway in this prototype is that proprioception is an important sense while interacting with the installation. Proprioception refers to the sensations that come to humans through muscles and tendons and joints, and could be related to self-awareness of motions or biological changings (Lanier and Weyl 76). It is a sense of position and movement, falling under our "sixth sense", such as knowing what texture the feet are on without looking. The knitted blanket used in this prototype provides a soft feeling for the sense of proprioception. The participant needs to use this sense to balance the body position and to move freely to respond to the visualizations. And my understanding of proprioception is that our sense of our body is beyond its physical boundaries, thus interactive works can activate this limited space.

Also, the combination of the traditional craftsmanship (sculptural objects) and digital media (visualization, sonification) provides a balanced space for interactive performance. The dual sides of the daydreams are presented as two scenarios in this prototype, with potential to prompt the participants to consider how they would reflect on different narrations.

CONCLUSION

6.1 Reflection

This research aims to forge a comprehensive experimentation of how art and technology together could unpack an immersive and interactive space to connect with the human body. Using the theoretical framework (Biosignal Visualization, Daydreaming, Performance in an Immersive and Interactive Setting, and Hybrid Arts) as a supportive structure, the practice-based research methodology as a valuable approach, I particularly benefited a lot from my iterations of prototypes - both the achievements and failures during the making process. For instance, the difficulty with interaction in the first prototype led me to the idea of duality, and the success of making a velostat pressure sensor in the second prototype strengthened my confidence to work with sensors.

In the final analysis, one interesting finding was that I gravitated to create a unified, balanced, and harmonious aura intuitively while creating this thesis project - I sought for the duality of a narration, the unification of interdisciplinary methods, the intersection of hand craftsmanship and technology, as well as the balance in mixed realities. For example, I presented both bright and shadowy sides of daydreams through narrative visualizations, and I successfully merged the handmade artifacts and digital devices.

The biggest challenge in this research was that because of the Covid-19, instead of inviting participants to interact with my project, I as the creator had to play the role of the participant in this interactive and immersive installation. The other significant challenge for me was to figure out how the sensors and computer softwares could fulfill my demands. During the making process, there were coding issues coming up. I especially appreciate the help from my partner Frank Zhao, who offered generous technical support to my thesis project. Through the iterations, these challenges offered a great opportunity for me to gain knowledge on unfamiliar fields, which added breadth and depth to my interdisciplinary art profession.

As to the impact of Covid-19, I was not able to participate in the open exhibition that could have had the potential to invite public participation. In my previous works, I tended to involve multiple others in my projects, which led me to think about including collective individuals in this thesis work. By extracting interesting findings from participants' collective responses to the

changing visualizations through interaction, I aim to explore how the process and result could be connected to the significant theory of *social dreaming*. Despite different perspectives of *social dreaming* described in the books *Speculative Everything* (Dunne and Raby) and *Social Dreaming in the 21st Century* (Clare and Zarbafi), my understanding of *social dreaming* is to share our dreams to a larger group, and together to explore the unexplored to yield new ideas. By involving more participants to experience this thesis project in the future, I will further explore the possibilities of using collective imaginations to move toward social dreams and social changes.

6.2 Future Research

Apart from the future plan to set up an open exhibition for more participants and to collect their feedback as a user testing, there are other research directions to consider.

For the short-term research, I have the following directions:

1. Opening up more space for participants to freely explore in this project. For example, instead of arranging the elements in two predesigned scenarios, I can set the visual components in a database for the participants to choose from to build their unique daydreams.

2. Continuing the research for the hybrid materials "where electronics and smart materials are embedded in traditional ones" (Lim et al. 403). Since the (Adafruit Circuit Playground Express was a powerful board with many built-in sensors, in this thesis project I mostly used it in a direct way. I would like to gain more knowledge on the technical side and endeavor to use material and texture itself as a part of soft engineering. In this way, the art and technology would merge more smoothly, and could offer potentials for creating portable wearable pieces.
   Also, I used the fiber optics as a part of the blanket in my final video documentation. I would consider how this element could be better related to my practice except for the current role as a lighting source and an additional pattern. Plus, I would explore more on the sonification practice as I used sound to represent the pulse in this project which shows much potential for me to develop further.

3. Researching for the theory of *proprioception* which came up non-negligible in this thesis project. The connectedness of how the participant interacted with the surroundings was important: how the body moved within a physical or virtual spatial dynamics, how the participant was aware of the biological changings, and how the brain would perceive and reflect on the visual experience based on cognitive engagements.

For potential long-term research, I am also interested in visualizing human biosignals through easily accessible ways (such as using a wearable interface with sensors to detect the signals), and presenting the narrative visualizations through portable digital devices or through Virtual Reality devices (by using haptic objects as interface). The interest of interpreting this project to an online platform is motivated by the Covid situation. While the need of social distancing eliminated most of the opportunities for people to be in a gallery or other enclosed public spaces, I kept thinking how art works could survive in such an environment.

Also, during my thesis research phase, I took a six-month internship at Myant Inc. where the company concentrated on Skiin product to track and visualize the health data for better family cares. As stated on the website,

> *"Our clothes create a comprehensive baseline of your health and well-being, and then provide you with information, feedback, and nudges through the Skiin Connected Life App to encourage continuous improvement." (Skiin)*

Inspired by Myant's concept of visualizing biological data in a health context to improve the self and care for family and friends, I would consider to relocate my thesis project in another context. What if I located this project in a medical context? What if the narrative visualization replaced the data infographic in the health applications? Or what if instead of visualizing biosignals, the daydreams (using EEG technology or pure word descriptions) were visualized, aiming to heal the people with mental pressures?

My future research will also include the following papers and books:
Yeboah, Georgina. *The User, The Space and Everything Else in Between: Designing Context-Driven Interactive Spaces through Direct-User Inputs.*
Chatterjee Adnani, Veda. *COUNTING ON: Humanizing self-tracked data in a connected world.*
Jones, Lee. *Your Body of Water: A Somaesthetic Display for Embodied Reflection.*

del Pilar Fernandez Davila, Maria. *Remember you will [not] die: Mortality versus immortality in a world of patterns and randomness*.
Laurie Frick's work : www.lauriefrick.com
Wilson, Stephen. Art + Science Now.
Wilson, Stephen. Information Arts: Intersections of Art, Science, and Technology

I would continue researching the creative form of art from interdisciplinary perspectives and situate the project in a social context, to arouse empathy, to stimulate imaginations, or to heal those who would need it.

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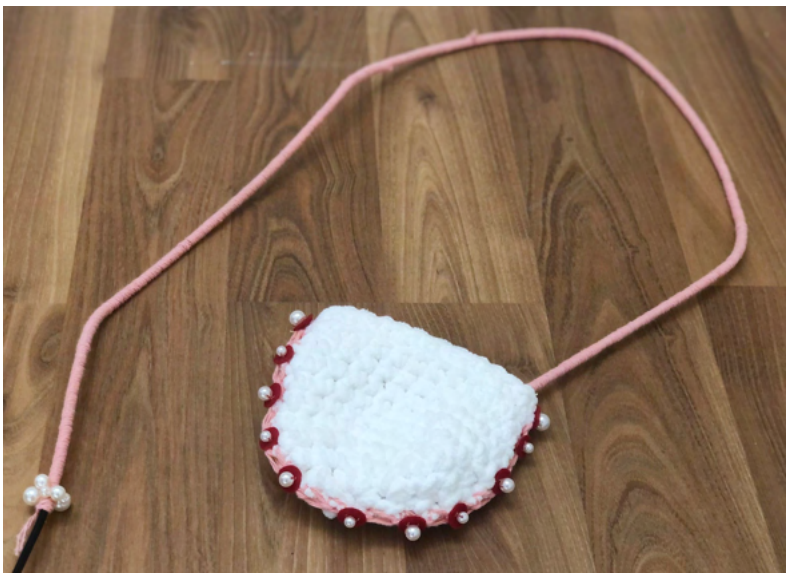
APPENDICES

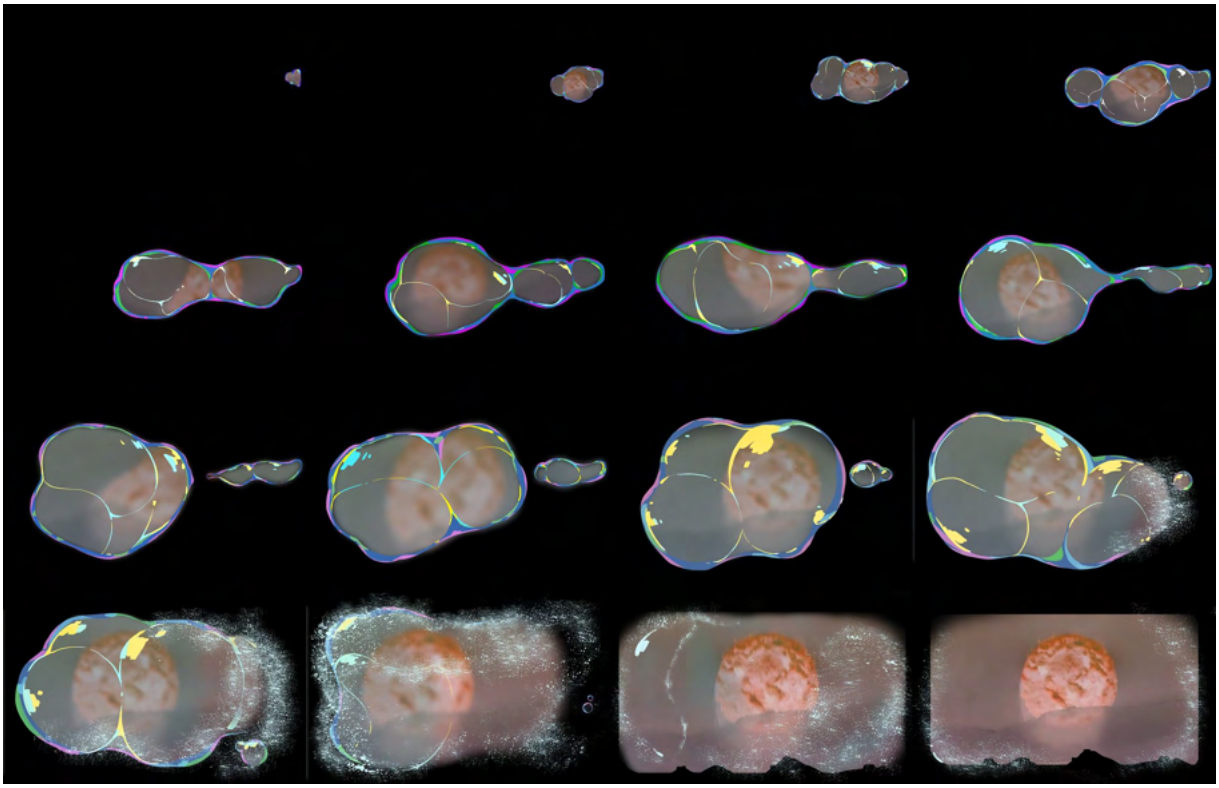
Appendix A: Installation Documentations

Sculptural Object - Blanket. S. Cao. 2021.

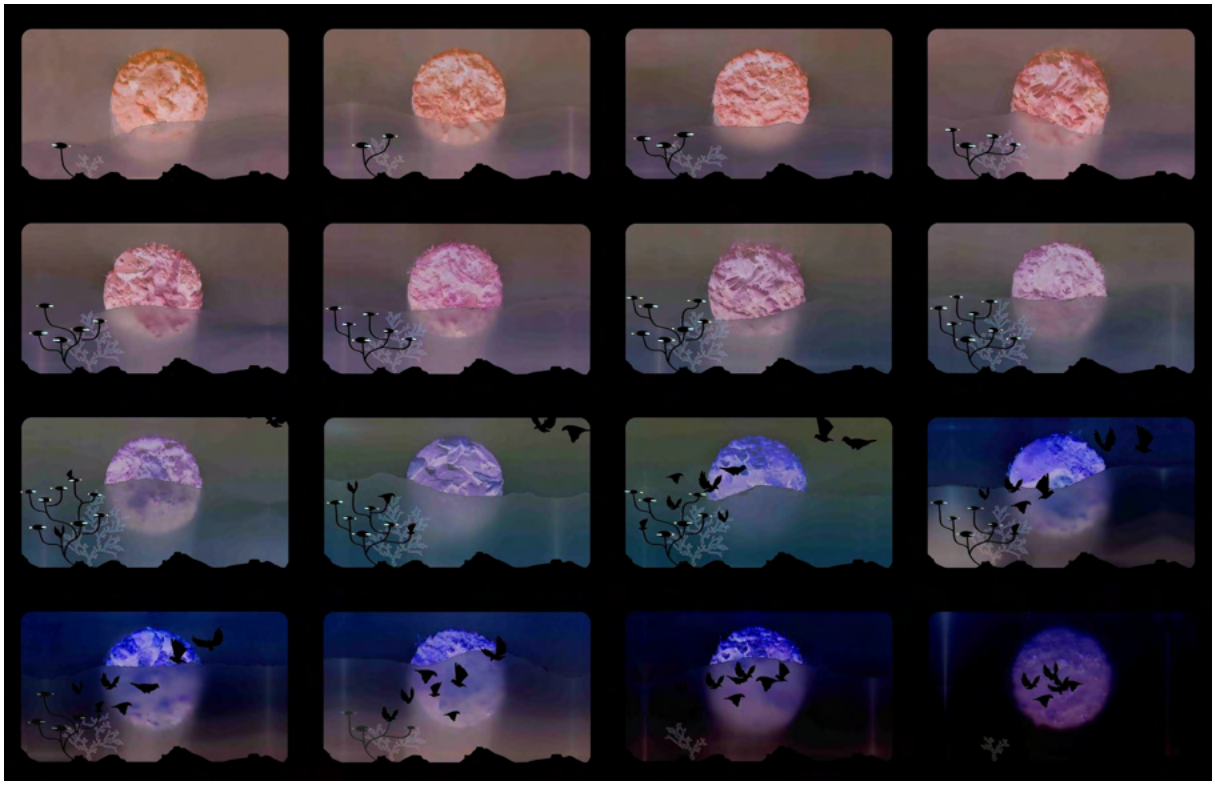


Sculptural Object - Pocket. S. Cao. 2021.

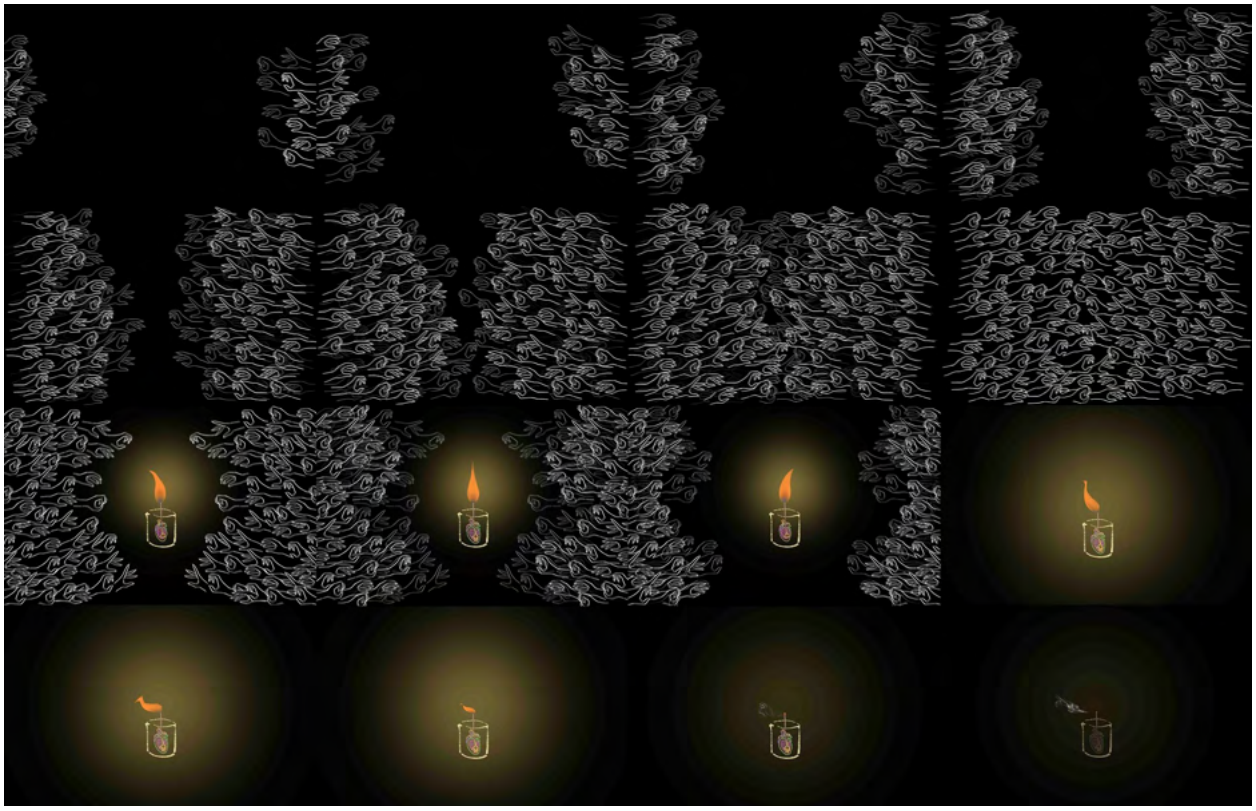
Bubble Blower. S. Cao. 2021.



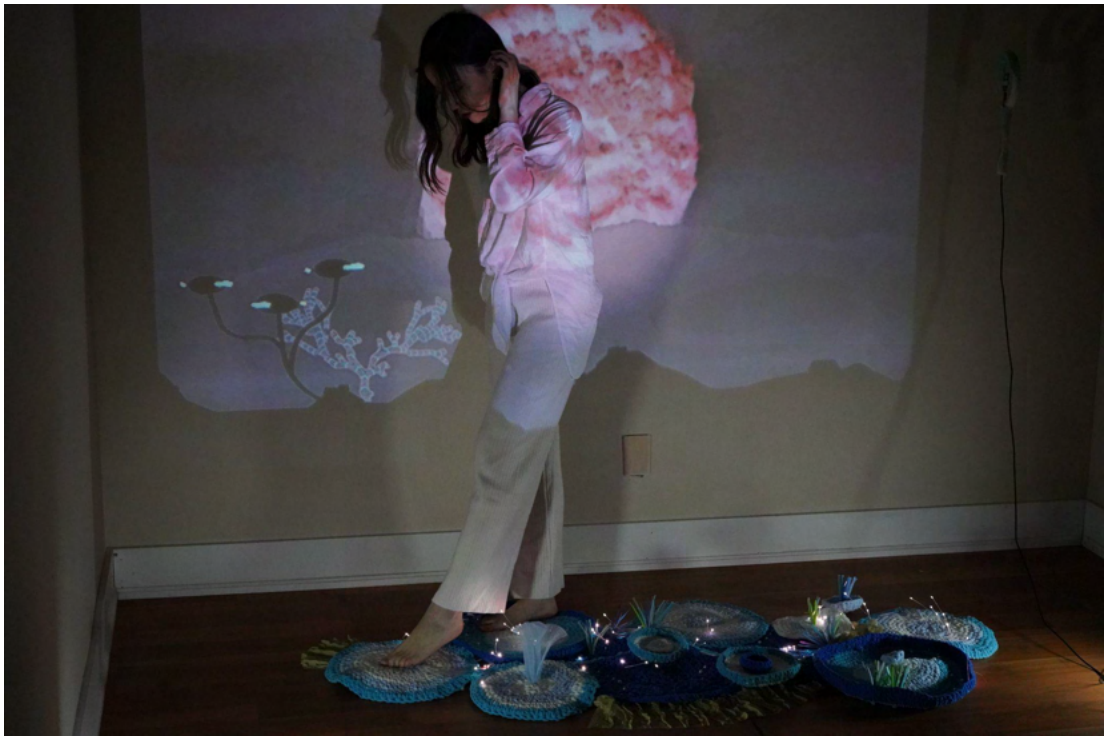
Digital Visual Frames - Blowing out a daydream. S. Cao. 2021.



Digital Visual Frames - First Scenario. S. Cao. 2021.



Digital Visual Frames - Second Scenario. S. Cao. 2021.

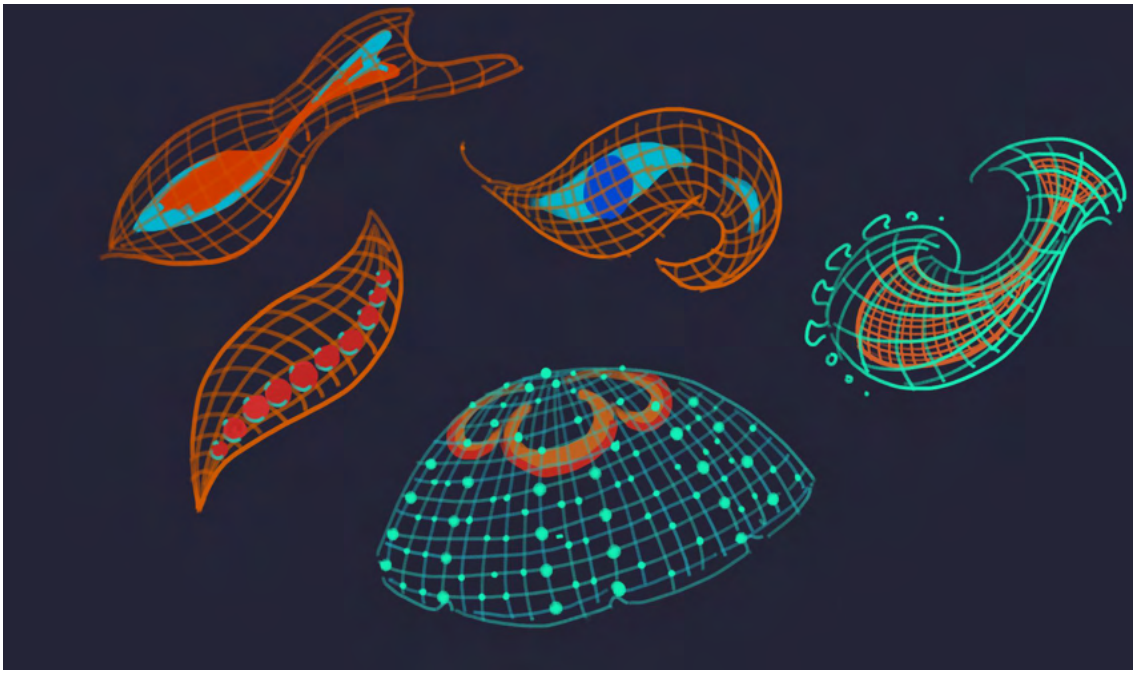


Interacting with the Blanket in the First Scenario. S. Cao. 2021.

Appendix B: Process Documentations

Organic Pigment Experimentation. S. Cao. 2021.

Organic Pattern Experimentation. S. Cao. 2020.



Digital Element Experimentation. S. Cao. 2021.

Digital Element Experimentation. S. Cao. 2021.

Blanket Making Process. S. Cao. 2021.

Pressure Sensor Making. S. Cao. 2021.

Felting Process. S. Cao. 2021.

Knitting Process. S. Cao. 2021.

Appendix C: Poem Collection

huó yú
活 鱼
[meaning: live fish]

它向我游来，
机械地转动着
钉在两边脸颊的眼睛。
我抬起左脚，
它将尾巴甩向左边。
我抬起右脚，
它将尾巴甩向右边。
好像我们之间
产生了微妙的永久平衡。
于是我变成它的影子。

Artificial Fish

It swims towards me,
With its eyes moving mechanically
On separate cheeks.
I lifted my left foot.
It flexes its tail to the left.
I lifted my right foot.
It flexes its tail to the right.
Something is between us
that is equilibrium.
Then I become its shadow.

ping zhōng niǎo
瓶中鸟
[meaning: birds in bottles]

展馆里有一个房间，
悬挂着一排玻璃瓶，
里面陈列着漂亮的小鸟。
我走到其中一只小鸟旁边，
凑近了看她。
过了一会儿，
我发现我被关进了玻璃瓶，
小鸟在瓶口看我。

I step into a gallery room
Hung with some glass bottles,
With pretty birds inside.
I walk close to one of them,
Looking at her,
Closer and Closer.
And I get trapped inside the bottle,
The bird is looking at me outside.

Then I Am In the Bottle

yān zhī
胭脂
[meaning: rouge]

怎么会没有羞臊美梦呢，
蚊子一头扎进胭脂。
我叮咬你的侧脸，
竟也染上，
夏夜的样子。

Blood Of A Mosquito

Isn't there a bliss in my dream,
The mosquito runs into the rouge.
And I bite on your cheek,
Tattooed with the shape
Of a summer night.

As I Blow Out A Daydream

In that sunset,
You stood in the ocean with bare feet.
"Is there another world?" You asked.
"Yes," I said. "There is."
"Why?"
I had no answer.

The sun was always the same one.
The ebbs and flows, the sunrise and sunset,
That changed the shape of my shadow.
But my presence is still the same.
My breath, my heartbeat, my footprint.

wǒ jiāng tā chuī miè
我將它吹滅
[meaning: I blow out (a candle)]

那天的夕阳下，
你光着雪白的脚踩在海里，问我：
"你觉得会有其它的世界吗？"
我说，会的，会有的。
你又问："为什么？
我只是希望如此，我也并无答案。

我看到过的太阳，
始终只是那一个。
潮起潮落，东升西下，
在我的皮肤烙下变化。
我却还是我，
我的呼吸，
我的心跳，
我的脚印。

我害怕燃烧，
我渴望化为灰烬。

我害怕缺氧，
我渴望溺水而亡。

我害怕遗忘，
我渴望将梦刺杀，

然后被梦追逐。

I am scared of burning.
I am burnt by the sun.

I am scared of suffocation.
I am drowning in the ocean of rain.

I am scared of forgetting.
I am caught by forgotten daydreams.

Like a ghost.

rú guǒ gǎn zhī shì fā mèng de yuán xiōng

如果感知是發夢的元兇

[meaning: if sensation is the activator of daydreams]

我在群居宿舍被执法人员赶出住所，
不知缘由。
身边女人紧紧抱着她的孩子，
襁褓里的婴儿没有啼哭。
四岁的女孩在台阶上唱悲伤的歌。

我跑向了车站，不知道要去往哪里。
和我一起逃离的女孩追不及待地上车，
却看到了脏乱的场景
座位上全是恶心的屎渍。
大巴上两个女孩冷漠地说
对不起弄得这么脏。
我永远忘不了这个司机女人眼里的悲伤。

我没有上车，偷返宿舍收拾东西。
可是当我再次离开的时候，
一切却又不一样了。
街上还是一样，很热闹，
学生们讨论着去哪里吃饭。
爸妈也开车找我，好像和平时无异。
朋友发着出去玩的朋友圈，
没有人意识到发生了什么。
我不知所措。

我想要逃离，
于是我挣扎着醒来。
我睁开双眼，大口喘息，
然后我的感官回来了。

我活着的，
好像是两个世界。

If Daydreams Are Fabricating The Sensations

"Get out! Right now!"
The police shouted in a rude manner.
I had to leave my home.
I would call it a home because
It was the only place that I could stay,
Although it was only a cohabitation.
I glanced at the lady standing next to me.
She was holding her baby tightly.
I thought the baby would start bawling
But he did not.
I took my stuff and left.
I heard someone singing a sad song.
It was four-year old girl
Sitting on the stone steps.
The sound of the sound
stabbed my heart,
All of a sudden.

I kept running,
Until I arrived at the bus station.
My companion jumped on to the bus.
But the seats were so disgusting.
Passengers on the bus said drily,
"Sorry about that."
I could not forget the despair
in those eyes of the driver.
She was so beautiful.
But her eyes were so dead.

I turned around,
Did not go on the bus.
Then I turned around again.

It was all the same as before,
Before I had that weird dream.
The students were discussing
where to have dinner.
My parents were driving to pick me up as usual.
I looked at the phone in my hands.
My friends were sharing photos on Instagram.
Nobody knew what happened as I did.

Fireworks were sparkling in the daylight.
Vehicles were flying like winds.
Little princes and princesses
were laughing loudly.
I ran into a flower store and it was warm.

I wanted to escape.
But I was not able to wake up.
I was nailed into my chair.
And I opened my eyes.
My body trembled.
My senses came back.

Where I lived,
Were two worlds.

Appendix D: Software, Hardware, and Codes

Software used in this thesis research:

Adobe Photoshop 2021 (Mac)
Final Cut Pro (Mac)
Adobe Audition 2021 (Mac)
GarageBand (iPad)
Arduino IDE 1.8.13 (Mac)
Processing 3.5.4 (Mac)

Hardware used in this thesis research:

MacBook
iPad
Adafruit Circuit Playground Express
VANKYO Leisure 3 Mini Projector
Sony a7 III Full-Frame Mirrorless Camera

Here presents the coding documentation for the final prototype.
Thanks Tianhong (Frank) Zhao for offering the coding assistance.
Coding reference website: Stack Overflow

1. **BLOW SENSOR**

   Arduino IDE Code:

```
//software version: Arduino IDE 1.8.13; operating system: macOS Big Sur
//source code: Arduino IDE library - Adafruit Circuit Playground - Microphone_Demos
  - Birthday Candle; altered by Frank Zhao, date: 2021.2.20

#include <Adafruit_CircuitPlayground.h>
void setup() {
  Serial.begin(115200);
  CircuitPlayground.begin();
}
void loop() {
```

```
  float sample = CircuitPlayground.mic.soundPressureLevel(50);
  Serial.println(sample);
  delay(200);
}
```

Processing Code for blowing bubbles:

```
//software version: Processing 3.5.4; operating system: macOS Big Sur
//code: written by Shunrong Cao, integrated by Frank Zhao, date: 2021.2.21

import processing.serial.*;
Serial mySerial;
String myString = null;
float myVal;

PImage[] bubble = new PImage[18];

void setup() {
  String myport = Serial.list ()[1];
  mySerial = new Serial (this, myport, 115200);
  for (int i = 0; i < 18; i++) {
    bubble[i] = loadImage("bubble"+(i+1)+".jpg");
  }
  fullScreen();
  frameRate(30);
}

void draw() {
  while (mySerial.available()>0){
   myString = mySerial.readStringUntil('\n');
   if (myString != null)
    myVal = float(myString);
   println(myVal);
    int i = (int) (myVal-65) / ((105-65)/17);
```

```
    if (i<0)i=0;
    if (i>=17){
    i=17;
    noLoop();
    }
    background(0);
    image(bubble[i],0, 0, width, height);
  }
}
```

Processing Code for blowing out the candle:

```
//software version: Processing 3.5.4; operating system: macOS Big Sur
//code: written by Frank Zhao, date: 2021.2.26

import processing.serial.*;
Serial mySerial;
String myString = null;
float myVal;
int final_index = 0;
boolean increase_index = true;

PImage[] blow = new PImage[8];
PImage[] final_img = new PImage[3];

void setup() {
  String myport = Serial.list ()[1];
  mySerial = new Serial (this, myport, 115200);
  for (int i = 0; i < 8; i++) {
    blow[i] = loadImage("blow"+(i+1)+".jpg");
  }
  final_img[0] = loadImage("final_left"+".jpg");
  final_img[1] = loadImage("final_mid"+".jpg");
```

```
  final_img[2] = loadImage("final_right"+".jpg");
  fullScreen();
  frameRate(10);
}

void draw() {
  while (mySerial.available()>0){
   myString = mySerial.readStringUntil('\n');
   if (myString != null)
   myVal = float(myString);
   println(myVal);
   if (myVal < 65){
    if (final_index==2)increase_index=false;
    if (final_index==0)increase_index=true;
    background(0);
    image(final_img[final_index], 0, 0, width, height);
    if (increase_index)
     final_index++;
    else
     final_index--;
   }
   else{
    int i = (int) (myVal-65) / ((105-65)/8);
    if (i<0)i=0;
    if (i>=7){
    i=7;
    noLoop();
    }
    background(0);
    image(blow[i],0, 0, width, height);
   }
  }
}
```

2. PULSE SENSOR

Arduino IDE Code:

```
//software version: Arduino IDE 1.8.13; operating system: macOS Big Sur
//source code: https://www.youtube.com/watch?v=Rfko5UnqDI4;
   altered by Shunrong Cao, date: 2021.2.24

#include <Adafruit_CircuitPlayground.h>

void setup () {
 while (!Serial);
 Serial.begin(9600);
 Serial.println("Pulse test");
 CircuitPlayground.begin();
 CircuitPlayground.setPixelColor(1, 0, 255,   0);
 }

void loop() {
 Serial.println(CircuitPlayground.lightSensor());
 delay(20);
}
```

Processing Code:

```
//software version: Processing 3.5.4; operating system: macOS Big Sur
//source code: https://www.youtube.com/watch?v=QbTogbZG1Io
//altered by Shunrong Cao, date: 2021.2.21

import processing.serial.*;
import processing.sound.*;
SoundFile file;
Serial mySerial;
String myString = null;
float myVal;
```

```
void setup() {
  size(640, 360);
  background(255);
  String myport = Serial.list ()[1];
  mySerial = new Serial (this, myport, 9600);
  file = new SoundFile(this, "breath.mp3");
}

void draw() {
    while (mySerial.available()>0){
    myString = mySerial.readStringUntil('\n');
    if (myString != null)
      myVal = float(myString);

      System.out.println(myVal);
      if (myVal > 200){
      file.play();
     }
    }
}
```

3. PRESSURE SENSOR

Arduino IDE Code:

```
//software version: Arduino IDE 1.8.13; operating system: macOS Big Sur
//code: written by Shunrong Cao, learned from Kate Hartman's class, date: 2021.2.16

#include <Adafruit_CircuitPlayground.h>

#define ANALOG_INPUT0  A0
#define ANALOG_INPUT1  A1
#define ANALOG_INPUT2  A2
#define VALUE_MIN     0
```

```
#define VALUE_MAX     200

void setup() {
  Serial.begin(9600);
  CircuitPlayground.begin();
}

void loop() {
    uint16_t value0 = analogRead(ANALOG_INPUT0);
    uint16_t value1 = analogRead(ANALOG_INPUT1);
    uint16_t value2 = analogRead(ANALOG_INPUT2);
    Serial.print("mid ");
    Serial.println(value0,DEC);
    Serial.print("left ");
    Serial.println(value1,DEC);
    Serial.print("right ");
    Serial.println(value2,DEC);
    int sum = value0 + value1 + value2;
    Serial.print("sum ");
    Serial.println(sum,DEC);
    delay(500);
}
```

Processing Code for the first scenario:

```
//software version: Processing 3.5.4; operating system: macOS Big Sur
//code: written by Shunrong Cao, integrated by Frank Zhao, date: 2021.3.2

import processing.serial.*;
import processing.sound.*;
SoundFile[] files = new SoundFile[3];
boolean play = true;

Serial mySerial;
```

```
String myString = null;
String[] str_list;
float myVal;
final float sensitivity = 50;

PImage[] left = new PImage[19];
PImage[] mid = new PImage[19];
PImage[] right = new PImage[19];

void setup() {
  String myport = Serial.list ()[1];
  mySerial = new Serial (this,myport, 115200);

  for (int i = 0; i<19; i++){
    left[i] = loadImage("left"+i+".jpg");
    mid[i] = loadImage("mid"+i+".jpg");
    right[i] = loadImage("right"+i+".jpg");
  }
  fullScreen();

   files[0] = new SoundFile(this, "drop1.mp3");
   files[1] = new SoundFile(this, "drop2.mp3");
   files[2] = new SoundFile(this, "drop3.mp3");
}

void draw() {
  while (mySerial.available()>0){
    myString = mySerial.readStringUntil('\n');
    if (myString != null){
      str_list = split(myString," ");
      myVal = float(str_list[1]);
      println("Pos:"+str_list[0]+"value:"+myVal);
      if (myVal > 250 && str_list[0]!="sum"){
        int index = (int)(myVal-250)/40;
```

```
      if (index>=18)index=18;
      if (str_list[0].equals("left")){
       image(left[index],0,0, width,height);
       if (play==true){
        files[0].play();
        play=false;
       }
       break;
      }
      if (str_list[0].equals("mid")){
       image(mid[index],0,0, width,height);
        if (play==true){
        files[1].play();
        play=false;
        }
       break;
      }
      if (str_list[0].equals("right")){
       image(right[index],0,0, width,height);
        if (play==true){
        files[2].play();
        play=false;
        }
       break;
      }
     }
     if (str_list[0].equals("sum")) {
      if (myVal < 450){
      play=true;
      }
     }
    }
   }
}
```

Processing Code for the second scenario:

```
//software version: Processing 3.5.4; operating system: macOS Big Sur
//code: written by Frank Zhao, date: 2021.3.4

import processing.serial.*;

Serial mySerial;
String myString = null;
String[] str_list;
float myVal;

boolean draw_start = true;
boolean light = false;
boolean increase_index = true;
int pic_index=0;
int light_index=0;

PImage[] start = new PImage[10];
PImage[] left = new PImage[3];
PImage[] mid = new PImage[3];
PImage[] right = new PImage[3];

void setup() {
 String myport = Serial.list ()[1];
 mySerial = new Serial (this, myport, 115200);
 for (int i = 0; i<10; i++)
  start[i] = loadImage("start"+i+".jpg");
 for (int i = 0; i<3; i++) {
  left[i] = loadImage("left"+(i+1)+".jpg");
  mid[i] = loadImage("mid"+(i+1)+".jpg");
  right[i] = loadImage("right"+(i+1)+".jpg");
 }
```

```
 fullScreen();
 frameRate(4);
 background(0);
}

void draw() {
 if (!light) {
  if (draw_start) {
   image(start[pic_index], 0, 0, width, height);
   if (pic_index==7)
    draw_start = false;
  } else
  {
   if (pic_index==10)pic_index=8;
   image(start[pic_index], 0, 0, width, height);
  }
  pic_index++;
 }

 while (mySerial.available()>0) {
  myString = mySerial.readStringUntil('\n');
  if (myString != null) {
   str_list = split(myString, " ");
   myVal = float(str_list[1]);
   println("Pos:"+str_list[0]+"value:"+myVal);

   if (myVal > 550 && !str_list[0].equals("sum")) {
    light = true;
    if (light_index==2)increase_index=false;
    if (light_index==0)increase_index=true;

    println("i: "+light_index);

    if (str_list[0].equals("left")) {
```

```
        image(left[light_index], 0, 0, width, height);
       }
       if (str_list[0].equals("mid")) {
        image(mid[light_index], 0, 0, width, height);
       }
       if (str_list[0].equals("right")) {
        image(right[light_index], 0, 0, width, height);
       }

       if (increase_index)
        light_index++;
       else
        light_index--;
       pic_index=0;
      }
      else if (str_list[0].equals("sum") && myVal <= 550)
       light = false;
    }
  }
}
```