Brain-Controlled Interface for the Motile Control of Spermatozoa

A Biopolitical Feminist Work

By Anne [Ani] Liu

Master of Architecture, Harvard University, 2014
Bachelor of Arts, Dartmouth College, 2008

SUBMITTED TO THE PROGRAM IN MEDIA ARTS AND SCIENCES, SCHOOL OF ARCHITECTURE AND PLANNING, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE DEGREE OF

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Abstract

Acknowledging and reflecting upon the cultural and scientific discourses that shape the notions the female body, this thesis presents a biopolitical feminist work in which a woman controls the motility of spermatozoa through the agency of her thoughts. The intellectual investigation of this project is threefold: 1. to engineer a system that directs the movement of sperm via the signals of brain activity, 2. to communicate the project aesthetically and expressively through art and design, 3. to situate the project philosophically and pose critical cultural questions.

Technologically, this project implements a brain-computer interface, where the electric signals generated by the brain are translated into a system engineered to control the movement of sperm through a phenomenon known as galvanotaxis.

Philosophically, this project is situated within Michel Foucault's notion of biopolitics, and Donna Haraway's theorization of the body as a material-semiotic actor. While Foucault lays the foundation for exposing the body as a battleground for political power, the ideas of Haraway respond to the inherent gender prejudices of this landscape by disassembling the binary of sex through technology to spark a reimagining of new corporeal futures.

Artistically, this thesis creates an act of female empowerment, responding to political regimes in which women are losing rights related to procreation within her own body. Investigating the body as a medium of culture, this project raises questions as to how we operate in our politically gendered landscape.

Navigating the divergent connections between art and science, this work challenges the viewer to question what is possible. Whereas our biological understanding of sperm is usually deterministic (i.e., as an inherent homing device racing towards the chemical signatures of an egg) or colored by gendered cultural constructs (i.e., its semiotic use in pornography) this project seeks to invert all

preconceived notions. By creating a work that is simultaneously technological, functional, and symbolically potent, it seeks to expand our notions of what it is possible, and what is possible to question.

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I owe my deepest gratitude to Hiromi Ozaki, Anthony Dunne, and Paola Antonelli for their guidance and support in my quest to think critically and discover the world through the double eyes of art and science.

I wish to thank my mentor Krzysztof Wodiczko for igniting the spark that would cause me to firmly chase this path of interrogative design.

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No dedication could be complete without mentioning my loving family, Mindy, Henry, William, and Moby. I want to especially thank Adam, for his incredible patience, love, and undying support towards my obsession for art.

Last but not least, I wish to deeply thank my parents, who came to this country as immigrants and labored with blood, sweat and tears to give me every opportunity to pursue my dreams. To them, I owe everything.

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Figure 5.7 Example of the storyboard. Description included a visual sketch in the form of a drawing or prototype photograph, the camera direction, and the voiceover. Image credit: Ani Liu.

Figure 5.8 A shot list for the day of filming. Primary considerations involved whether the model would sit behind the projection, or actively be immersed in it from above. Image credit: Ani Liu

Figure 5.9 Film still from the video. Image credit: Ani Liu.

We need the arts because they make us full human beings. But we also need the arts as a protective factor against authoritarianism. In saving the arts, we save ourselves from a society where creative production is permissible only insofar as it serves the instruments of power.

Eve L. Ewing
Why Authoritarians Attack the Arts

1.

Introduction

1.1 The Current Political Landscape

The female body has long been a site of contention, where opposing ideologies in religion, politics, and cultural differences often play out. A body is not just a body; it has become a vessel by which systems of ideas are manifested. Can a woman vote or serve in the military? Does she have agency in deciding her own reproductive health choices? Can she wear pants, or must she be veiled? The first two examples-- voting and serving in the military-- reflect the way we construct our political reality through the civic administration of bodies. The second example, that of reproductive health, reflects the complex interplays between our scientific and cultural beliefs surrounding biology and what we consider "natural." The last two examples-- the type of garment she is or is not allowed to adorn her body with-- serve as reinforcing cultural signifiers for our beliefs.

It is well into the twenty-first century at the writing of this thesis, and although I live in a well developed Western democracy, gender inequalities still persist. These inequalities are pervasive in a myriad of ways: reflected in the disparity of gender diversity in political representation and participation, in the gender pay gap, in prejudice, and in violence and sexual assault. Closely related to these issues of gender inequality is that of women's health, and who has control over these choices. In 2017, US President Donald Trump signed an executive order which cut off all U.S. funding to international NGOs whose work includes abortion services or advocacy.[1] Images of this executive order being signed by Donald Trump flanked by a cabinet of men have widely circulated, with the subtitle, "As long as you live you'll never see a photograph of 7 women signing a legislation about what men can do with their reproductive organs."[2]

Figure 1.1: Twitter image about Donald Trump indicative of political climate. Caption reads "As long as you live you'll never see a photograph of 7 women signing a legislation about what men can do with their reproductive organs." Image credit: Martin Belham. Retrieved from http://www.twitter.com/martinbelam

[1] Koran, Laura, and James Masters. "Trump reverses abortion policy for aid to NGOs." CNN. January 24, 2017. Accessed February 05, 2017. http://www.cnn.com/2017/01/23/politics/trump-mexico-city-policy/.
[2] WITW STAFF. "Photo of Trump and male staffers signing anti-abortion measure inspires feminist satire." New York Times. January 27, 2017. Accessed February 5, 2017. http://nytlive.nytimes.com/womenintheworld/2017/01/27/photo-of-trump-and-male-staffers-signing-anti-abortion-measure-inspires-feminist-satire/.

This image, along with the caption, brings to light the gender imbalances in the authorities making policies concerning women.

Devastatingly, beyond his political actions, U.S. President Trump has also been recorded making incredibly misogynist statements, including: "You can do anything … Grab them by the pussy. You can do anything."[3] Statements such as these, combined with executive orders that specifically impact particular genders create a biased illusion of normality. Recent events such as these, along with a long history of gender inequality, have caused me to investigate the interwoven forces that shape our perceptions of gender, and to consider how we might shift them.

1.2 Science and Cultural Critique

The theory of the human body is always a part of a world-picture…
The theory of the human body is always a part of a fantasy.

James Hillman, "The Myth of Analysis"

The subjectivities of humans have long been influenced by scientific and technological developments. As we know from the writings of critical designers Anthony Dunne and Fiona Raby, technology is never neutral, it carries ritual and symbolic meaning.[4] But perhaps more more

[3] "Transcript: Donald Trump's Taped Comments About Women." New York Times. October 8, 2016. Accessed January 5, 2017. https://www.nytimes.com/2016/10/08/us/donald-trump-tape-transcript.html?_r=0.
[4] Dunne, Anthony. Hertzian tales: electronic products, aesthetic experience, and critical design. Cambridge, Mass: MIT Press, 2008.

camouflaged is the way science, despite its attempt for objectivity, is also tainted by social prejudices. As an artist at an institution of science and technology, I have become interested in how scientific theories shape gender stereotypes.

While the goal of science is to gain objective knowledge of the world, scientists themselves are human, subject to the influences of our culture. Certain stereotypes and norms affect the way findings about the natural world are described, at times, engendering biases.[5] Perhaps one of the clearest ways these gender stereotypes are observed are in the scientific writings about reproductive biology, where the "natural" inferiority of women is lodged in the subtext. Many major scientific texts depict sperm as an active entity, while the egg is seen as passive. Sperm is often described with enthusiasm- with an emphasis on its "sheer magnitude" of production. On the other hand, medical texts will describe menstruation as "the debris of the uterine lining," utilizing words such as "ceasing," "dying," "losing," denuding," and "expelling."[6] In a compilation of scientific images, a electron micrograph of an enormous egg next tiny sperm is titled "A Portrait of the Sperm."[7] As science anthropologist Emily Martin points out, "This is a little like showing a photo of a dog and calling it a picture of the fleas."[8] These warped scientific descriptions imbue a scientific myth of the inferiority of the female body- further affecting our cultural landscape. Beyond shining a light on these imbalances, how might we utilize the tools of science to reconfigure them?

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[5] Agapakis, Christina. "No, there aren't "two cultures"." Scientific American. January 21, 2014. Accessed May 07, 2017. https://blogs.scientificamerican.com/oscillator/no-there-arene28099t-e2809ctwo-culturese2809d/.
[6] Martin, Emily, "The Egg and the Sperm: How Science Has Constructed a Romance Based on Stereotypical Male-Female Roles," Signs: Journal of Women in Culture and Society 16, no. 3 (1991): , doi:10.1086/494680.
[7] Nilsson, Lennart, "A Portrait of the Sperm," in *The Functional Anatomy of the Spermatozoon,* ed. Bjorn A. Afzelius (New York: Pergamon, 1975), 79-82.
[8] Martin, Emily, "The Egg and the Sperm: How Science Has Constructed a Romance Based on Stereotypical Male-Female Roles," Signs: Journal of Women in Culture and Society 16, no. 3 (1991): , doi:10.1086/494680.

As Sophia Roosth and Astrid Schrader eloquently ask in their article "*Feminist Theory Out of Science: Introduction"*:

> **"What is the relationship of critical feminist theory to science studies? How might we envision critical theory's encounter with scientific accounts of the world? Might we read scientific theories as already critical, the lived world as already doing science, busily generating theories of itself?.... How do scientific theories inform cultural critique? How might scholars generate critical theories *out of* scientific ones?"**[9]

With every technology and scientific breakthrough, our plastic subjectivity goes through modifications and expansions. As an artist, I reflect on and expose these forces in works incorporating the language and techniques of science and technology. In the creation of this thesis, two systems of thought related to gender are investigated: that of biology, and that of body politics. Bridging between these systems is culture- our notions of gender do not solely exist anatomically- they are constructed culturally, subjectively, and socially. These social constructs are both affected and affect by our scientific objectivity and political veracity. It is my aim to harness what I've learned to subvert the status quo of what we know about the egg and sperm to draw to reveal the absurdities of current control practices regarding gender and reproductive health.

1.3 Motivation: A Feminist Response to the Biopolitical Landscape

Reflecting on the cultural and scientific discourses that shape notions of the female body,

[9] Roosth, S., and A. Schrader. "Feminist Theory Out of Science: Introduction." Differences 23, no. 3 (2012): 1-8. doi:10.1215/10407391-1892880.

in an expression of female empowerment, I engineer a system by which I (a woman) can control something inherently and symbolical male: spermatozoa (sperm). Through the use of a brain-computer interface, I control the movement of sperm along an XY axis with the agency of my thoughts.

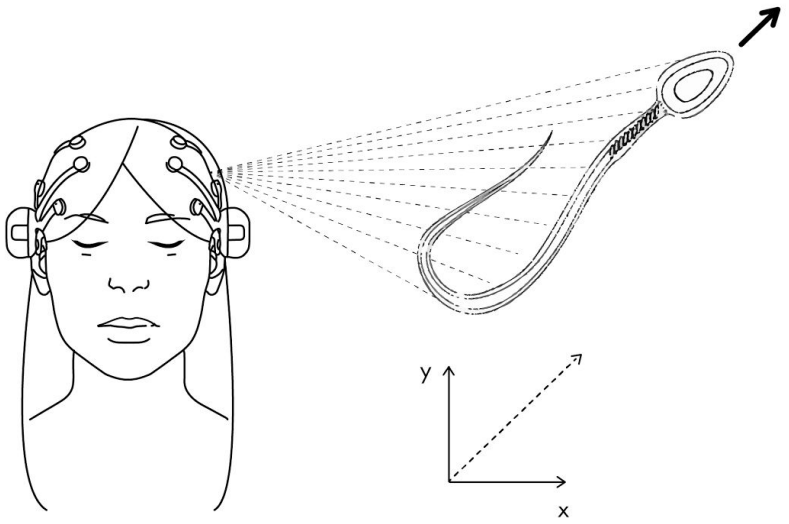

Figure 1.2: Diagram of project concept, in which a woman controls sperm with her mind. While at first pass the idea of controlling sperm might be absurd, it is my hope that it causes the viewer to reflect on the very real absurdities of control happening to the bodies of women. Image credit: Ani Liu

While at first glance the idea of controlling sperm might be absurd, it is my hope that it causes the viewer to reflect on the very real absurdities of control happening to the bodies of women. Genital mutilation, forced sterilization, sexual abuse, rape, and contraceptive regulation currently occur as forms of control projected onto female bodies. In creating a subversive counter-narrative to these practices of control, this thesis presents a hope for reimagining and shifting our notions of gender.

1.4 Thesis Overview

Through the following pages, I [1.] present the political context that motivated the creation of this work, [2.] trace the philosophical and theoretical frameworks to which this work contributes, [3.] explain the project technologically, and [4.] describe the aesthetic decisions involved in communicating this project as a work of art.

Philosophically, I will trace technologies of bodily control as a main mechanism for the manifestation of power by governing entities, referencing Foucault's notion of biopolitics. To respond to the inherent gender inequalities in this biopolitical landscape, I refer to the work of Donna Haraway's *Cyborg Manifesto*, to position the body as an evolving entity, as augmented by technology, laying the foundations for a work of art that reimagines the thresholds of sex and gender.

Technologically, this project instrumentalizes a natural phenomenon known as galvanotaxis, by which the movement of an organism is affected by an electric field. A commercial grade brain-computer interface records EEG signals from the user, and translates them into signals that operate a circuit built to control the movement of sperm. This movement is captured by a digital microscope, processed by a computer, and projected into a room where the performance of the mind-controlled sperm takes place. The whole performance is documented and made into a film for further distribution and discussion online and in galleries.

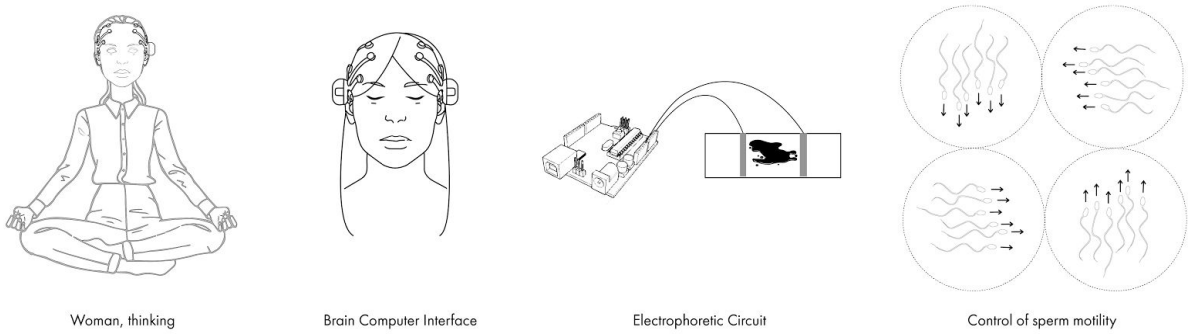

Figure 1.3: Diagram of the key components of the project. Thoughts are captured by a brain-computer interface and rendered through a microcontroller programmed to create conditions to direct the movement of sperm. Image credit: Ani Liu

As a work of art, this thesis creates an act of female empowerment, responding to patriarchal regimes in which female reproductive rights are being challenged. Investigating the body as a medium of culture, this project raises questions on how we operate in our politically gendered landscape. Through the use of science and technology as a medium, this thesis presents a hope to expand our notions of what it is possible in the cultural landscape of reality.

2.

Background & Related Work

2.1 Art Influences

Art can change our political habits.
Tania Bruguera

2.1.1 Feminist Art

Barbara Kruger

The image below is pinned to my laboratory bench and continues to inspire my work. Barbara Kruger created this image for the Women's March in 1989 to protest a wave of anti-abortion laws contesting the 1972 Roe v. Wade Supreme Court decision. Iconic, stark, and bold, this image speaks

to the role of media in politics. Utilizing the language of tabloids, being authoritative, direct and sensational, Kruger reclaims commercial aesthetics for the use of cultural critique. In a similar vein, I aim to use the language and tools of science and technology to make a provocation on who owns the decision making rights on the female body.

Figure 2.1: Barbara Kruger created this image for the Women's March in 1989 to protest a wave of anti-abortion laws contesting the 1972 Roe v. Wade Supreme Court decision. Utilizing the language of tabloids, being authoritative, direct and sensational, Kruger reclaims commercial aesthetics for the use of cultural critique. In a similar vein, I aim to use the language and tools of science and technology to make a provocation on who owns the decision making rights on the female body. Image credit: Kruger, Barbara. (1989). *Untitled [Your Body is a Battleground].* Photographic silkscreen on vinyl. 112 x 112 in. Accessed February 4, 2017. Retreived from http://www.thebroad.org/art/barbara-kruger/untitled-your-body-battleground

French Feminist Group- 52

In a satirical response to the official signing of the "Global Gag Rule", which bans international groups associated with abortion rights from receiving US funding, French Feminist collective 52 (named in acknowledgement that women comprise 52 percent of France's population) created an alternate history in which Hillary Clinton is shown surrounded by women as she signs a ban on male ejaculation for non-procreative purposes.[10]

Figure 2.2: Satire from French feminist group 52: "Breaking News: it is now forbidden to ejaculate outside of procreation in the USA. #PussyGrabsBack #Trump." Image credit: 52 [French feminist collective]. Digital image. Twitter. Accessed February 4, 2017. Retrieved from https://twitter.com/noussommes52
tleground

[10] WITW STAFF. "Photo of Trump and male staffers signing anti-abortion measure inspires feminist satire." New York Times. January 27, 2017. Accessed February 5, 2017. http://nytlive.nytimes.com/womenintheworld/2017/01/27/photo-of-trump-and-male-staffers-signing-anti-abortion-measure-inspires-feminist-satire/.

As Sophie, a 52 member explains in an interview: "It's a joke...to ridicule something that boggles the mind: For centuries, it's been men who dictate women's bodies. Women are told what they should wear, what salary they're entitled to." She goes on to state, "Trump has only just become president, and the first thing he does is take a step backward by signing this piece of legislation."[11] A provocative design fiction, this photo collage ridicules the gender inequalities that continue to exist in today's culture.

2.1.2 Performance Art as Protest

Another influential piece of art in the research of this project is "Interior Scroll" by Carolee Schneemann. In a seminal moment of performance art history, Schneemann pulls a scroll from her vagina, and reads from it. The text is from a filmmaker, speaking about women, and how they were "unable to access access certain traits such as logic and rationality, which he described as specifically male."[12]

As Schneemann explains, the idea behind "Interior Scroll" was to "physicalize the invisible, marginalized, and deeply suppressed history of the vulva, the powerful source of orgasmic pleasure,

[11] Kirschen, Marie. "Meet The French Feminists Behind A Viral Meme About A Male Ejaculation Ban." BuzzFeed. January 26, 2017. Accessed February 03, 2017. https://www.buzzfeed.com/mariekirschen/this-response-to-the-photograph-of-trump-signing-a?utm_term=.viw501Gbo#.tuWon47bQ.

[12] "Feminist Art Movement, Artists and Major Works." The Art Story. Accessed May 07, 2017. http://www.theartstory.org/movement-feminist-art-artworks.htm#pnt_4.

of birth, of transformation, of menstruation, of maternity, to show that it is not a dead, invisible place."[13]

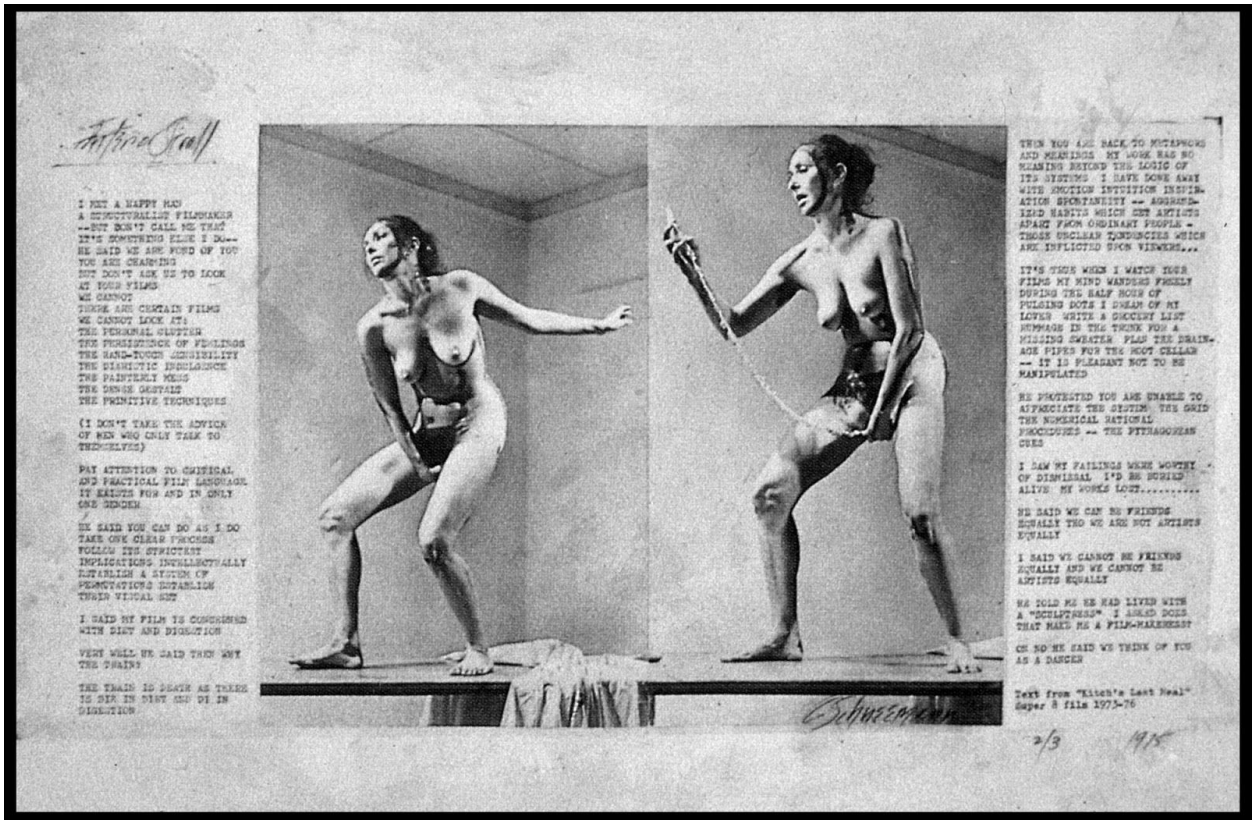

Figure 2.3: In seminal moment of performance art history, Schneemann pulls a scroll from her vagina, and reads from it. Image Credit: Schneeman, Carolee. "Interior Scroll" (1975). Photo by Anthony McCall. Image retrieved from: https://www.sartle.com/artwork/interior-scroll-carolee-schneemann

Schneeman goes on to explain that the source of her inspiration "evolved from a dream in which 'a small figure extracted a text from her vagina that simply said 'the knowledge.' As such, "Interior Scroll" asserts the vagina not only as a site of physical creation, but as a source of thought and creativity. By pulling a physical object from an otherwise hidden space, the interior becomes visible, and therefore, vocal."[14]

[13] Moreland, Quinn. "Forty Years of Carolee Schneemann's." Hyperallergic. September 01, 2015. Accessed May 07, 2017. https://hyperallergic.com/232342/forty-years-of-carolee-schneemanns-interior-scroll/.
[14] Moreland, Quinn. "Forty Years of Carolee Schneemann's." Hyperallergic. September 01, 2015. Accessed May 07, 2017. https://hyperallergic.com/232342/forty-years-of-carolee-schneemanns-interior-scroll/.

By pulling the scroll from her own body, she makes the point that only a woman could truly represent the female experience or speak on its behalf. By placing her vulva unapologetically in the center of the performance, she sheds the norms of suppressing what is taboo, or asking permission to fully express her female reality.

Regarding the power of using the vulva as a means of female expression, art historian Leroy McDermott reflects that it may signify "an advance in women's self-conscious control over the material conditions of their reproductive lives." This last line really stayed with me- the power of a cultural artefact to express the material conditions of our reproductive lives. How might we express the political conditions of reproduction today? How might the body express matters of political control? Inspired by Schneemann's work, I aspire to express issues of femininity and sexuality fearlessly, and viscerally- to confront social stigmas and to expand the discourse on bodies.

2.1.3 Brain-Computer Interface Art

One of the first examples of art using a brainwave sensor that I encountered is a piece called *Eunoia*, by Lisa Park. In this performance, she uses a commercially available electroencephalogram (EEG) headset measure her brain activities, and translates that data into sound waves that vibrated a set of plates filled with water.

The brain activity she was measuring related to her states of emotion, which were then linked to an array of 48 transducing plates, symbolically representing philosopher Baruch Spinoza's definition of 48 emotions.[15] I have always admired this project for its explorations into the thresholds between mind and body through technology. While EEG technology was not new at the time of her project, Park takes the data of her brain activity and translates it into a poetic and beautiful experiential experience- making tangible the preverbal impulses of the brain.

Figure 2.4: The artist Lisa Park controlling the motion of pools of water with signals from her brain. Image credit: Park, Lisa. "Eunoia II." Digital image. Lisa Park Portfolio. Accessed February 4, 2017. Retrieved from http://www.thelisapark.com/.

[15] Park, Lisa. "Work." LISA PARK. Accessed February 05, 2017. http://www.thelisapark.com/#/eunoia/.

2.2 Science Influences

2.2.1 Biotic Games

This thesis project is also highly inspired by the work of Ingmar H. Riedel-Kruse, Alice M. Chung, Burak Dura, Andrea L. Hamilton and Byung C. Lee and their work on biotic games. Taking advantage of a variety of biological processes, they designed a collection of games in which live microorganisms such as paramecia are used as avatars for game play.

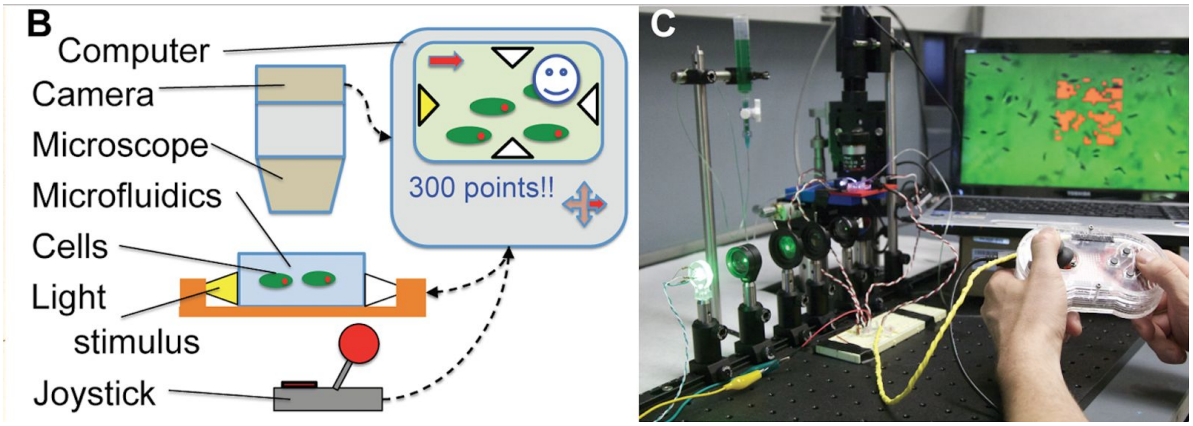

Figure 2.5: Conceptual overview of a biotic game setup. Image C: The hardware and software integration of a built and played biotic game. Image credit: Cira, Nate et al. PLOS Biology.

Some of the biotic actions are triggered via electric fields, chemicals, or light stimulation. An example of such a game that they developed is called "Pond Pong", inspired by the classic video game "Pong". In this game two players send the paramecia back and forth with chemicals released from their respective controllers with the goal of sending the paramecia to the other player's side.[16]

[16] Riedel-Kruse, Ingmar H., Alice M. Chung, Burak Dura, Andrea L. Hamilton, and Byung C. Lee. "Design, engineering and utility of biotic games." Lab Chip 11, no. 1 (2011): 14-22. doi:10.1039/colc00399a.

The researchers of the biotic games state that their intention is to create interactive, engaging ways for students to learn about microbiology. They cite the development of digital video games as a source of stimulus for the development of related technologies, such as those of graphic cards, virtual reality, 3D modeling and rendering. Their hopes are that fun, hands-on design experiences will inspire a new generation of students to engage in Science, Technology, Engineering, Arts and Mathematics (STEAM) education, particularly with the development of robotics in biological engineering.

Upon learning about their research, I immediately became inspired to recreate a biotic circuit to see if its effects could be extended to that of sperm, to explore the conceptually charged potentials of controlling sperm as a woman. I have also been fascinated by the concept of using a living organism as a pixel, and the philosophical implications this has in our relationship to other lifeforms.

3.

Theoretical & Philosophical Underpinnings

3.1 Biopolitics: the body as a site for political power

Sexuality exists at the point where body and population meet.

Michel Foucault

So after a first seizure of power of the body in an individualizing mode, we have a second seizure of power over the body that is not individualizing but, if you like, massifying, that is directed not as man-as-body but at man-as-species. After the anatomo-politics of the human body established in the course of the eighteenth century, we have, at the end of that century, the emergence of something that is no longer an anatomo-politics of the human body, but what I would call a "biopolitics of the human race.

Michel Foucault

The term biopolitics refers to the complex intersection between the fields of biology and politics, often involving the technologies and techniques by which governments manage control over a population. The term was made famous by Michel Foucault in his lecture *Society Must Be Defended,* where he examines the "the strategies and mechanisms through which human life processes are managed under regimes of authority over knowledge, power, and the processes of subjectivation."[17]

Tracing power through its mechanisms of bodily control, Foucault describes the basic classical definition of sovereignty as the regulation of bodies.[18] On the extreme end, these mechanisms of control include the jurisdiction over life and death. Along the spectrum, it includes the control of bodies in regards to spatial distribution, surveillance, productive force, disciplinary action and labor.

In many ways, through the agenda of control, governments transform bodies from a sentient, feeling being that is alive, to a dehumanized material that is to be handled and manipulated. The body as an object of power extends beyond *anato-physical*, as Foucault terms it, and becomes *biopolitical,* when the methods of control move from the individual body to a collective mass: "...the new disciplinary power is applied not to man-as-body but to the living man, to man-as-living-being; ultimately, if you like, to man-as-species."[19] He broadly separates these out as disciplinary vs. regulatory mechanisms of the State.

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[17] Garrison, Laura. "Biopolitics: An Overview." The Anthropology of Biopolitics. January 21, 2013. Accessed April 17, 2017. https://anthrobiopolitics.wordpress.com/2013/01/21/biopolitics-an-overview/.

[18,3] Foucault, Michel, and François Ewald. Society must be defended: lectures at the Collége de France, 1975-76. London: Penguin, 2008.

[19]

This is conceptually significant because it takes the body from an individual subjective self and construes it as a population problematic, and along the way, creating a network of ideologies that have domino consequences of their own. The struggles within biopolitics blur the lines between the scientific and the political, the human and the material, turning vital aspects of evolutionary and biological life into mechanisms of power and control.

3.1.2 Biopolitics and Gender

One of the ways in which biopolitical control is manifested is through the technologies of population control practices, which inherently draw into play the politics of gender and sexuality. As a result, the rights of the female body, and the question of who has power over it becomes a site of political contestation. Everything from the cultural practices dictating the sexual "norms" of women, to the governmental policies surrounding reproductive health and family planning become constructed around this issue of control. At times, these ordinances assume the form of material projections: latex, in the form of contraceptives, hormones, in the form of birth control pills, the uterus, as a conduit to populace. Beyond its material delegations, sex itself becomes an appropriation of power and control. Political desires become manifested into ideologies, as seen in the appropriation of the female body as object of male desire. Caught in these ideological struggles, our society simultaneously fetishizes and condemns the female body for its sexuality.

What are some counter narratives to this male dominated history of female discrimination? In an age of technological advancement where we often speak of transcending our bodies to the point of

posthumanism, why do are we still influenced by dubious theories of biological determinism? As a response, the of this thesis explores these themes through the symbolic act of controlling sperm. Through this control of the cellular unit of male reproduction, this project uses control as a both a tactic and medium to highlight and discuss the absurdity of bodily control in government practices.

3.2 Embodied Technology as a Social Construct

> *The cyborg is our ontology; it gives us our politics. The cyborg is a condensed image of both imagination and material reality, the two joined centres structuring any possibility of historical transformation.*
>
> **Donna Haraway**

Given the previous discussion on biopolitics and the manifestation of power through bodies and population control, the future may appear destined to continue its trajectory of inequality. But perhaps there is a hope for change through our ever changing technologies. Throughout history, technological revolutions have influenced the evolving notion of our bodies. While the first industrial revolution can be said to have augmented our physical body- such our strength and our speed- through mechanic gears and locomotion, and the current industrial revolution is said to be one of the mind: augmented cognition and intelligence through networked devices and machine learning. We live in a time where we experience both with our physical, biological bodies and our virtual bodies. Whereas once everything from that in which we manifested was tangible, in today's world you can hold meetings as an avatar in virtual reality, automate your emotional support through social media, and conduct existential conversations with a chatbot.

The role of our bodies, and our relationship to it continues to change as new forms of technology mediate the thresholds between our corporeal selves, its sensorium and its capacities. In the next few sections, I am going to make a case for a response to biopolitical control as manifested through the female body by inventing an alternate notion of the body, via technology. As such, I will deeply reference Donna Haraway's seminal text, *Cyborg Manifesto.*

To begin considering a future notion of a body, one can consider the body in three ways: as a biological construct, as a social and cultural construct, and as a hybrid of the two, each augmented by a technological dimension. Borrowing from the ideas of philosopher of technology Don Ihde, the first conception of the body is a phenomenological one, where our understanding of the world, both perceptually and emotionally is understood through our flesh and its sensory experiences. The second body is a culturally and socially constructed one. Traversing these two notions of the body is the third dimension of a technological body.

And what significance is this third constructed technological body? Each of our bodily tools become extensions of our senses and identity, and their design reflects on our human desires. If experience is structured by all of the senses, the kinds of technologies that augment these phenomenological experiences can thereby augment our understanding of reality. In the case of this thesis, a system is designed that allows for the control of live specimens through the power of thought. A novel sensory experience becomes manifested, a new relationship between mind and

matter. What new cultural bodies emerges from such an experience, and how do we give them meaning?

3.3 Mind in Matter: *The Materiality of Intention*

In designing a project that attempts to build the third constructed technological body, I started to consider the how ideas and agency are manifested. The relationship between mind, body, and matter has long been a subject of philosophical query, and I turn this lens to the matter of this thesis. The body often serves as a conduit from civic aspiration to actuation. The act of voting, and of legislating--particularly the act of filibustering- all require participation and presence. Many times, this bodily participation serves as a signifier. For example, in acts of political protest, an intention is transferred to the presence of a body, or many bodies, to signify the presence of conflict within the population. How might we traverse the different governing entities of the body, particularly the relationships between the mind and the body? What does the materialization of thought processes look like, and how might we constitute intention as a "medium"? To take the view of Cartesian materialism, where consciousness is "realized in the physical materials of the brain",[20] we might begin by looking to the physiological workings of the brain.

Mediating between our psychic and external reality is our body, and at the center of this coordination is the brain. A human brain is composed of approximately 100 billion nerve cells (neurons) arranged in particular patterns that coordinate thought, emotion, behavior and sensation. Communication occurs between each of the neurons to generate the particular patterns perceived

[20] O'Brien, G and Opie, J. "A connectionist theory of phenomenal experience." The Behavioral and Brain Sciences. Feb;22 [1], (1999): 127-48.

as cognition. This communication occurs through biochemical phenomena that generates electrical impulses, by which the nerve cells are stimulated.

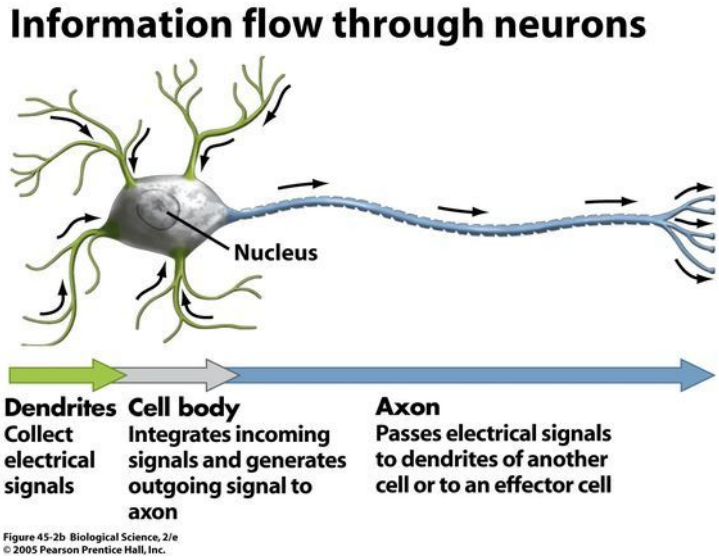


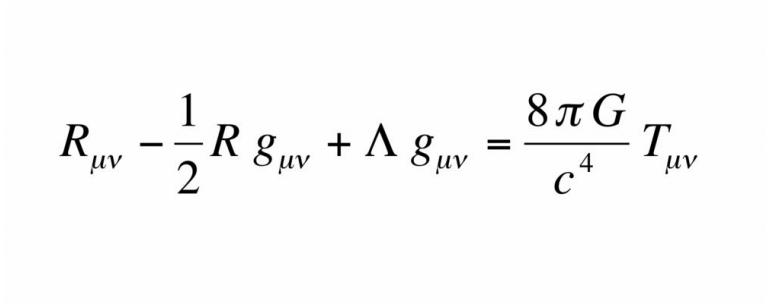
Figure 3.1: Diagram showing the information flow through neurons through the flow of electric signals. Dendrites collect electrical signals, the body of the neuronal processes these signals and the axon passes these electrical signals to the dendrites of another neuron. Image credit: Pearson Prentice Hall, Inc.

In this way, that which is immaterial: energy, in the form of electric impulses, work together with the material: various chemical compounds, neurotransmitters and ions, to create a complex, integrated information processing and control system that regulates the body.

But beyond this, in this coupling between imagination and material reality, there is a revelation on the vibrant materialism in the system. Drawing from the ideas of political theorist Jane Bennett, things, living entities, and the fields of energy that shape both, all exist in an intricate weave by which the remaking of one could rescript all the other elements in the network.[21] Upon reflection,

[21] Bennett, Jane. Vibrant matter: a political ecology of things. Durham: Ducke University Press, 2010.

one might draw a parallel in science, where the practice is one in which the world is observed transformed into universal symbols and equations, in which the world can be simulated, disassembled and reassembled into parsable exchanges. Equations such as Einstein's theory of relativity forever entangle our notions of space and time, energy and matter.



$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Above: Einstein's general theory of relativity. The equation tells us how a given amount of mass and energy warps spacetime. The left-hand side of the equation, describes the curvature of spacetime whose effect we perceive as the gravitational force. The right-hand side of the equation describes everything there is to know about the way mass, energy, momentum, pressure and the speed of light are distributed throughout the Universe.

In both vibrant materialisms and in Einstein's quantified exchange of material to the immaterial, the interwoven quality in the fabric of our reality is inextricably drawn to attention.

If we can understand thought as a series of electrical impulses, we can begin to imagine a system which binds together that which is person, matter, and energy. In this project, this notion is explored, following the journey of an electrical impulse. This journey begins as a thought from the brain, mediated by a computer, sent through the mechanical body of a circuit. These electric impulses eventually arrive between two electrodes controlling of a pool of spermatozoa, collectively representing the material semiotic of patriarchy.

In many ways the tracing of the electrical pathways of this project echoes many of biopolitical philosopher Robert Esposito's sentiments: "Not only are objects intermingled with human elements, solidified and made interchangeable for others, people are in their turn traversed by information, codes, and flows arising from the continuous use of technical objects."[22] In considering this project, I wanted to take a moment to explore that thick, nebulous border in which a being enters the threshold of becoming a thing. Is there an occupiable verge between the body as an individual, and the body as a vessel to social and political control? And between these folds, is there a space we can mediate alternative narratives between the binary of male and female, biological and engineered, domination and subordination?

3.4 Towards a New Notion of Gender

In an attempt to develop alternative narratives for imbalanced gender politics, might we reconsider our notion of binaries completely, especially when it comes to gender? In Donna Haraway's seminal work, *Cyborg Manifesto,* she begins her essay by evoking the notion of a cyborg: a cybernetic organism, an amalgam of both machine and organism, a "creature of social reality as well as a creature of fiction."[23] The cyborg is of particular interest to me for is its hybridity between thing and life, material and person, grown and manufactured.

[22] Esposito, Roberto. Persons and things: from the body's point of view. Cambridge: Polity Press, 2015. Bodies (108-118; 127-138)

[23, 5] Haraway, Donna Jeanne. Simians, cyborgs, and women: the reinvention of nature. New York: Routledge, 2015.

Donna Haraway calls for a sexuality that is not generated by the history of power-- a dream for remapping our bodies-- and thereby, social reality. As she reminds us

> "Social reality is lived social relations, our most important political construction, a world-changing fiction. The international women's movements have constructed 'women's experience', as well as uncovered or discovered this crucial collective object. This experience is a fiction and fact of the most crucial, political kind. Liberation rests on the construction of the consciousness, the imaginative apprehension, of oppression, and so of possibility. The cyborg is a matter of fiction and lived experience that changes what counts as women's experience in the late twentieth century. This is a struggle over life and death, but the boundary between science fiction and social reality is an optical illusion.[24]

In the decomposition of the binary of sex through a cyborg body, a new entity can be invented, a sex that is free of history, politics and power. The project of this thesis takes the ideas mentioned above, reflecting on the entanglement between science, technology and society, and creates a work to remake our relationships to the body, reproductive rights, politics, and gender.

[24] Haraway, Donna Jeanne. A cyborg manifesto: science, technology, and socialist-feminism in the late twentieth century. 2009.

4.

Engineering the System

From Theory to Practice

Every technology asks us to confront our human values.
Sherry Turkle

4. 1 Overview: The System

For all of the conceptual, artistic and intellectual reasons explained in the previous pages, I am creating a system by which a woman can control the movement of sperm with her mind. This system utilizes several different technologies, which are described in further detail below. A commercial grade brain-computer interface (BCI) is used to read the electrical signals from my

brain, and these signals are translated into commands for a microcontroller. Through these commands, the microcontroller moderates the charges on a circuit on which semen is placed. The directional motility of sperm is gained through a phenomenon known as galvanotaxis, where cells migrate towards a specific charge in an electric field. A microscope connected to a digital camera sends live images to a video screen to allow viewers to see the directional movement of the sperm. Through this system, the motility of sperm on an XY coordinate system is gained through the thoughts of a woman.

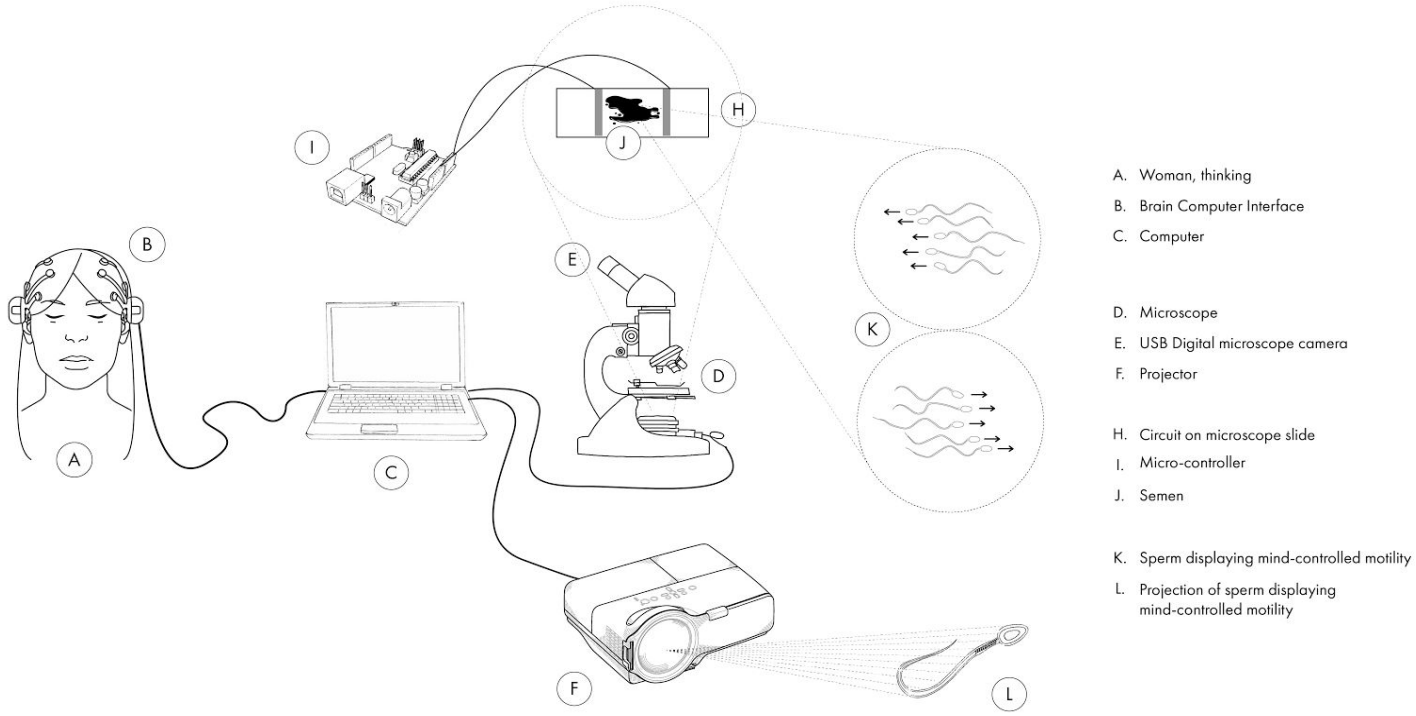


Figure 4.1: A commercial grade brain-computer interface (BCI) is used to read the electrical signals from my brain, and these signals are translated into commands for a microcontroller. Through these commands, the microcontroller moderates the charges on a circuit on which semen is placed. The directional motility of sperm is gained through a phenomenon known as galvanotaxis, where cells migrate towards a specific charge in an electric field. A microscope connected to a digital camera sends live images to a video screen to allow viewers to see the directional movement of the sperm. Image Credit: Ani Liu.

4.2 Sperm Motility

Sperm motility describes the ability of sperm to move within a reproductive tract or a liquid medium to reach an egg. In science, sperm motility is often equated with "quality", which results in successful conception.[25] In evaluating motility, sperm are classified from a range of motile to non motile, as well as from progressively motile to non-progressively motile. A progressive sperm swims in a straight line, while a non-progressive motile sperm swims in aberrant paths, such as in tight circles or spirals.[26]

These considerations in motility are relevant to this project for the aesthetic considerations of how the movement of the sperm are controlled. Sperm motility is considered normal in humans when the total motility that is greater than 50%, which means that in every sample, there is a considerable number of sperm that exhibit non-progressive motile swimming. This means that not every sperm in a sample is capable of swimming in straight lines even given the adequate stimulus in an electric field.

[25] "Sperm motility." Wikipedia. December 21, 2016. Accessed February 05, 2017. https://en.wikipedia.org/wiki/Sperm_motility.
[26] Rouge, Melissa. "Sperm Motility." Sperm Motility. January 20, 2003. Accessed February 05, 2017. http://www.vivo.colostate.edu/hbooks/pathphys/reprod/semeneval/motility.html.

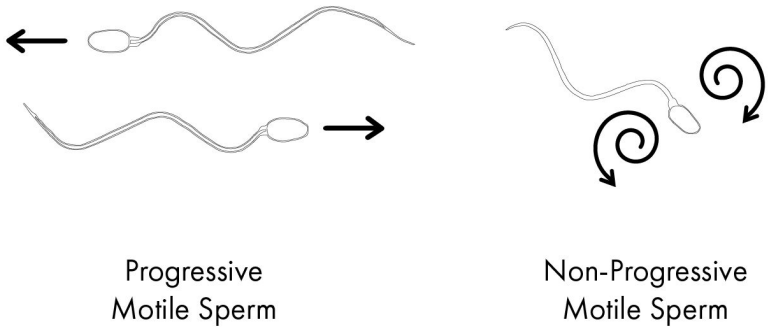


Figure 4.2: Diagram to show progressive vs. non-progressive sperm motility. Up to 40% of an ejaculate can contain non-progressive sperm motility. These considerations in motility are relevant to this project for the aesthetic considerations of how the movement of the sperm are controlled. Image Credit: Ani Liu

In my experiments, I have found that I am able to move all the sperm in a sample at 12V/cm towards the positive electrode (known as the anode). Because of varying sperm motility in the sample, not all the sperm appear to be swimming directly towards the anode. In order for the desired aesthetic to film sperm swimming headfirst towards the specified direction, the more progressive motile sperm have to be separated from the non-progressive motile sperm. I attempted to do this through a two stage electrophoresis process, in hopes that the progressive motile sperm, which tend to be bigger, could be captured in an initial pass. This yielded a varied success rate; in the end, not all the the non-progressive motile and non-progressive non-motile sperm could be completely separated from the sample.

4.3 Galvanotaxis and Electrophoresis in Sperm

Galvanotaxis, also known as electrotaxis, refers to a phenomenon where cells migrate directionally towards electrodes in a direct current (DC) electric field (EF).[27] Galvanotaxis has been observed and documented in over 14 cell types, including mammalian granulocytes, bone cells, amphibian neural crest cells, and mouse sperm.[28]

Electrophoresis refers to the motion of dispersed particles in a fluid under an electric field.[29] Standard, mature human sperm carry a net negative charge, and electrophoresis can be used to move sperm towards the positive electrode under an electric field.[30] This technique has been used to separate out larger, more robust sperm for processes related to in vitro fertilization (IVF).

Using a combination of the phenomenon of galvanotaxis and electrophoresis, I am directing the movement of sperm through the manipulation of electric fields. As mentioned above, the specifications I have come to through experimentation is 12V/cm. It should be noted that while it is possible, it is difficult to visually detect sudden changes in movement in the sperm. This is because while all the sperm are moving one direction, to suddenly change its course causes certain fluid

[27] Gao, R.-C., X.-D. Zhang, Y.-H. Sun, Y. Kamimura, A. Mogilner, P. N. Devreotes, and M. Zhao. "Different Roles of Membrane Potentials in Electrotaxis and Chemotaxis of Dictyostelium Cells." Eukaryotic Cell 10, no. 9 (2011): 1251-256. doi:10.1128/ec.05066-11.
[28] X. Zhang, L. Jin, I. Takenaka. "Galvanotaxis Response Of Mouse Epididymal Sperm: In Vitro Effects Of Zinc And Diethyldithiocarbamate." Archives of Andrology 45, no. 2 (2000): 105-10. doi:10.1080/014850100418792.
[29] Wikipedia. Accessed February 05, 2017. https://en.wikipedia.org/wiki/Electrophoresis#cite_note-1.
[30] Fleming, Steven, and R. John Aitken. "Electrophoretic Sperm Separation." Sperm Chromatin, 2011, 423-29. doi:10.1007/978-1-4419-6857-9_29.

dynamics to occur within the media, creating a swirling pattern. To counter this, the sperm are let to "rest" for a few minutes of a non-charged interval between direction changes.

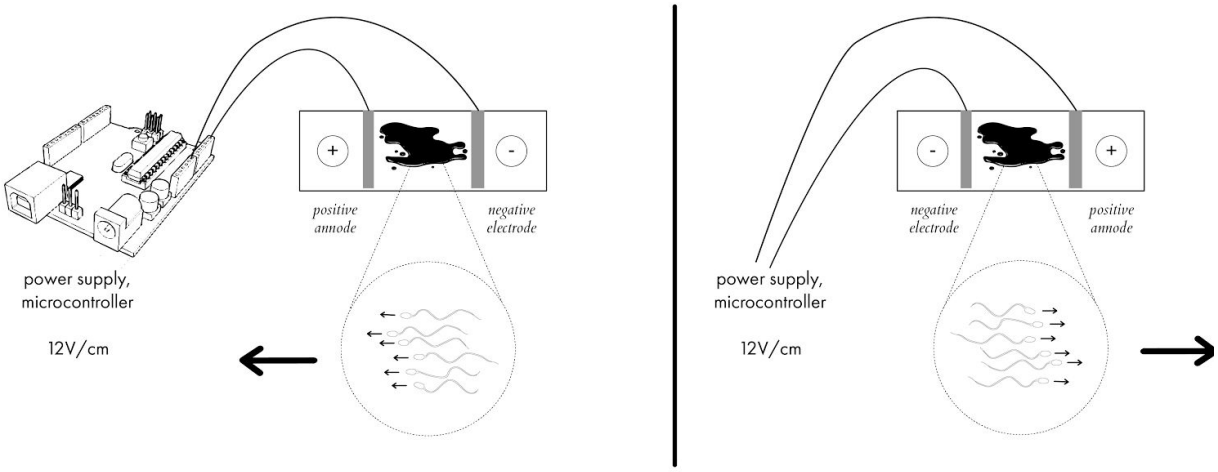


Figure 4.3: Diagram to show electrophoretic effect on sperm. Sperm will move towards the negatively charged cathode at 12V/ cm. Image credit: Ani Liu.

4.4 Brain-Computer Interface (BC) and Electroencephalogram (EEG)

Electroencephalography (EEG) is method to record the electrical activity of the brain with the use of noninvasive electrodes placed along the scalp.[31] It is a form of electrophysiological monitoring, which is the study of electrical properties of living cells and tissues. EEG measures the electrical fluctuations of the brain, caused by the action potential activity of neurons over time.[32]

[31] Koubeissi, Mohamad Z. "Niedermeyer's Electroencephalography, Basic Principles, Clinical Applications, and Related Fields, 6th ed." Archives of Neurology 68, no. 11 (2011): 1481. doi:10.1001/archneurol.2011.251.
[32] Buzsáki, G. 2006. Rhythms of the brain. n.p.: Oxford ; New York : Oxford University Press, 2006., 2006. MIT Barton Catalog, EBSCOhost (accessed April 16, 2017).

A brain-computer interface (BCI) takes this EEG electrical activity, analyzes them, and sends the signals to a computer which can be programed for various commands and outputs. BCIs have been used in medicine in a variety of ways, including in the aid of patients suffering from neuromuscular disorders such as stroke, amyotrophic lateral sclerosis, cerebral palsy, or spinal cord injury. Medicine based BCI devices have focused on the complex control of cursors, robotic arms, wheelchairs, and other devices.[33]

As explained in an overview by J. Shih, D. Krusienski and J. Wolpaw in the Mayo Clinic journal, a BCI system typically consists of four components: 1. signal acquisition, 2. feature extraction, 3. feature translation, and 4. device output. These four components are orchestrated through a computer.

Within the last 15 years, commercially available BCIs have unlocked a proliferation of its usage for creative means of expression.[34] Reflecting on an era of continual human computer symbiosis, I am incorporating BCI technology into my project to further investigate the threshold and continuum between the mind and the body as augmented by a computer interface.

Two different commercial grade brain-computer interfaces were used in creating the work of this thesis. The Emotiv was chosen for its aesthetic quality and readily available software development kit (SDK). The OpenBCI was chosen for its increased resolution of accuracy (as compared to the

[33] Shih, Jerry J., Dean J. Krusienski, and Jonathan R. Wolpaw. "Brain-Computer Interfaces in Medicine." Mayo Clinic Proceedings 87, no. 3 (March 2012): 268-79. Accessed January 26, 2017. doi:doi:10.1016/j.mayocp.2011.12.008.
[34] Nijholt, Anton, and Chang S. Nam. "Arts and Brain-Computer Interfaces (BCIs)." Brain-Computer Interfaces 2, no. 2-3 (2015): 57-59. doi:10.1080/2326263x.2015.1100514.

Emotiv), and for its open source libraries. Both were used to gather the requisite data to induce the directional motion of the sperm. Two undergraduate research assistants were employed in this area of research. Baula Xu worked predominately with the Emotiv, and Xin Wen worked with the OpenBCI.

4.4.1 Emotiv

The Emotiv EPOC+ is a fourteen channel wireless headset that records EEG data. This headset measures both EEG and 9-axis motion data, with two reference sensors located right behind the ear. Whereas conventional EEG systems typically use sticky gels, the Emotiv uses saline based wet sensors, which was a desirable attribute for this project for its ease of activation and cleanup. The Data is transmitted wirelessly through Bluetooth, which was an important consideration for ease of communication to the computer, microcontroller, and subsequently, the electrophoretic circuit under the microscope.

Figure 4.4: Image of the Emotiv EPOC+ Headset. Image Credit: Emotiv Inc. Digital image. Accessed April 13, 2017. Retrieved from https://www.emotiv.com/epoc/

The data extracted from the headset is rendered through Emotiv's free software called Insight App, as well as a subscription based software called EMOTIV Pure EEG Raw EEG Software. This software feeds the electrical activity from each 14 channels from the headset through an interface as seen below, as well as .csv file.

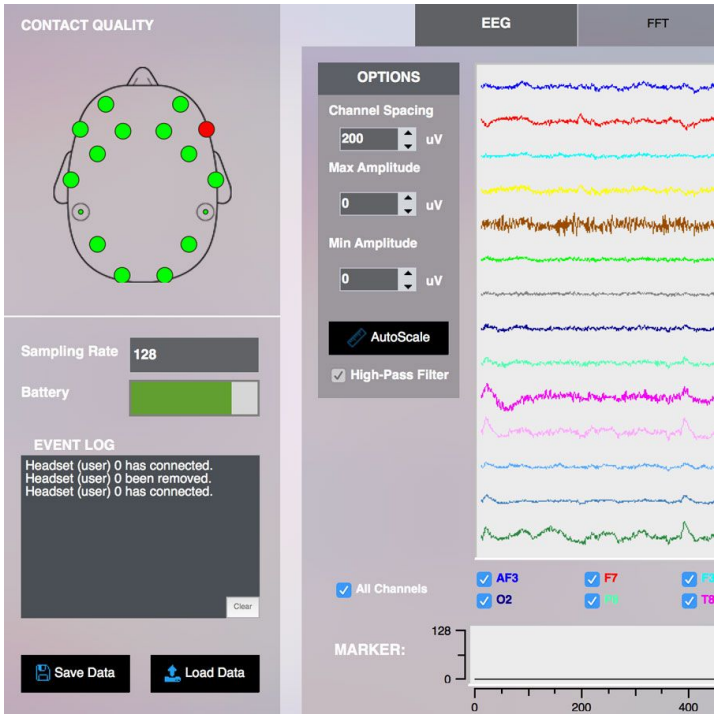


Figure 4.5: Image of the Emotiv Pure EEG Raw EEG Software interface. Image Credit: Emotive Inc. Digital image. Accessed April 13, 2017. Retrieved from https://www.emotiv.com/product/emotiv-pure-eeg/

A drawback of the Emotiv EPOC is the difficulty receiving a consistent signal on subjects with dense and/or long hair, due to the interference between the sensor and the scalp. Additionally, due to the flexibility of the extrusions holding the sensors in place, each time the headset is worn, the placement of each node is not always identical to the previous session, leading to potential inaccuracies in the collected data between sessions.

4.4.2 OpenBCI

The OpenBCI is an open source brain-computer interface platform. The boards can be used to measure a range of electrical activity produced by the body, including EEG for the brain, EMG for muscles, and EKG for the heart. It was chosen for its hackability due to its open source hardware and software, range and clarity of documentation online, as well as its ease of integration with the Arduino microcontroller.

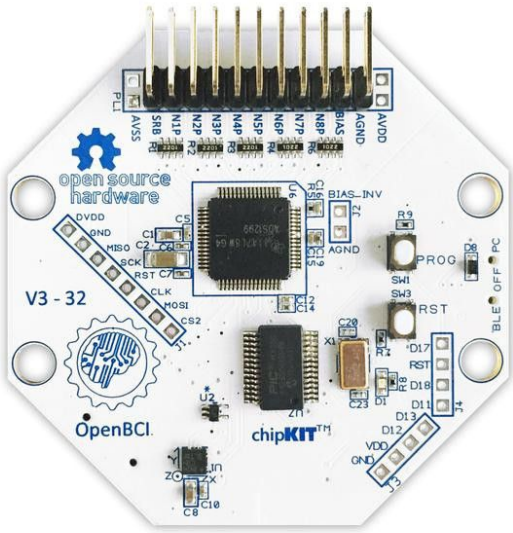


Figure 4.6: Image of the OpenBCI Cyton biosensing board. Image credit: OpenBCI. Digital image. Accessed April 8, 2017. Retrieved from https://shop.openbci.com/collections/frontpage/products/cyton-biosensing-board-8-channel?variant=38958638542

For this project, the Cyton biosensing board with eight channels was used, with their gold cup electrodes and Ten20 conductive paste. Wireless communication was achieved through the OpenBCI USB dongle using RFDuino radio modules. In early experiments, the electrodes were held in place with sweatbands and subsequently, a swim cap. However, due to the density of the

users' hair, a consistent signal was difficult to achieve, and an Ultracortex "MArk IV" EEG headset, an open source 3D printed headset designed by OpenBCI was acquired.

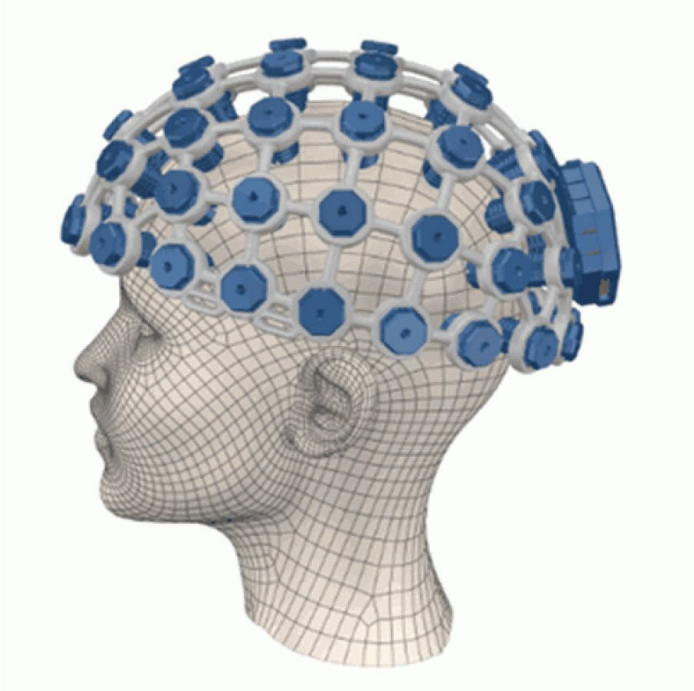


Figure 4.7: Image of the Ultracortex "MArk IV" EEG headset, and electrode placement. Image credit: OpenBCI. Digital image. Accessed April 8, 2017. Retrieved from https://3dprintingindustry.com/wp-content/uploads/2015/11/openbci-3D-printed-EEG-headset-1-906x906.gif

The signals from the OpenBCI board were processed with their open source GUI found at https://github.com/OpenBCI/OpenBCI_Processing, which displays the waveforms of electrical activity for all eight channels, as well as a heatmap of sensor activity on a diagram of the electrode placement on the head.

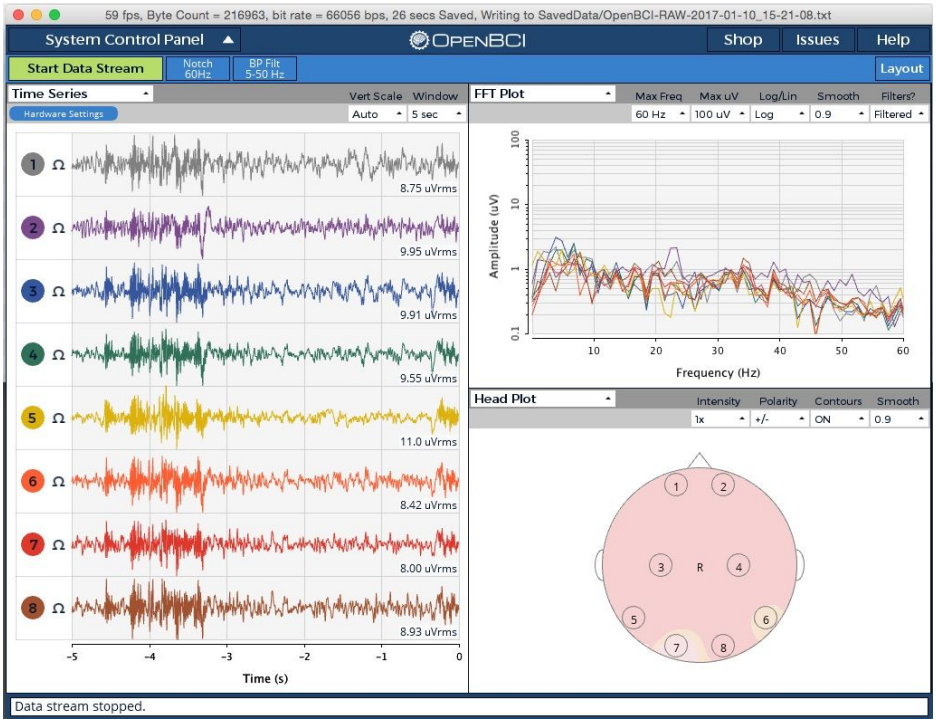


Figure 4.8: Image showing the OpenBCI graphic interface. GUI includes a plot of each brain wave frequency, an overlay of all the plots together, and a heatmap of activity on a spatial diagram of the head. Image Credit: OpenBCI. Accessed April 8, 2017. Retrieved from http://openbci.com/.

The OpenBCI delivered more accurate data than the Emotiv, and the open source nature of their hardware and software made it easier to manipulate. However, the formfactor of the headset, as well as the stickiness of the paste used with the electrodes were drawbacks to this system. In the end, both the Emotiv and OpenBCI were used to gather the requisite data, and the Emotiv was used for the visual communication of the project.

4.5 Optics / Microscope

The system for optics in this project is a USB enabled digital camera connected to a microscope. The video footage gathered from the microscope will be collected onto a computer and live

streamed through a projector, to allow for an immersive experience of the performance. Human spermatozoa are typically 50 micrometers in length, and require a microscope objective of at least 10X. In my tests, a magnification of at least 40x is desired, for clarity and proper resolution for projection.

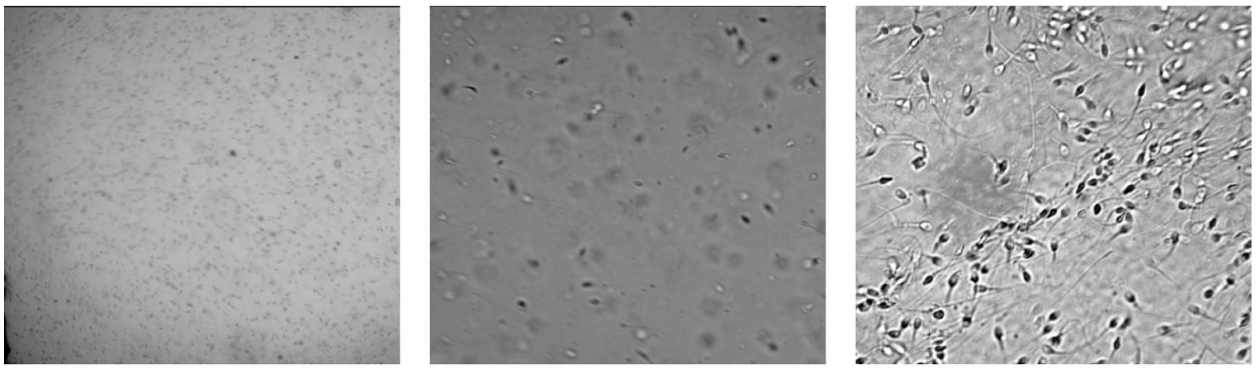


Figure 4.9: Image of the sperm at 4x magnification, 10x magnification, and at 40x magnification. Whereas the 4x shows the global movement more clearly, at 40x the flagella becomes visible and the the iconic shape of the spermatozoa becomes apparent. Image credit: Ani Liu

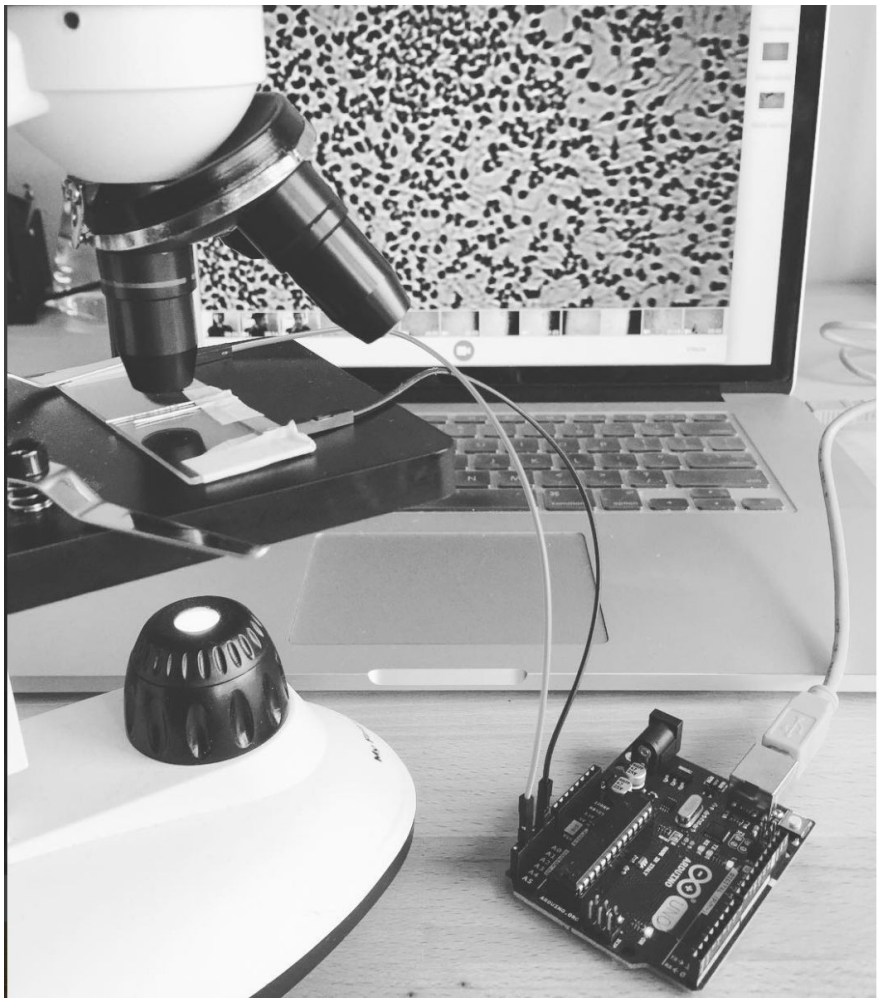


Figure 4.10: Image of the current setup in my lab. A consumer grade toy microscope with a USB camera is streaming live footage of the contents on the slide onto the screen of my laptop. Electrodes placed 5/12 cm apart is controlled by an Arduino UNO sending 5V, achieving the effect of sperm migration towards the cathode. Image credit: Ani Liu

4.6 Fabricating the Circuit

While most of the components of this project rely on existing entities- (projector, microscope, digital camera for the microscope, and EEG machine), there were some aspects of the work that was custom built, primarily the circuit that the sperm swam on. In order for the galvanotaxis to occur, the sperm must be placed between two electrodes 1 centimeter apart for every 12 volts administered.

The main parameters of the circuit are that 1. it can contain microorganisms 2. it can hold liquid media without drying out quickly 3. it can create and maintain an electric field. An additional challenge encountered is that a common material in most electronic fabrication-- copper-- is a spermicide. The first prototype of the circuit referenced the set-up by the Stanford lab researching biotic games. In this version, a square of acrylic is laser-etched with a 2mm square, where the biological media will sit. Surrounding the square, four mechanical pencil leads are placed on the edges, becoming the conductive material by which the electric field is created.

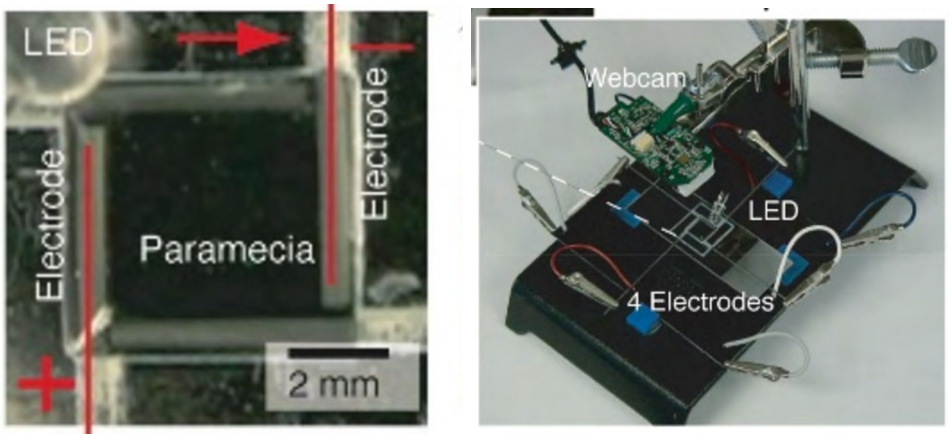


Figure 4.11: On the left, an image of the slide preparation. A piece of acrylic is etched with a 2mm square, where the biological media swims. Four mechanical pencil leads are placed on each edge, becoming the conductive material by which the electric field is created. On the right, an image of the overall setup, including the electrodes connected to the pencil leads, the digital camera, and LED for illumination. Image credit: Riedel-Kruse Lab.

I tried this setup several times, to varying degrees of success. One of the problems was that the etching of the acrylic obscured the contrast of the sperm under the microscope. Another concern was that the pencil leads were not conductive enough to create an adequate electric field. After much experimentation, I decided to use copper sheets with an adhesive backing on glass microscope

slides. On top of the copper sheet was a thin layer of microfilm, to protect the sperm from the spermicidal properties of copper. Connected to each copper sheet I soldered an insulated wire, which was run to the Arduino microcontroller. To create a chamber for the sperm to sit in without drying out, I cut a cover slip into four slices, assembled into a square to create a pool. An additional coverslip was placed on top to retain moisture over the course of the experiment.

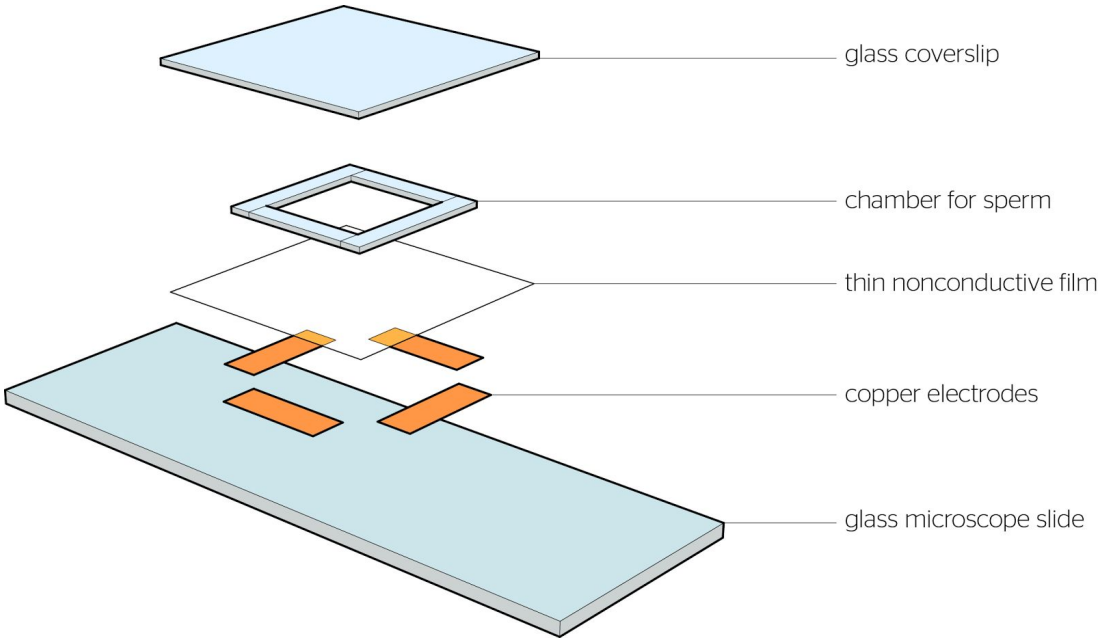


Figure 4.12: Above, an image of circuit setup. It is composed of a standard microscope glass slide, with four copper electrodes placed in a square. A thin microfilm is placed on top of the electrodes to protect the sperm from the spermicidal copper. The sperm sit within a glass chamber, with a glass coverslip on top to prevent evaporation. Image credit: Ani Liu.

With the circuit described above, and an arduino microcontroller and a 30V power supply, I was able to drive the movement of sperm in four directions: up, down, left and right.

4.7 Programming the Circuit: EEG Signal Processing and Control Tasks

In programming this project, the objective is to drive an Arduino using distinct brain activity recorded by the consumer grade EEG device OpenBCI. This portion of the research was completed in conjunction with my undergraduate research assistants Xin Wen and Baula Xu. To achieve this goal, we first used the openBCI Cyton board EEG generated by different thought patterns. Our first rounds of experiments was to see if we could get distinct EEG patterns from thinking left and right. After many tries, we concluded that the resolution of data acquired from consumer grade EEG machines would not be sufficiently distinguish between the cognitive states of directional thinking. After some research, we decided upon two stages that consistently produced distinct EEG readings: a state of meditation or relaxation, which generates mostly alpha waves (8-12 Hz), and a state of attention, generating Beta waves (12-38Hz.) While each of my research assistants and I had varying degrees of consistency conjuring up these states on command, it became more consistent with practice. Additionally, keeping eyes closed very consistently generated the meditative states that trigger the alpha waves.

While the Cyton board has an microprocessor that can do some signal processing on-board, we analyzed the data in Matlab for the software's ability for more complex signal processing. After the signals were processed, we sent commands from Matlab to an Arduino. To transfer data from openBCI software to Matlab, we could either save recorded data from the openBCI GUI and read the file in Matlab, or use Lab Streaming Layer (LSL) to stream data from openBCI to Matlab for real time analysis. The way each component works will be explained in the following paragraphs.

We started with measuring alpha brain waves (around 10 Hz) produced by relaxing or closing the eyes, which is one of the strongest EEG signals. We used the electrodes that came with the Cyton board and Ten20 electrode paste to connect the SRB2 pin and BIAS pin to the left and right ear lobe, respectively, the 2N pin to Fp2 in the 10-20 system (one inch above right eyebrow and one inch to the right of center of forehead), and 7N pin to O1 in the 10-20 system (on the back of my head one inch above the inion and one inch to the left).

To export the data to Matlab for processing, we could either read the saved data in Matlab, or stream data through Lab Streaming Layer for live analysis. Lab Streaming Layer (LSL) is "a system for the unified collection of measurement time series in research experiments that handles both the networking, time-synchronization, (near-) real-time access as well as optionally the centralized collection, viewing and disk recording of the data." (For reference, the LSL github can be found at https://github.com/sccn/labstreaminglayer). We used a script written by the OpenBCI community for streaming data from openBCI python API to LSL so that data can then be extracted from LSL into other software for analysis.

With EEG data, we looked for periods with high frequency signals to turn on corresponding electrodes on the microscope slide. In the Matlab script, we used a sliding window of size 62 and step size of 31 to iterate through the EEG data from stages of attention (left) and stages of relaxation (right) simultaneously, i.e. the script would first analyze data point 1 to 62, and then point 32 to 93, point 63 to 124. OpenBCI has a sample rate of 250 Hz, thus 62 data points are about one quarter of a second worth of recording. This number was chosen based on experimentation,

and could be adjusted for different data set. For each window, we calculated the frequency spectrum of the data using FFT (fast fourier transform). Since we know attentive states produce high frequency signals, we looked at the amplitudes of the higher frequencies in the frequency spectrum, namely between 50Hz and 60Hz. When the amplitudes reached a certain threshold, Matlab would send a command to Arduino to turn on the electrodes corresponding to the data set (left or right).

5.

Designing the System

From Function to Form

5.1 Atmospheric Considerations

The aesthetic communication of this project was challenging on many fronts, much of which had to do with materializing the immaterial through projection. The first challenge was in visualizing that which is invisible to the naked eye: the movement of microscopic sperm. The second was in illustrating the performative aspect of the project that is inherently invisible: the activity of thought that occurs within the participant's brain. Lastly was the challenge of creating a dignified and empowered atmosphere while working with the highly emotionally charged materiality of semen.

The goals of the video were to capture this project, both intellectually and emotionally, and to employ it as a means to extend the conversation beyond the lab and studio. The affective qualities to be captured included a feeling of female empowerment, the expression of tension between mind, matter, and biopolitical control.

In the many transferences from mind to microscope, microscope to projection, and projection to film, I drew from and reflected on the work of media theorist Bernhard Siegert's *Cultural Techniques: Grids, Filters, Doors and Other Articulations of the Real*. **In it, Siegert speaks of the folds of each threshold as a mediation of a "cultural technique." In traversing the journey from body to technological visualization, several thresholds were created, each relating the the projection of thought back onto flesh. In some scenes, the footage is literally projected back onto the body. There was some debate on whether the microscope should be visible in the shot, to create a visual correlation between the imagery projected and where it comes from. In the end, it was decided to separate it, due to the visual disarray of the cables and the disparate scales of the microscope, the figure, and the projection. However, it was important to imply the microscope in some way, as it serves as one of Siegert's doorways- "a passage into a new understanding."[35] In the end, the projected footage was cropped to a circle, to give it the quality of being seen under a microscope, suggesting its presence.**

[35] Siegert, Bernhard, and Geoffrey Winthrop-Young. Cultural techniques: grids, filters, doors, and other articulations of the real. New York: Fordham University Press, 2015 (193).

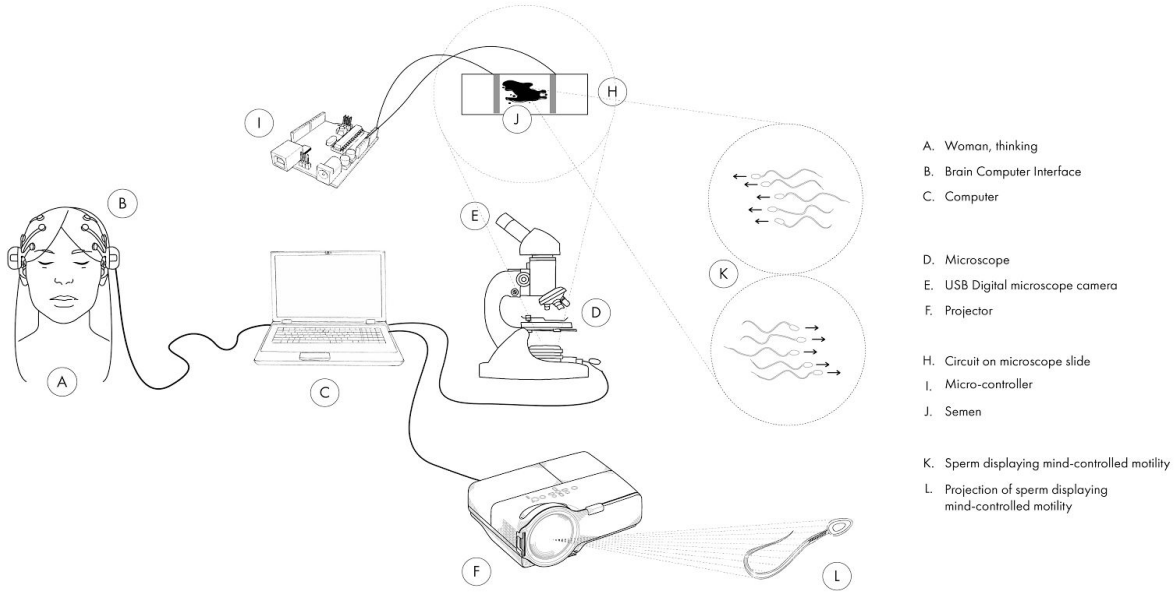


Figure 5.1: Diagram showing the different elements of the performance, each element a tool in visualizing the invisible. The brain-computer interface captures the electrical impulses of thought and sends these signals to a circuit designed for the motility of sperm. A digital microscope captures the activity and a projector renders the footage at a scale visible to the naked eye.

To visually communicate the invisible act of thinking, there was a conscious choice to prominently displace the EEG device on the head. This included parting the model's hair down the middle, and keeping the hair style very simple and clean, despite having a very talented hair stylist on the set. There was a consideration to cast a model with light colored hair so that the EEG (which is black) would stand out better, but at the end, the model Chloë O'Neal was chosen for her strong, empowered gaze. During the filming, the model was instructed to move her head slightly, to meditate, and to open and close her eyes at specific intervals to evoke the sense of being in deep thought. Additionally, there was the decision to add cinematic effects of blurring and halos from the use of strong single point lights to create a dreamlike atmosphere intended to blur the thresholds between the viewer and the the subject.

Figure 5.2: Photograph during the prototyping stage of the project. Elements tested included the lighting conditions on the model and on the projection, the color of the projection, the surface the projection was directed on, and color of garment of the model. From this series of tests, it was decided that the main illumination would come directly from the projection itself, with a secondary light pointed directly at the model's face. A small backlight would be placed behind the model to create a slight halo effect, drawing an outline from the figure in an otherwise shadowy and depthless field. Photo credit: Jimmy Day. Digital post process editing by Ani Liu.

To navigate the challenge of maintaining a dignified atmosphere while working with the culturally charged materiality of semen, a conscious effort was made to keep the set abstract, minimal, and

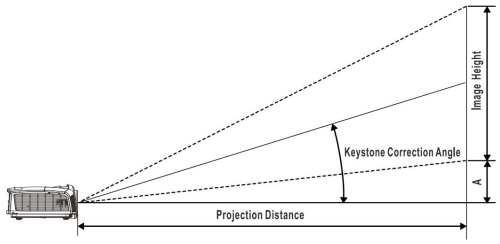
relatively stark. The purpose of this was to evoke a timelessness, allowing the viewer to fill in the details with his or her own history. To counterbalance the sterile aesthetic, I chose a juxtaposition of emotionally charged music. The soundtrack for the video of this performance was composed in collaboration with the talented musician Wendy Eisenberg. She was given the abstract prompt of creating a score that felt feminine, empowered, fluid and abstract.

5.2 Designing the Performance

The main elements for considerations in the performance include 1. The projection 2. The venue 3. The lighting conditions 4. The performer.

The projector used in this project is the InFocus IN3134a. It has a 8000:1 contrast ration and projects at 4200 lumens. The main technical factor was to consider the ratio between the distance of the projector and the surface projected on, and the size of the projection. (See figure 5.3 for the ratio of projection distance vs. projection size.)

Projection Distance vs. Projection Size



Projection Distance and Size Table

IN3138HD					
Image Diagonal (mm/inch)	Image Width (mm/inch)	Image Height (mm/inch)	Projection Distance (mm/inch) From	Projection Distance (mm/inch) To	Offset-A (mm/inch)
1524 / 60	1328.3 / 52.29	747.2 / 29.42	2098.7 / 82.6	2550.3 / 100.4	112.1 / 4.4
1778 / 70	1549.7 / 61.01	871.7 / 34.32	2448.5 / 96.4	2975.3 / 117.1	130.8 / 5.1
1828.8 / 72	1593.9 / 62.75	896.6 / 35.30	2518.4 / 99.2	3060.4 / 120.5	134.5 / 5.3
2032 / 80	1771.0 / 69.73	996.2 / 39.22	2798.2 / 110.2	3400.4 / 133.9	149.4 / 5.9
2133.6 / 84	1859.6 / 73.21	1046.0 / 41.18	2938.2 / 115.7	3570.4 / 140.6	156.9 / 6.2
2286 / 90	1992.4 / 78.44	1120.7 / 44.12	3148.0 / 123.9	3825.4 / 150.6	168.1 / 6.6
2438.4 / 96	2125.2 / 83.67	1195.5 / 47.07	3357.9 / 132.2	4080.5 / 160.6	179.3 / 7.1
2540 / 100	2213.8 / 87.16	1245.3 / 49.03	3497.8 / 137.7	4250.5 / 167.3	186.8 / 7.4
3048 / 120	2656.6 / 104.59	1494.3 / 58.83	4197.4 / 165.3	5100.6 / 200.8	224.1 / 8.8
3429 / 135	2988.6 / 117.66	1681.1 / 66.19	4722.0 / 185.9	5738.2 / 225.9	252.2 / 9.9
3810 / 150	3320.7 / 130.74	1867.9 / 73.54	5246.7 / 206.6	6375.7 / 251.0	280.2 / 11.0
5080 / 200	4427.6 / 174.32	2490.5 / 98.05	6995.6 / 275.4	8501.0 / 334.7	373.6 / 14.7

Figure 5.3: A table of the distance vs size parameters of the projection. A limiting factor of the visual qualities of the performance involved sourcing a warehouse with high enough ceilings to achieve the size of projection that would cause the model to appear as though she was sitting in front of a pond.

For the aesthetic communication of this project, the footage of the sperm from the digital microscope had to be enlarged and projected on the floor in front of the model. From a photoshoot testing for the right proportions of this projection, it was determined that the projector had to be a minimum of 8' off the ground, giving the resulting image a dimension of roughly 5' x 3'.

Given the desire to create a projection that was at minimum of 3' in diameter, there was the challenge of finding a way to hold it up 8' in the air. The projector has fixtures to hold it in a default horizontal position, but no fixtures to hold it vertically, with the lamp facing downwards. As a solution, a cradle was custom designed and lasercut to a fix it to a variety of surfaces with clamps.

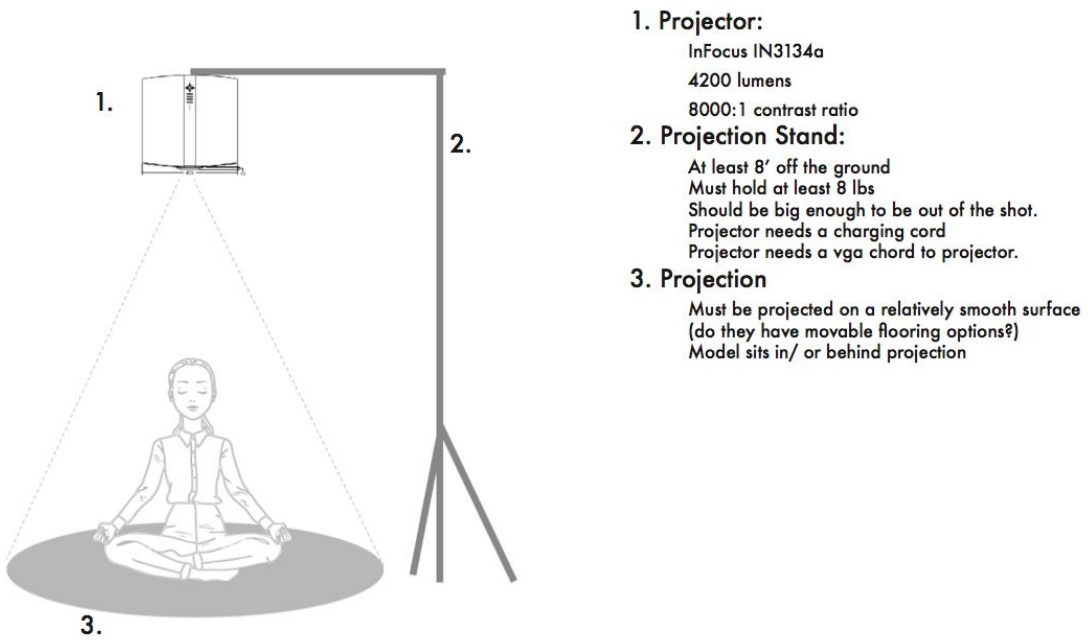


Figure 5.4: A diagram of the physical setup of the performance. Main elements for consideration included the minimum distance the projector had to be off the ground, its weight, and how it would structurally cantilever over the model securely and safely.

After the project was securely affixed to the structural elements of the ceiling, other visual elements were tested. A main challenge was the lighting conditions. Whereas a projection look best in darkness, the performer can only be seen with illumination. A variety of conditions were tested, and in the end, the solution was to rely on the projection as the primary source of light, followed by a single point of light aimed at the face of the model, and a small light placed right behind her, to create a slight halo outline around her figure.

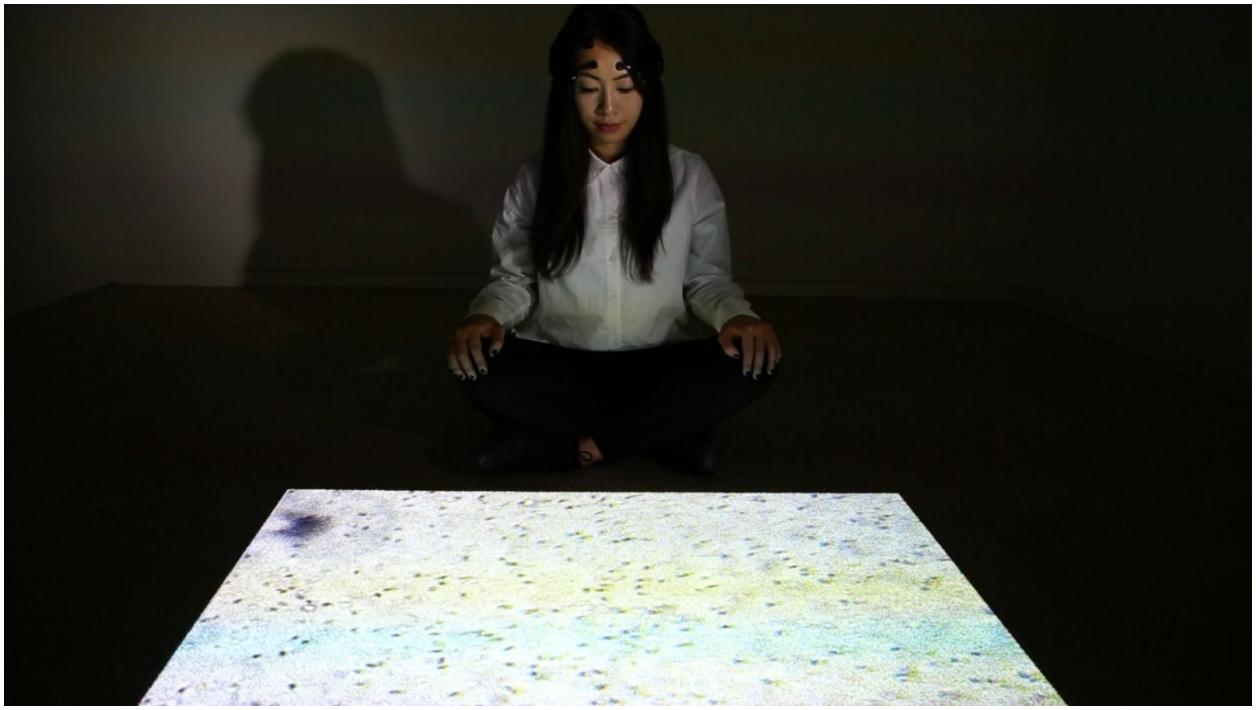


Figure 5.5: Video still of mind-controlled performance during prototyping stage. Elements tested included luminosity of projection, lighting on the model, choice of dark or light colored clothing and its aesthetic impact on the figure/ground relationship. It was noted that in the video and still images, the projection appears to have colored bands running through it, due to the hertz of the RGB lamps in the projector. Photo credit: Jimmy Day

To help with the legibility of the figure in low light conditions, there was a decision to keep the footage of the projection black sperm on a predominately white field, vs white sperm in a primarily dark field. Additionally the model wears primarily light colored clothing, to ambiently reflect the light off the projection back towards her face and hands.

There was a decision to crop the projection into a circle, to mirror the view through the microscope, and to evoke the imagery of a petri dish, by which we associate scientific research about life to take place.

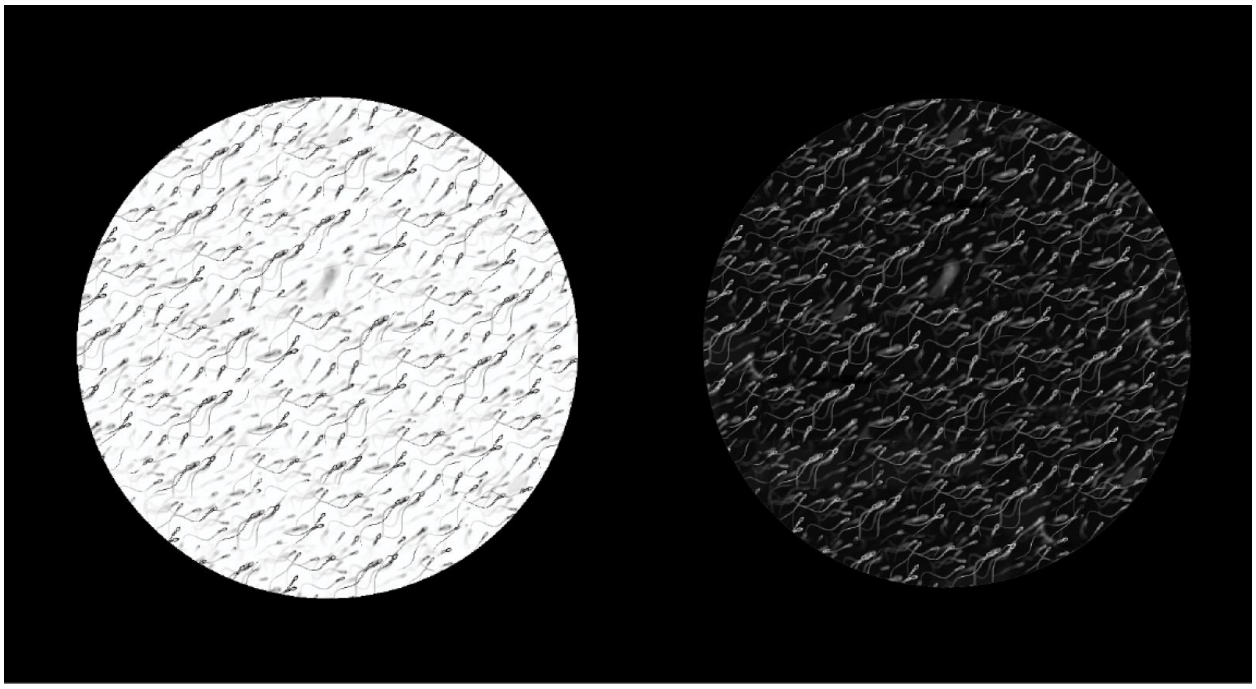


Figure 5.6: Aesthetic considerations included cropping the projection into a circle, to mirror the view through the microscope and to evoke the imagery by which we associate scientific research about life. The figure/ ground relationship was also tested, to see if the sperm would be more legible on a white or black field.

5.3 Designing the Film

To goals of the video were to capture this project, both intellectually and emotionally, and to employ it as a means to extend the conversation beyond the lab and studio. The affective qualities to be captured included a feeling of femininity, empowerment, the tension between mind and matter, and biopolitical control. The aesthetic qualities desired was the imbue a timelessness through a clean, "contextless" set, allowing the viewer to fill in the context themselves. Having no

prior experience in videography, this process was an enormous learning experience. After many iterations of the video, it was decided that two editions would be made: a short, 30-60 second video that would be used to tell the story in a quick, internet friendly way, and a longer, more affectively nuanced version. The decision to split the two was due to irreconcilable differences between the two objectives: one being the desire to be accessible to the widest audience, the other being the desire to push the boundaries for expression.

The initial stage involved storyboarding the project, to tell a clear narrative, and to test its clarity of delivery with an audience. The first iteration of the video involved multiple news clippings, panning shots over photographs with subtitles and a voiceover to tell the narrative of the project.

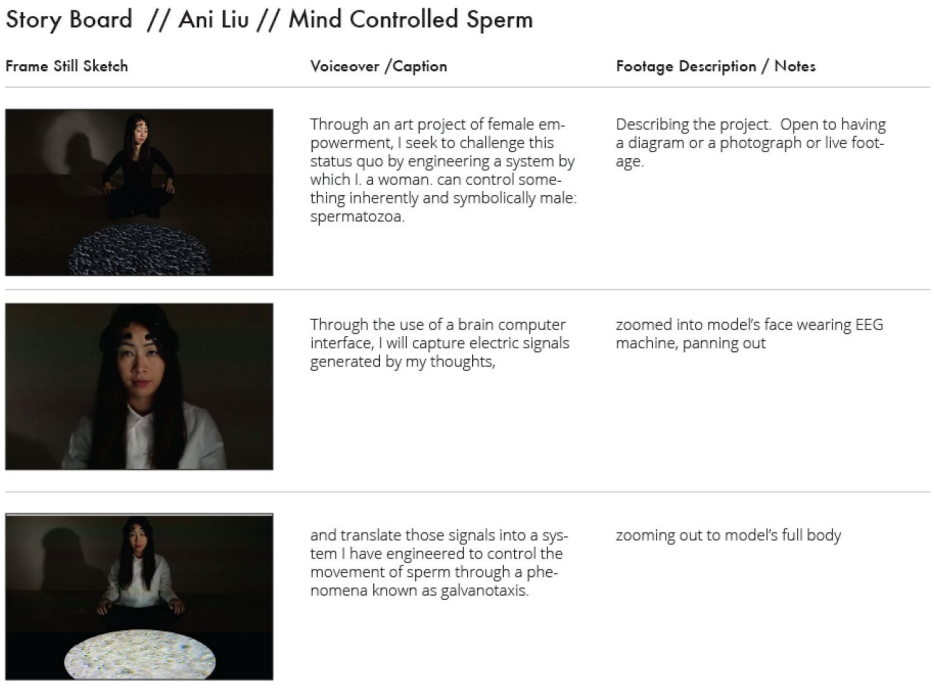


Figure 5.7: Example of the storyboard. Description included a visual sketch in the form of a drawing or prototype photograph, the camera direction, and the voiceover. Image credit Ani Liu.

This first prototype of the video was then presented to viewers who had never seen this project, for feedback on clarity, quality, and engagement. Most viewers agreed that the project was provocative, interesting, and engaged a timely and significant problem in a novel way. There was a negative reaction to the amount of voiceover, and its didactic narrative. There was a suggestion to include ambient music instead of the voiceover, and to limit the subtext in general.

With this feedback in mind, a new storyboard was formed, a list of camera angles and shots was developed (See figure 5.8.) The shots list was developed to be broad, so that the elements could be further developed in the studio via post processing. The cinematographer for the video documentation for this work is Matthew Workman, who was chosen for his professional experience and clean aesthetic.

SCENE #:	1	SCENE:	Studio, Black background, minimal		PAGES: 1 1/8						
✓	STORYBOARD #	SHOT #	SUBJECT	SHOT SIZE	ANGLE	MOVEMENT	EQUIPMENT	LENS	SOUND	SETUP TIME	NOTES
			Model wearing EEG headset thinking, starting with tightshot of her face, panning out to full body with projection of sperm in front of her		Eyelevel	Pan					• Model sits **behind** projection • Projection footage is animation
			same as above, microsope footage		Eyelevel	Pan					• Model sits **behind** projection • Projection footage is microscoped
			same as above, model sits in projection		Eyelevel	Pan					• Model sits **in** projection • Projection footage is animation
			same as above, model sits in projection		Eyelevel	Pan					• Model sits **in** projection • Projection footage is microscoped
			Model wearing EEG sitting behind project of sperm, shot from above. Camera slowly zooms into projection to see the sperm move left, right, and down		High Angle	Zoom					• Model sits **behind** projection • Projection footage is animation
			same as above, microsope footage		High Angle	Zoom					• Model sits **behind** projection • Projection footage is microscoped
			same as above, model sits in projection		High Angle	Zoom					• Model sits **in** projection • Projection footage is animation
			same as above, model sits in projection		High Angle	Zoom					• Model sits **in** projection • Projection footage is microscoped

Figure 5.8: A shot list for the day of filming. Primary considerations involved whether the model would sit behind the projection, or actively be immersed in it from above. Image credit: Ani Liu.

The challenges of filming this project included the flickering colors and lights from the projector, and the low level lighting conditions overall. To obtain the highest resolution footage that we could in such low light settings, we used a variety of camera stands and other stabilizing equipment. We used several different cameras on a smooth dolly track to create scenes that begin tightly on the model's face, emphasizing thought, and panning out to show the projection of sperm which she is controlling. To control for the color, we pointed a spotlight directly at the model's face and body, and refilmed every scene with her sitting directly in the projection and slightly behind it.

Figure 5.9: Film still from the video. Image credit: Ani Liu.

The video can be viewed at www.ani-liu.com/pussygrabsback

5.4 Composing the Score

The music of a film contributes enormously to its affective quality, but due to the abstract nature of describing music with words, finding the right collaborator and communicating the ambience of the piece was enormously challenging. In the end, I worked primarily with two musicians, José Alejandro Rivera, and Wendy Eisenberg. Although the work was not chosen in the end, Luke Martinez, a talented experimental musician also created a cut for this project, which was an innovative mixture of synthesizers and vocals.

The main prompt for the sound to be feminine, empowered, and evoke wetness. I had imagined something ambient, abstract, and borderline noise music, but with some amount of melodic element so that the audience does not get completely lost. For the sound, I had a starting impression for the rumbling noise experienced when tears build up. José Alejandro Rivera came back with a track that was primarily digital, made with synthesizers, and textured. The upbeat, cyborgian nature of it was a good fit for the 30-60 second video aimed at communicating this project to a broad audience.

Wendy Eisenberg proposed a radically different take, with a track that was composed of only three notes, completely vocal, and layered and arranged in a multitude of ways. As soon as I heard it I got shivers; it gave the work an immediate embodiment. Through the music, there is a decided effort to deconstruct existing sounds, while maintaining an aura of hinting at the original material. The same wavelengths and frequencies of electrical activity generated by the brain become sonified,

creating the specific scales of the music. Deconstructed, the voice is both familiar and defamiliarized, and has vulnerability, strength and corporeal texture. This combination of the sterile, clean aesthetic of the set, juxtaposed with the evocative textures of the music served to navigate the sensitive nature of using sperm as a material for an art piece to express feminism.

6.

Reflections & Conclusion

Perhaps the way we can measure art is by what we become because of it.
Tania Bruguera

This thesis presents a work of art through the novel engineering an interface between the biological and the machine as an act of feminist expression, and to provoke contemplation on the imbalances gender as it plays out in biopolitical control. Triggered by the disturbing loss of female reproductive rights in the Trump regime, the work of this thesis attempts to express alternative biological narratives, to inspire a reimagining of what is possible in the landscape of gender politics.

The evaluation of a project rooted in the arts is typically done at a formal critique, where a panel of experts experience the art and have a discussion on its ideas, execution, and cultural contributions to the field. Due to a lack of the structure of art critics at the Media Lab, I am presenting this work to each of my readers independently for feedback. I have also shared this work with Giuliana Bruno, a professor of Visual and Environmental Studies at Harvard University and renowned scholar in the visual arts, film, and media. At the conclusion of a seminar that I took with her in my final semester, she had this evaluation of this work:

> **Your sperm mind control performance really puts theory into action in the best sense. Lest it be forgotten in our seminar's ideal intellectual setting, philosophical notions of material agency, the "body as thing", and the medium of intentionality are indeed urgent in this precarious post-election landscape. Your project recasts these questions poetically and technically in an atmospheric space of projection, all with an emphasis on feminist advocacy. So much hangs in the balance of your art-science speculation, and your practice is inspiring in its political potency. Bravo!**

Additionally, this project will be shared online, through my website and various social media channels. At the writing of this conclusion, an article about the project is scheduled to be released on Broadly, the women's focused channel of Vice, an influential magazine and website focused on arts, culture, and news topics. It is my hope that this exposure will spark more reflection and discussion amongst the broader public on issues of gender and equality.

Navigating the divergent connections between art and science, this work challenges the viewer to question what is possible. In a world where the digital prevails, this project seeks recode and reconsider the role of material culture through the body. Paying homage to to Foucault's biopolitics, this project reflects on the body beyond its constituent flesh and into its political role as

a connector and pawn in systems larger than itself. Reflecting on Donna Haraway's *Cyborg Manifesto,* it transgresses the boundaries of gender, human, and machine to overcome biopolitical control.

As a work of art, this project attempts to mediate between the relationship between our own biological realities and a speculative dream for a different one. Whereas our biological understanding of sperm is usually deterministic (i.e., as an inherent homing device racing towards the chemical signatures of an egg) or colored by gendered cultural constructs (i.e., its semiotic use in pornography) this project seeks to invert all preconceived notions. By creating a work that is simultaneously technological, functional, and symbolically potent, it presents both a hope to expand our notions of what it is possible, and what is possible to question.

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