Aesthetics of Maker Culture: the Active Role of the Audience

Final thesis for the academic degree of Doctor of Philosophy (Ph.D.)

Submitted to the Faculty of Art and Design of the Bauhaus University Weimar

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Bauhaus University of Weimar, 2022

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Disputation on 26.09.2022

Layout and Design:
Juan Pablo Díaz

Proofreading:
Elizabeth McTernan, Tristen Bakker

Software:
Scribus 1.4.5 Open Source, Desktop Publishing (Ghostscript-Version 8.71)

Fonts:
Carlito. Foundry: Łukasz Dziedzic.
License: SIL Open Font License v1.

Abstract

In this work, practice-based research is conducted to rethink the understanding of aesthetics, especially in relation to current media art. Granted, we live in times when technologies merge with living organisms, but we also live in times that provide unlimited resources of knowledge and maker tools. I raise the question: In what way does the hybridization of living organisms and non-living technologies affect art audiences in the culture that may be defined as Maker culture? My hypothesis is that active participation of an audience in an artwork is inevitable for experiencing the artwork itself, while also suggesting that the impact of the umwelt changes the perception of an artwork. I emphasize artistic projects that unfold through mutual interaction among diverse peers, including humans, non-human organisms, and machines. In my thesis, I pursue collaborative scenarios that lead to the realization of artistic ideas: (1) the development of ideas by others influenced by me and (2) the materialization of my own ideas influenced by others. By developing the scenarios of collaborative work as an artistic experience, I conclude that the role of an artist in Maker culture is to mediate different types of knowledge and different positions, whereas the role of the audience is to actively engage in the artwork itself. At the same time, aesthetics as experience is triggered by the other, including living and non-living actors. It is intended that the developed methodologies could be further adapted in artistic practices, philosophy, anthropology, and environmental studies.

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Research Practice Documentation

In terms of research practice, online documentation of each project is included here. All iterations are accessible through the last URL, the personal website. All other URLs listed are the front pages of each iteration of the project, which contain links to the various components, including concepts and descriptions of toolkits, installations, manuals, video tutorials, and photo and video documentation.

Introduction to Posthuman Aesthetics (2016–2019),
http://triple-double-u.com/introduction-to-posthuman-aesthetics/
Self-Repair Lab (2017–2019),
http://triple-double-u.com/self-repair-lab/
Self-Repair Lab aka TOP lab (2016–2022),
http://www.top-ev.de/lab/
Self-Repair Lab aka Alt lab (2019–2022),
http://www.o-o.lt/alt-lab/
Microorganisms &Their Hosts (2020),
http://triple-double-u.com/microorganisms-and-their-hosts/
You and I, *You and Me* (2021),
http://triple-double-u.com/you-and-i-you-and-me/
Personal website,
http://triple-double-u.com/

Acknowledgments

First and foremost, my gratitude goes to Prof. Ursula Damm and Prof. Dr. Henning Schmidgen, my supervisors at Bauhaus University Weimar for seeing this project through to the end with precious comments, support, and challenging questions.

I am deeply indebted to Matthew Fuller, who encouraged me to continue my research at Bauhaus University; to my friends, colleagues, and teachers Arūnas Spraunius, Wolfgang Knapp, Hubertus von Amelunxen, and Hannes Brunner with whom I regularly had conversations about art, sciences, and technologies. A special thank you to Elizabeth McTernan and Tristen Bakker, who made this thesis more readable.

I am very grateful to my family—my mom, Stasė Gapševičienė, dad, Adolfas Gapševičius, and sister, Vilma Suchockienė—who encouraged me throughout this project.

While working on my dissertation, I worked on a number of projects, each involving several collaborators. Thanks to Brigita Kasperaitė, who was there to shoot and edit video tutorials of the *Introduction to Posthuman Aesthetics* and document the toolkits. Also to Alanas Gurinas who was kind enough to document all the *Self-Repair Lab* workshops. My gratitude goes to Dr. Brian Degger, Dr. Julian Chollet, Dr. Mirela Alistar, and Juan Pablo Díaz, who collaborated while executing DIWO experiments on symbiosis within the toolkit "My Collaboration with Bacteria for Paper Production" and workshop *SCOBY, Shit and Humus*. I would also like to express my gratitude to Martin Howse, who kindly contributed with experiments involving electronics and collaborated in the production of the video tutorial “Mycorrhizal Networks, or How I Hack Plant Conversations.” I would like to express my gratitude to Wolfgang Spahn, who kindly agreed to collaborate on an interface that generates sounds from the human body and also in the production of the video tutorial “Ultra-Low-Voltage Survival Kit” as well as the workshop *I, Machine, and Energy Harvesting*. Thanks to collaborators around the “How I Prepare Myself to Be Cloned” toolkit and related *Lactose-Intolerance DNA Portraits* workshop. This project was kindly supported by Philip Bayer and Michael Blessenohl from Life-Science Lab Heidelberg and Miglė Kalvaitytė and Auksė Gaižauskaitė from Vilnius-Lithuania iGEM team.

I am grateful to my collaborators of the *Microorganisms & Their Hosts* solo exhibition: scientist Auksė Gaižauskaitė (microbiology), artists Antanas Gerlikas (glass), Laura Kaminskaitė (exhibition design and glass), and curator Valentinas Klimašauskas. Also to: Bon Alog (video editing), Tristen Bakker (proofreading), Juris Dunovskis (glass), Mark Eckstrand (glass), Alanas Gurinas (camera, sound), Nerijus Kėblys (graphic design), Juozas Masiulis (microbiology), Mindaugas Miselis (electronics), Mantas Rimkus (graphic design), Martin Schied (electronics), Bevan Taka (glass), Hege Tapio (workshop), Vilius Vaitiekūnas (video documentation), Andrej Vasilenko (photo documentation), and Adomas Žudys (3D modeling).

Many, many thanks to the main collaborators of the *You and I, You and Me* project: Maria Safronova Wahlström (headwear design, project development), Helga Mogensen (jewelry), and Leon Crayfish (shoe design). This project wouldn’t have been possible without: Ian Erik Stewart (neuroscience consultant), Mantas Mizgiris and Simona Nakrošiūtė (jewelry), Mindaugas Miselis and Alexander Selifonov (electronics), Bon Alog (photography and video), Arūnas Baltėnas (photography), Gvidas Bindokas (video documentation), Antanas Skucas (programming), Antanas Gerlikas (installation), Živilė Etevičiūtė, Tadas Šarūnas, and Johanna Glaza (models), Kamilė Krasauskaitė and Ernesta Šimkutė (curators), Taktika Studio (design), Audrius Antanavičius and Jonas Balsevičius (tech support), Marijonas Račkauskas, Karolina Valentaitė, and Roberta Alksnytė (event), Tūla Kristina, Gabija Augustinavičiūtė, Eglė Skinderytė, Kamilė Laurinavičiūtė, Grėtė

Ona Tvarkūnaitė, Vilma Suchockienė, Solveiga Stankevičiūtė, and Ona Ringaitytė (participatory event), and others. Thank you!

I would also like to thank all the participants in the *Self-Repair Lab* workshops, while working on the *Proposal for Microbial Therapy* installation, and also the *How to Personalize Yogurt?* workshop. At least fifty names should be listed here, most of which are mentioned in the work below.

Most of the projects would not have been possible without the financial support from the Lithuanian Council for Culture, Bauhaus University Weimar, Vilnius Municipality, and the Nordic Council of Ministers. Thank you!

Many, many contributions came also through the organizations: Institutio Media, Lithuanian Interdisciplinary Artists' Association, TOP e. V., Ars Electronica Festival, the Lithuanian National Gallery of Art, Biorama Projekt, and Dunovglass. It was a great time to develop things together!

Ačiū!

Introduction

One of the most significant current discussions in culture theory focuses on humans and their relation to technologies (Braidotti 2013; Haraway 2008; Hayles 1999). In the arts, a parallel discourse appears in Bioart (Myers 2012; Mitchell 2010), post-digital aesthetics (Cramer 2014, Transmediale festival), and hybrid arts (Ars Electronica festival). These discourses are often accompanied by the Maker culture context (Papadopoulos 2014; Ratto 2011a).

In this thesis, with the aforementioned context in mind, I propose that the reconsideration of artists' role and artistic production through a maker lens does not only manifest a changing position of artists themselves, or art audiences, but also opens up a space for new artistic methodologies. This reconsideration includes aesthetic, philosophical, and practical use of tools and rapidly changing technologies that enable the hybridization of digital resources, physical tools, and aesthetic experience. In this context, the integration of living organisms in creative practice is more than welcome.

An interesting position toward interactive arts was recently introduced by Varvara Guljajeva in her dissertation "The Disappearing Role of the Active Participant," where she sketched post-participative arts (Guljajeva 2018). The idea proposed by Guljajeva differs from interactive art of the 90s, which required an active participation from audiences and built upon inactive participation, or system-to-system interaction, where only data of the participant is tracked but no active participation from the perspective of audience is needed. However, these settings do not communicate the knowledge needed to make the machines act. Considering that the "making" of machines act as the continuation of the interactive arts of 90s, I propose to rethink the role of the artist and the audience in reference to Maker culture. By suggesting that a participant of an artistic workshop is also an audience of an artwork, I argue that idle participation of the audience in the referred artworks would not contribute to the understanding of the work itself. More than that, avoiding understanding of how the artwork is built, post-participative art as system-to-system interaction would not stimulate an audience to develop new ideas (or meanings), which in turn would have the potential to lead to a new outcome of cultural or economic value. Thus, the art would stagnate. I assume that in such a setting there would also be no place for humanity—only for machines. Thus, there would be no need for humans to do art.

Next to Guljajeva's passive position of the art audiences, in this work, I propose to rethink aesthetics, fulfilling the gap between the digital and physical, art and science. For example, in Maker culture, the role of humans is perhaps not necessarily inactive. Quite the opposite: makers actively share their production in social media, use available online resources for further research, or initiate discussions on the net.[1] Doing things on the Internet has also become a new normal for artists,[2] especially in the context of the current pandemic, when people are forced to move their social lives to the digital realm.[3] The shared physical and virtual presence of artists and art audiences broadens the understanding of artistic work from engaging audiences in the interactive installations to doing things online together with audiences. In having unlimited digital resources, artists are challenged to learn from the audiences and at the same time share their know-how with audiences.

While asking the question, In what way does the hybridization of living organisms and non-living technologies affect art audiences in the culture that may be defined as Maker culture?, I emphasize arts, which are driven by the idea that technological tools can be used to create unique results (and experiences) that don't exist on the market. Fulfilling a setting where interaction between different peers (including non-human organisms, tools, and machines) unfolds, arts provoke one to experience things with others and also to contribute to society with outcomes, which, in turn, are again fed back into the social space.

Experiencing things with others is not new in my artistic practice. Collaborations with other fellow humans have followed me in my artistic practice since 1998,

*1 See, for example, https://makezine.com/ (Accessed 17 December 2021).
*2 See, for example, Hendriks and Novitskova (2014).
*3 See, for example, recent Ars Electronica Festival, https://ars.electronica.art/newdigitaldeal/en/ (Accessed 17 December 2021).

when I came up with my first series of net.art projects, focusing on technical experiments around the Internet.[4] These experiments continued with a more philosophical problematic in my artwork[5] and artistic research, which wrapped up at Goldsmiths University,[6] when I questioned the creativity of a machine and the use of computers in creative practices. Still, at that point, the collaborative aspect in my art was more on a social level, more in line with the audience's passive contribution to my art, something Guljajeva focused on in her work. Being critical of machine creativity and also of idle human participation in art installations, but also understanding the importance of the impact on human creativity by non-human actors, I have had to re-evaluate my further artistic practice and research while literally adding non-human actors to my collaborative setting.

While inviting humans and integrating non-human actors into my artistic practice, my artworks have developed into self-reflective frameworks based on interaction between living and non-living.[7] They all combine in themselves humans, non-human organisms, and technological objects. The technological objects serve two purposes: On one hand, they are made for aesthetic reasons, and on the other hand, they are provided to be used as tools; whereas human and non-human organisms are directly involved in this framework through aesthetic experience. While approaching the objects and non-human organisms directly, the audience becomes part of the larger setting, which, in turn, experiences the impact of non-human actors on themselves and the impact of them on the "Umwelt," Jakob Johann von Uexküll's term defining environment as specific to its actor.[8]

Having explored the hybridization of living organisms and non-living technologies in recent art festivals, biennials, and exhibitions, my gaze encountered a significant demand in participatory workshops and participatory events with artists themselves. Also, I traced the vanishing of the borders between making, arts, sciences, and technologies. For example, in 2019 Maker Faire in Rome[9] launched a new section dedicated entirely to art, curated by Valentino Catricalà.

*4 See, for example, http://www.o-o.lt, http://o-o.lt/mi_ga/diary, http://www.asco-o.com.
*5 See, for example, http://triple-double-u.com/mailia (2006), http://triple-double-u.com/bookshelf (2006), http://triple-double-u.com/carpet/t-shirt/?s (2006–2011).
*6 For more details, see http://triple-double-u.com/0.30402944246776265 (2013–2015).
*7 My experiments and artworks of this research include participatory events and workshops that include shared work with living organisms and computational technologies. For more details, see Introduction to Posthuman Aesthetics, http://triple-double-u.com/introduction-to-posthuman-aesthetics (2016–2019), *Self-Repair Lab*, http://triple-double-u.com/self-repair-lab/ (2017–2019), Microorganisms & Their Hosts, http://triple-double-u.com/microorganisms-and-their-hosts/ (2020), and You and I, You and Me, http://triple-double-u.com/you-and-i-you-and-me/ (2021).
*8 For more information, please refer to pages 32, 131.
*9 Maker Faire focuses on Do-It-Yourself (DIY) and Do-It-With-Others (DIWO) projects. It was held for the first time in San Mateo in California in 2006.

Included for the first time, the art section focused on environmental sustainability, global warming, the relationship between humans and nature and the most demanding themes in politics[10] and at recent art festivals.[11] This edition of Maker Faire added value to the art by making it accessible to those who had little interest in it before.

Among other artworks, Maker Faire in Rome presented *Biosphere* by Joaquín Fargas and *Human Study* by Patrick Tresset, both exhibited in the same year at the Ars Electronica festival for art, technology, and society in Linz. The second one was additionally shown at the KIKK festival for digital and creative cultures in Namur, Belgium. Having scientific, technological, and artistic features, visual arts became, on one hand, indistinguishable from technological or scientific innovations and, on the other, it expanded to areas considered being outside arts. Therefore, it is crucial to, first of all, contextualize the technological tools in art. The two artworks mentioned will also help the reader to reflect on the use of technological tools in art from two different perspectives and, at the same time, to contextualize the relation of audiences to the inquired art itself.

The installation *Biosphere* by Joaquín Fargas (2007) combines a number of transparent spheres, isolated from the environment and representing an enclosed ecosystem, which are being influenced by the temperature and light. At the same time, the artist actively communicates with the audience. Interesting in this project is the artificial system, which would evolve, depending on the organisms, enclosed in the spheres, but independently from the actual environment. Since the physical environment is excluded from direct interaction, the audience may give a thought to evolving biological systems, but not be able to influence them. In this installation we see an aestheticization of nature that excludes the influence of the human on it and vice versa.

The installation *Human Study* by Patrick Tresset (2012) combines a number of old school desks and robots that draw portraits of humans in real time. The audience also sees how the artist tries to deal with robots and the audience itself. While taking the position of a model, I tried to hack the installation in terms of how the interaction between the model and the machines was organized. Even

*10 It is now almost two years since European Commission President Ursula von der Leyen unveiled a new European initiative, “The European Green Deal,” which sets out the roadmap for a green European strategy to make the EU a fair and prosperous society with a modern, resource-efficient and competitive economy. Very specific funding programs are now being announced (e.g. New European Bauhaus, renewed HORIZON, Creative Europe programs) to help a wide range of initiatives to implement the outlined guidelines, including the inclusion of all members of the community (women, LGBTQI+, migrants) in common activities.
*11 See, for example, Ars Electronica festival, https://ars.electronica.art/ or Transmediale, https://transmediale.de/.

if the artist himself was not happy about me moving to the right and left and drinking coffee, I wanted to understand how the robots were being built. I was expecting the result to be more abstract, as actually it became. Therefore, I assumed, that the cameras pointed at me were not really drawing me live. Instead, I guessed, the algorithms were using the preselected captured frames and predefined algorithms. On one hand, I liked the idea of a human being a model and of having contributed to the result proposed by a robot. On the other hand, having the vision of an artist to simply replace humans with robots, the work rather illustrated life, and while programming the robots, the artist rather tried to replicate humans. While bringing into the discourse artificial intelligence (AI), the piece reminded me of ELIZA software, written by Weizenbaum in the 1960s[12] while manifesting the inability of a computing machine to be an "artist." At the same time, the influence of humans on robots and vice versa in the work of Tresset was very limited in terms of experience.

Being present in the same festivals, both works developed similar discourses: They offered thoughts in regard to technological development, and they involved the artists themselves, who actively mediated technological, scientific, and artistic ideas behind their installations. At the same time, however, in both works the interaction between the actors were limited, so that the settings were illustrative rather than interactive. On the other hand, the active participation of the artists and audiences in the installations were somehow different from Guljajeva's proposed idle participation of the audiences in the post-participative artworks. Therefore, the installations made me think about active participation by the artists and audiences in other kinds of technological artworks than those described by Guljajeva.

Such a context led me think about the specifics of art that uses artistic formats and methods based on active participation, e. g. performance art, workshop, participatory event, and the like. Therefore, in the "Framework" chapter of the thesis, I will invite the reader to follow my aesthetic and theoretical considerations that led me into positioning the research next to "hybrid" aesthetics, Maker culture, and theoretical contexts merging living organisms with computing machines.

The chapter "Setting Up Tools for the Research: *Introduction to Posthuman Aesthetics*" introduces my artistic tools for the research. These tools might be seen as tools for technological or scientific experiments, but also might be considered as artworks themselves. This chapter forms the basis for the research that follows in the other chapters.

*12 For more information, see "Alan Turing at 100," https://news.harvard.edu/gazette/story/2012/09/alan-turing-at-100/ (Accessed 6 December 2020).

The chapter “Collaborative Experience in the *Self-Repair Lab*” is reserved for the experiments with the tools presented in the second chapter. In this chapter, the framework of the collaboration and the eventual outcomes are presented. At the same time, the reader gets acquainted with artistic methods that led to the emergence of the new ideas and forms.

The idea of the emergence of the new ideas and forms is further analyzed in the chapter “A Shift in the Role of an Artist”, which brought me to some first conclusions regarding the changing position of artists in the artworks targeted in this research. I conclude that, in a collaborating setting, the role of the artist changes from a centralized to a mediating one.

The chapter “Aesthetics through the Lens of the Posthuman”, then, is reserved for the final artworks of this research, reflecting previously executed research. In this chapter, I start with introducing interactive settings between humans and non-human organisms. This chapter further develops aesthetic experiences of the integrated human and non-human settings. Here, I conclude that humans, non-human organisms, and machines, while interacting with each other, change the perception of audiences. Thus, I suggest that aesthetic experiences of a human in targeted artwork is distinct from the one described by Guljajeva as post-participative artwork.

The final chapter is reserved for conclusions and summarizes my entire thesis. Here, I conclude that artists, along with the audiences and machines, should take an active role in an artwork in order to respond to the environment and the changing world. At the same time, the role of an artist in Maker culture is both to produce an artwork and to actively communicate meanings between different peers (the changing role of an artist). Being within the interaction between humans, non-human organisms, and machines, it only makes sense if aesthetics is being understood through the experience. The cultural added value is built by extending artistic processes to areas other than art and by incorporating scientific and technological tools into art; whereas the aesthetic experience of audiences is affected by non-human actors, including non-human organisms and machines. This chapter also concludes that the developed methodologies could be further adapted in artistic practices, philosophy, anthropology, and environmental studies.

Framework

Rationale and Methodology

The research is practice based and is designed to provide qualitative insights into aesthetics of Maker culture. The methodology for this research was dictated by previous research at Goldsmiths University that dealt with distributed computer networks. There, my research took the form of an artistic computer installation that reflected an imaginary social network based on the Freenet project, a peer-to-peer platform for publishing and communication. Although I stated that the computer installation was more than hypothetical, it lacked a human (and non-human organisms), one of the most important factors in an interactive installation. Therefore, this research had to involve humans into artistic projects first and foremost.

The scope of this research to investigate the hypothesis focuses on
1. understanding current theoretical framings of aesthetics around the Maker culture to test the assumptions of the research hypothesis;
2. experiencing of the tools to be used in artistic and other related practices;
3. exploring hybrid settings for aesthetic experience; and
4. developing different methods to involve a variety of audiences.

For this research, I have chosen to work with aesthetic formats that were unusual to my artistic practice, that is, collections of tools used for experimentation, manuals, video tutorials, workshops, and participatory events. The work includes my artistic practice, which unfolds in this thesis as an installation of toolkits (*Introduction to Posthuman Aesthetics*), a series of workshops (*Self-Repair Lab*), a solo exhibition *Microorganisms & Their Hosts*), and a participatory event (*You and I*, *You and Me*). The toolkits are presented in the chapter "Setting Up Tools for the Research: *Introduction to Posthuman Aesthetics*," their application in the chapter "Collaborative Experience in the *Self-Repair Lab*," and other artistic projects based on the same tools in the chapter "Aesthetics through the Lens of the Posthuman."

Understanding of the limitations of humans in a posthuman society and seeking to avoid speculative and imaginary settings, the goal of this research became the real integration of human and non-human actors in an artistic setting. Limited knowledge of biology and technology suggested learning DIY methods and engaging in DIY communities. This has led me to open two DIY biolabs and collaborative spaces: the TOP Transdisciplinary project space in Berlin[13] and the Alt lab, a non-disciplinary research lab for conducting interdisciplinary projects in Vilnius.[14]

Related Artistic Considerations

Readymades, performance art, relational aesthetics, post-digital, bio art, hybrid media—all genres seem to be "related," but not exactly contextualizing the field of research. Finally it is not of essential importance, as far as the contextualized genre of art, to involve emotions, computational logic, and practical experience. My logic suggests to start with referring to post-digital art and then move onwards to "Maker culture" representing the subculture of *prosumers*—individuals who produce and consume things themselves. The logic is based on the definition of the Transmediale festival, which "creates a space for critical reflection on cultural transformation from a post-digital perspective"[15] and is a festival for art and digital culture.

The positions describing the term post-digital differ, fluctuating between hybridization of forms (Alexenberg 2011), the introduction of failure to digital aesthetics (Cascone 2000), and the importance of process in regard to the packaged product (Cramer 2014). Although Alexenberg's definition suggests that the post-digital has a feature of hybridity—a balance of physical and virtual, form and action—the meaning he puts behind the post-digital is rather philosophical, imaginary, and spiritual (Alexenberg 2011, 10). The post-digital for Alexenberg

*13 For further information, see http://www.top-ev.de.
*14 For further information, see http://www.o-o.lt.
*15 See https://transmediale.de/about (Accessed 25 May 2021).

is an imaginary state where the digital becomes part of the analog, but at the same time, it is too vague in saying how this hybrid functions.

A different emphasis is put on the post-digital by researcher and media theorist Florian Cramer, who presented his ideas on post-digital research during a discussion that was part of the Transmediale festival in Berlin in 2014. This position unfolds from two perspectives: on one hand, as a merging of digital and analog and, on the other, through the everyday use of computers and digital information. In the reader of the discussion on the post-digital, Cramer writes that neither "old" nor "new" media are meaningful, as they merge in the post-digital (Cramer 2014). To illustrate the post-digital as having a different approach to aesthetics, Cramer points to the generation born in the 1990s, who do not remember times without computers; the "digital" is a given for them. Consequently, the youngest generation often uses different ways of interacting and have social lives influenced strongly by communication within virtual space. Cramer's idea suggests that we are living during a time of significant cultural change similar to that marked by the appearance of the digital computer in the 1950s. On one hand, this change marks the end of the digital revolution, and, on the other hand, the digital world has become as natural as, to paraphrase, the air we breathe. This is visible in the arts and mass culture, which have shifted to a stage wherein the tool(s) and the medium(s) used to produce artwork is not necessarily central. While recent decades have often encountered the terms "performance art," "video art," "digital art," "software art," and the like, in the post-digital, the tool and the medium have changed their meaning, no longer generating content solely through their novel "nowness" as measurement, as a genre. But in this meaning too, although referring to digital, the digital virtuality rather means the acknowledgment of it but not a function defined by zeros and ones.

Different from Alexenberg, who defines the post-digital as an in-betweenness of forms and meanings, post-digital aesthetics for Cramer focus rather on "processual" DIY cultures and the application of "new media" practices onto "old media." If, in the case of DIY cultures, the process itself has become aestheticized with the rebirth of "old media," the conditional change made by digital technologies is already de facto and is no longer considered revolutionary.

It is also worth bringing up the musician Kim Cascone, who introduced the term "post-digital" (Cascone 2000). While stating that the revolution of digital information is over, Cascone offers two features of the post-digital that distinguish the post-digital from the digital. First of all, he brings into the aesthetics of music a failure of the digital, the glitch. Second, he introduces a “tool” as a message instead of the medium being a message, an idea introduced much earlier by Marshal McLuhan (1964). If the “glitch” for Cascone speaks of the illusion of technological perfection and is the result of experimentation, the “message” is what one sees (or hears, in the case of sound) rather than reads. With the post-digital, Cascone defines a slight change in culture: on one hand, “failure” is introduced as a natural process for creativity, and, on the other hand, sound can be perceived by seeing how it is made. This position introduces the importance of the tool, which contextualizes the outcome.

Nevertheless, none of the positions highlighted above define the status quo in aesthetics followed in this research. With his in-betweenness, Alexenberg is no further from Georg Wilhelm Friedrich Hegel’s combination of sensuous and spiritual aspects of an art product, introduced in lectures on fine art between 1823 and 1829 (Hegel 1988), and Cascone’s tool or a glitch is not necessarily different from McLuhan’s medium, since both the tool and the glitch can be part of the medium for the message (McLuhan 1964). Cramer’s idea may sound more attractive where he aestheticizes the interaction between the virtual and the physical. However, the focus here is still on the result described by the distinction between old and new or virtual and physical.

To make my position clear, I will next bring forward two positions on aesthetics: Hegel’s, which focuses on contemplation of an object, and John Dewey’s, which focuses on experience, resulting in contemplation.

In his lectures on fine art, Hegel defines aesthetics as (1) being a result of human activity, (2) drawn from a sensuous field, and (3) having an aim in itself (Hegel 1988, 1–90). In other words, aesthetics, being an opposite to nature, is a human product, which carries in itself an idea of beauty, a fusion of idea and shape. A piece of art for Hegel is a reflection of nature and not nature itself. Therefore, it carries in itself an idea of beauty, the aim, which wouldn’t be the case of the result of human activities. This could be reduced to the fact that aesthetics has only something to do with senses like sight and hearing, while other senses like smell, taste, and touch remain excluded from artistic qualities. For Hegel, art is a result of subjective artistic productivity that combines sensual and spiritual aspects, a holistic interpretation of aesthetics. Here, the audience assumes a contemplative position while viewing, listening to, or reading a piece of art.

Instead of contemplating an art object, John Dewey puts it into the realm of experience, an idea he brought to his students in his lecture series in 1931 later compiled in a book *Art as Experience*. Dewey starts with flowering plants, which are the result of interactions of soil, air, water, and sunlight. As with an art piece, the Parthenon, it gains an aesthetic meaning only as a human experience (Dewey 1980, 4). In other words, opposite to the understanding of Hegel, as an object, it has no aesthetic value; it needs to be understood within historic, social, or needs context—in other words, experienced. Referring to Ancient Greece, Dewey calls art the "act of imitation," while Hegel called art "imitation of nature" (Hegel 1988, 41). And here Dewey considers life, which goes on not in the environment but because of it, because of interactions with it (Dewey 1980, 13). As an artist is a live creature, he "has his problems and thinks as he works" (16). Interestingly, Dewey compares artistic experience with other creatures as well: birds build their nests, whereas beavers build their dams until a satisfying culmination (24). Art as experience is thus a common feature of living organisms. Not excluded here is the audience, which experiences the artwork through interaction with the environment in which the artwork is located. At the same time, experience of thinking would rather be a conclusion of experience (37). For Dewey, then, Hegelian aesthetics would be nothing other than the result of artistic experience.

When I think of artistic examples that are directly related to artistic experience, the first thing that comes to mind is Fluxus with its happenings and performances (John Cage and Robert Rauschenberg, among others). Not excluded are events contextualized as relational aesthetics (see, for example, cooking sessions by Rirkrit Tiravanija or *Volksboutique* projects by Christine Hill). I would also think of artistic objects to be used by the audiences (see, for example, Georg Maciunas' "Fluxkits" or Daniel Spoerri's "Snare-Pictures"), instruction sets (for further references see Ken Friedman, Owen Smith, and Lauren Sawchin *The Fluxus Performance Workbook* or Etienne Thacker and Natalie Jeremijenko's *Creative Biotechnology: A User's Manual*), and workshops (e.g. Marc Dusseiller, Martin Howse). The latter are often placed in the context of DIY or Maker culture. They all contextualize the artistic practice and give the viewer the idea of aesthetics as experience.

I will attempt to contextualize artist practice within what might be called DIY or Maker culture. I hope this context helps the reader in my further reflections on the artistic challenges in a culture that uses scientific and technological tools for aesthetic experience.

Contextualization of Maker Culture

In the theoretical context, next to John Dewey's concept of art as experience, *Phenomenology of Perception* by Merleau-Ponty contextualizes artistic experience, in a broader sense, as the concept of human temporal perception and considerations within the time (Merleau-Ponty 2012). I would also like to highlight *The Savage Mind*, in which Claude Lévi-Strauss (1966) tries to distinguish between science and magic, the two different realms of knowledge acquisition.

According to Merleau-Ponty, the temporal perception is not defined as a process of considerations but rather as a unity of considerations and practical experience. To illustrate it, he described the perception of the table upon which he was writing. The idea of the table was evolving through a series of "sensations" that allowed him to experience writing (Merleau-Ponty 2012, 247).

On the other hand, Lévi-Strauss, places the experience into magical thinking. This magical thinking is defined through bricoleur, a person who works with "what is at hand." In this sense, Lévi-Strauss's bricoleur differs from Merleau-Ponty's and Dewey's artist in that he has a mythical thought and "works with his hands" to rearrange existing elements within a system. At the same time, a bricoleur is comparable to Merleau-Ponty's human with his temporal perception and John Dewey's artist who "thinks as he works." In other words, the acquisition of knowledge occurs through sensory experience rather than logical consideration.

Now, Maker culture as culture of the 21st century (Papadopoulos 2014) can be viewed through both sensory perception and a technological lens. Therefore, it must be distinguished from the Lévi-Strauss's bricoleur or, in a broader sense, the DIYer.

First of all, Maker culture is highlighted by the ability to 3D print physical objects, and printing physical objects would not be possible without a programmable computer machine. Second, Maker culture is inconceivable without access to the Internet, which provides access to instruction sets, scientific knowledge, and creative ideas to actually make things. Finally, access to tools and knowledge makes the maker aware of things that would not be obvious in either perceiving the physical world or making things with what is at hand.

What makes the programmable computing machine so important? Differently from the programmable machine, analog computation has followed humans throughout history and is not referred to programmable computation. Examples might include the Sumerian abacus, said to be invented between 2700–2300 BC, or sundials, said to be invented in ancient Egypt around 1500 BC. However, the programmable computing machine is able to process virtual calculations and embed them into a physical world in real time.[16] Such a machine is therefore able to interact (and form feedback loops) in real time between the physical world and the digital computations of a machine.[17]

While 3D printing is not so important within this research, it may visually simulate or, at some point in the future, transform humans into machines (the idea further elaborated in the following subsection). Worth mentioning is the RepRap project,[18] which focuses on a self-replicating computing machine—the idea that a printer could print itself and thus simulate a living organism. While Maker culture does not necessarily focus on the possibilities of simulating living organisms, it does focus on the acquisition of knowledge through sensory experience and self-expression through the available tools.

With easy access to online learning tools on the one hand, and being able to run personalized blogs and vlogs on the other, a maker of the 21st century may quickly define problematic issues, raise questions, discuss them, and find new solutions to the raised problematic issues.[19] Therefore a maker deals with philosophical aspects similar to those who relate themselves to Maker culture, such as equity, and ecological crisis.

In Maker culture, I would also distinguish collaboration and an ability to adapt to new environmental conditions. Instead of a focus on material production, both collaboration and "making" emphasize questioning and argumentation while experiencing. Here, the adaptation results in interaction with matter, tools, and people—makers do not do experiments just because of doing them, and makers do not use paper and pencil just because they are lying next to them. They do experiments and use paper to learn, to critically evaluate and to express themselves. I will bring forward three positions on "making": a "critical making" by a researcher Matt Ratto, "Generation M" by researcher Dimitris Papadopoulos, and "critical engineering" by an artist group The Critical Engineering Working Group.

*16 The first programmable computing machine Z3, built by Konrad Zuse in 1941, used a binary number system, had an interface for inputting commands, and output the result on a display. For more information, see Zuse (2007). Also worth mentioning is a more complex system connecting an early digital computer to a milling machine, built in 1952 by researchers at the Massachusetts Institute of Technology (MIT). For more information, see (Gershenfeld 2012). In both cases, two objects from a physical environment are bridged with digital computation.

*17 This idea was first presented by Alan Turing (Turing 1936).

*18 See further RepRap.org. Available at https://reprap.org/wiki/RepRap (Accessed 30 March 2020).

*19. Compare, for example, Lovink and Rossiter (2018), Papadopoulos (2014), and Galloway and Hertz (2015).

In the article "Critical Making," Matt Ratto states the following:

> Critical making... is less about the aesthetics and politics of design work, and focuses... on making practices themselves as processes of material and conceptual exploration. The ultimate goal of critical making experiences is not the evocative or pedagogical object intended to be experienced by others, but rather the creation of novel understandings by the makers themselves. (Ratto 2011a)

Here, the focus lies on making but not the objects made. The making is viewed through the exploration, more pedagogical rather than didactic.

At this point I would like to bring in the position of Dimitris Papadopoulos:

> Generation M makes stuff. Not through mass production but by tweaking and expanding the capabilities of existing things and processes. The maker's craft: hacking, tinkering, stretching, knitting, inventing, weaving, forking, recombining. (Papadopoulos 2014, 639)

And:

> Generation M is all about collaborations that create the very material conditions we live in. (639)

Here, the focus lies on making for expanding the capabilities of the made. In other words, the maker in Generation M contributes to the made, but also does it through collaborative work. If there is any pedagogical position, it is seen through the lens of collaboration and not the set of final instructions.

Another slightly different position is brought by The Critical Engineering Working Group, the CE (2011), a group of artists based in Berlin. Their very first statement says:

> The Critical Engineer considers Engineering to be the most transformative language of our time, shaping the way we move, communicate and think. It is the work of the Critical Engineer to study and exploit this language, exposing its influence. (CE 2011)

Although the idea of critical engineering is similar to the one of a maker, the approach to it is quite different. While Ratto's focus is on the critical exploration of processes, Papadopoulos's maker extends the capabilities of the made and CE's focus is on the presentation of study results. If in the first two cases the result is not didactic, in the third case it is didactic. While in the first case the result is the knowledge gained, in the other two cases the result is a new object. The taken position in this thesis is of Papadopoulos, with a strength on the added value of the made, and a pedagogical position through the mutual interaction.

Now, I would like to bring in two artworks: *Free Universal Construction Kit* by Golan Levin and collaborators (2012) and *Readymake: Duchamp Chess Set* by Scott Kildall and Bryan Cera (2014).

The *Free Universal Construction Kit*[20] is a collection of 3D models that allow interconnecting parts of different toys such as Lego, Duplo, or Fischertechnik for children. The idea behind the artwork is twofold: First, the construction kit introduces children to a non-systemic way of thinking about toy construction. Second, it is a critique of the toy industry, whose standards block the construction of cultural value on the tools provided. By introducing an artwork that can be used to produce new work, Golan Levin proposes to expand the possibilities for experimentation and creativity for the users of the kit. At the same time, the art is presented as a set of instructions to help people with no prior knowledge understand and practice art.

Another example is *Readymake: Duchamp Chess Set*,[21] a creative reproduction of *The Chess* Set created by Marcel Duchamp between 1917 and 1918. By recontextualizing an existing work, the authors bring a new context to art. On the one hand, the instructions for printing chess pieces invite laypeople to reproduce a work of art, and on the other hand, they provide an opportunity to experience art as the artist envisioned it. Not only is art made accessible, but it is also demystified to a level that may not necessarily be perceived as a work of art.

Golan Levin's artwork reflects very well Ratto's idea of critical making, while the work of Scott Kildall and Bryan Cera fulfills Papadopoulos's idea of the extended impact of the original artwork. None of the works is didactic from the perspective of the artists. On the other hand, both lead to a result that is as important as the process of production itself.

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*20 For more information, see http://www.flong.com/archive/projects/free-universal-construction-kit/ (Accessed 2 November 2021).

*21 For more information, see https://kildall.com/archives/3259 (Accessed 2 November 2021).

So what is the role of art and the artist in both cases? Obviously, there is a work of art created by the artists themselves. But there is also an updated result of the use of the artwork. From an artist's point of view, an art object in Maker culture could be summarized as an in-between object that is an outcome of a critical reflection, but at the same time invites the user to, again, critically reflect and create a new result. By bringing together available things, critically evaluating them, and proposing an object yet-to-be-used for a new outcome, an artist becomes an intermediary between the art object (or a model) and the future user.[22]

Art and the Posthuman

A relatively large chunk of the thesis is allocated to the notion of the posthuman. This term has led me throughout my research, perhaps because it defines the idea of the hybridization of human activity. Within the title of the thesis, I, though, avoided the term posthuman, as it could mislead the reader. Nevertheless, I want to briefly position my research in regards to the term, on one hand as a term defining environmentally responsible humanism, and on the other, as anthropocentric transhumanism. I tend to balance between the two, neither taking for granted environmentally balanced, nor anthropocentric positions.

Now the question arises about the relation of technology and humans in Maker culture. Here, again, are the three positions by the above-mentioned authors: Ratto, Papadopoulos, and the CE.

For Ratto, the relation of technology and humans is the

> engagement with technologies to supplement and extend critical reflection and, in doing so, to reconnect our lived experiences with technologies to social and conceptual critique. (Ratto 2011b, 253)

Papadopoulos provokes one in Generation M to refer to posthuman theories and actor networks:

> The hype of human-nonhuman mixtures cannot sustain the commitment to material justice. Posthumanism and actor networks are not good enough for this. An autonomous political posthumanism emerges

*22 Compare with Lévi-Strauss' description of an artist who would lie halfway between scientific knowledge (or scientist, engineer) and magical thinking (or bricoleur). While the artist, "communicate[s] … either with the model or with the materials or with the future user" (Lévi-Strauss 1966, 27), a scientist (or engineer) searches for a new message beyond the constraints imposed by a particular condition (ibid.).

> in the infrastructures of the M era: calculating interdependences, knowing and naming one's allies, building communities of justice, that is action groups of committed humans and engaged non-human others. (Papadopoulos 2014, 642)

And:

> Making, matter and the fusion of the digital and the material are defining generation M. (637)

Whereas CE understands the technology as an interface:

> The Critical Engineer expands "machine" to describe interrelationships encompassing devices, bodies, agents, forces and networks. (CE 2011)

Interestingly, both Ratto and CE see technology more as a tool to understand the world, while Papadopoulos goes a step further and portrays technology as an active agent in a network of humans and non-humans.

Posthumanist Perspective

Katherine Hayles's (1999) definition of the *posthuman* suggests that there are many different traditions of thinking about the current and future human state. This may include critical thought and a variety of futuristic scenarios ranging from traditional understanding of humans to enhanced human beings to completely new species.

While introducing the idea of downloadable consciousness proposed by Hans Moravec, Katherine Hayles has defined her vision of the posthuman with a fusion of the digital computer and the biological body, something Gershenfeld (2012) meant by the wired early digital computer with a milling machine. Hayles's possibility of evolution is presented from a virtual perspective, a digital machine operating in concert with a living organism, and introduces the human-machine system, bridged with information flow. Such a bridge becomes real, with disembodied information flowing between the organic body and its inorganic extensions. "When information loses its body," writes Hayles in her book *How We Became Posthuman*, "equating humans and computers is especially easy, for the materiality in which the thinking mind is instantiated appears incidental to its essential nature" (Hayles 1999, 2). Adding self-reflective feedback loops between organic and electronic parts that can flow between the subject and its environment (Hayles 1999, 2), she then concludes, that there are "no essential differences or absolute demarcations between bodily existence and computer simulation, cybernetic mechanism and biological organism, robot teleology and human goals" (3). Having described posthuman with no demarcations between cybernetic mechanism and biological organism, Hayles's posthuman may be described as Deleuze and Guattari's (1980) rhizome, which is neither a stem nor a root, rather something in between.

Also, the concept of the cyborg developed by Donna Haraway should be mentioned in a posthuman context. In her essay "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century," Donna Haraway (1991) described a cyborg as "a cybernetic organism, a hybrid of machine and organism, a creature of social reality as well as a creature of fiction" (Haraway 1990, 191). Introducing the cyborg as a hybrid of machine and organism, Haraway points to the social context and excludes the technical discourse of artificial intelligence. Framing the cyborg around a fiction, Haraway also distances herself from the scientific analysis of the machine with regard to humanity and does not provide futuristic scenarios. The cyborg is introduced in the social context as an imaginable reality.

I use the term posthuman in order to emphasize the interaction between humans, non-humans and computing machines. In my work, the posthuman is viewed from Katherine Hayles's perspective of a posthuman, present-future state where the human merges with technology. This state is defined by Hayles through a human who seamlessly articulates with an intelligent machine and approaches his or her body as a prosthesis (Hayles 1999). This perspective is also close to Rosi Braidotti's critical posthumanism and her awareness of being part of the Anthropocene (Braidotti 2013). Sometimes, especially when I describe my artistic work, this perspective merges an imagining of a cybernetic organism, that is, a hybrid of machine and organism defined by social and bodily reality (Haraway 1990).

Transhumanist Tradition

One of the tracks distinguishable within posthuman thought is its cybernetics line, proposing that artificial intelligence, along with computing machines and robots, may be developed or will develop up to a point comparable to human abilities to think and make decisions (Turing 1950). Moreover, at some point, machines and robots will also exceed these abilities (Kurzweil 2005; Moravec 1988). As the theory is considered to be more science fiction-like and less scientific, traditionally, there is a strong criticism of it. On one hand, the criticism is approached from the perspective of artificial intelligence, wherein digital computation is considered to lack an ability to compute consciousness (Searle 1980; Chomsky 2013), while, on the other hand, it is critiqued for its technocentric approach, which excludes biological, social, and economic impact (Hayles 2011; Wolfe 2010).

The main arguments behind machines reaching, or even exceeding, human abilities to think are based on all matter being constructed from atoms (Minsky 1986, 2013) and neural system functioning similarly to a Turing machine (McCulloch, Pitts 1946). The second argument is in line with Moore's Law, stating that processor power doubles approximately every two years. This argument leads to precise calculations of when machines will reach and exceed human abilities to think (Moravec 1988; Kurzweil 2005).

Referring to matter consisting of atoms, Minsky has suggested that there is no big difference between a computer and a brain. In *The Society of Mind*, Minsky argued that minds (or thinking, that is, processes that add up to consciousness) and brains are also the same; the first is the output of the second. Minds are only the outputs of many processes happening in the brain, like "choose a place to start the tower" or "add a new block to the tower" (Minsky 1988, 21). These processes—in Minsky's terms, agents—interact with each other, accomplishing a sub-society of agents, or an agency, a system of elements interacting with each other. Moreover, Minsky proposed having two different perspectives: inside and outside. While the outside perspective would be able to see the agency without knowing what the agents do, the inside perspective would not know what the agency is; the final result would be a set of processes that could be defined as minds. This perspective recalls Jakob von Uexküll's "Umwelt" theory, based on an inner world and an outside action, wherein the animal would process information gained from the outside in its own inner world.[23] In both cases we have a list of automated instructions processed by the organism. The processed information, of course, does not prove the idea of the brain functioning as a set of rules, like in the Turing machine concept; the processes are much more complex. However, it also does not mean that there is a difference between the brain and the mind, so what is missing in the brain-mind construct is only the knowledge of interconnected processes. Finally, Minsky proposed that a

*23 For more information, please refer to page 131.

simulation of minds (or consciousness) is just a question of time, when science finally reconstructs the processes of the brain (Minsky 2013).

With such an understanding of minds, Hans Moravec proposed the separation of a mind from an actual body and the download of that mind to an outside robot body, or a simulation and upload back into the real world after the mission is accomplished (Moravec 1988). Being able to separate minds from the body and, in such a way, reach immortality is a goal of transhumanists, which has been proposed as the final stage of human evolution (Moravec 1988; Kurzweil 2005; Minsky 2013). Referring to Moore's Law, transhumanists have suggested that machines will reach the capacity of the human brain or merge with humans within decades, possibly by 2040 (Moravec 1995), 2045 (Kurzweil 2005), or within our lifetimes.[24]

While transhumanists did not distinguish between the living and nonliving, thus continuing the idea of machinic autopoiesis, posthumanists have brought the human-machine system into the daily context, where the nonliving, inorganic machine merges with the living, organic body through direct interaction. Considering transhumanists far from what I tend to look at in this thesis, I will further follow Hayles's proposed definition of posthuman (Hayles 1999), merging inorganic machine and organic body, both able to form a single functioning system. In this work, however, I do not assume that the posthuman is able to download consciousness, as Hans Moravec suggests.

Posthuman Aesthetics

While briefly defining perspectives of posthuman, the question arises of aesthetics in a posthuman setting. In the introduction, I referred to the artistic research of Varvara Guljajeva (2018), who proposed the disappearance of the active participant in interactive installations driven by passively collected data. While the idea is interesting, Guljajeva avoided the active interdependence between the participant of the collaborative setting, such as a workshop or a participatory event. Guljajeva's position is reminiscent of an AI and a transhuman setting, but not the one that could be described with terms like posthuman or Maker culture. Moreover, the position of the human may here be criticized, as it is excluded from the interactive setting. So the question is, what kind of machines would interact with each other? Is the goal then to make them living organisms, or is it rather to illustrate human creativity as I have tried to present while bringing into the discussion the work by Tresset?

*24 In the article "What Should We Learn from Past AI Forecasts?" Luke Muehlhauser quotes Marvin Minsky referring to the book "Computers and the World of the Future," p.118, published in 1962, edited by Martin Greenberger. Available at https://mitpress.mit.edu/books/computers-and-world-future (Accessed 5 Feb 2022).

In my research at Goldsmiths University, I presented my other project, *Mailia*, which was about machine-to-machine interaction. More specifically, the system I presented involved sending emails to a computing machine, replying to them, and sending them back to the first machine, thus closing the processes into a feedback loop (Gapševičius 2016). Although the result could have sometimes become interesting, the consideration had to still be from the perspective of the human and not the machine. Thus, although I noted that the *Mailia* machine would have been able to create, the human had to still take an active position (e.g., in the form of collaboration) to make sense of the output of a machine (at least a conventional computing machine described by Alan Turing and implemented by Konrad Zuse). Thus, the system-to-system interaction proposed by Guljajeva would be more an illustration of human creativity, but not something that could be defined as cultural added value from a human perspective. Therefore, a human factor in a system-to-system interaction will inevitably have cultural added value in an artistic work.

Since it makes little sense for a machine to interact with another machine in terms of added value from a human perspective, my understanding of aesthetics must therefore take a different approach. In order to also distinguish aesthetics from the interactive art of the 90s, I propose to define it with the term *posthuman aesthetics*.

The term *posthuman aesthetics* has been used in a research project at Aarhus University on the posthuman in art and literature. On a website designed as an entry for the research, it reads:

> Believing that the posthuman dimension, in fact, signifies a long-enduring transformation of our high-technological culture, we aim therefore to investigate recurrent patterns for (a) the ways in which the posthuman is represented in art and popular culture in the last century; and for (b) the ways in which aesthetical and artistic values may contribute to a historical framing of the posthuman field.[25]

In short, the project explores the representation of the posthuman in art and the contribution to the discussion of the concept of the posthuman. The path taken here is the one introduced by Hegel.

With *posthuman aesthetics* I refer to settings introduced by Dimitris Papadopoulos and Katherine Hayles. Firstly, humans come into interactive settings

*25 "Project Outline." Available at https://posthuman.au.dk/project-outline (Accessed 20 December 2021). .

with tools for an aesthetic experience. And secondly, I refer to creative practices as an outcome of an integrated living organism and a computing machine. While the posthuman aesthetics introduced at Aarhus University follows the Hegelian type of understanding of aesthetics, here I follow the one presented by Dewey. Instead of focusing on the final result, in my proposed posthuman aesthetics the aesthetics is experienced. And instead of looking at *how* (in technical terms) the result is produced, I look into *who* and *how* (in qualitative terms) produces the result. Thus, with posthuman aesthetics, I am not redefining aesthetics, but inviting the reader to think of it by considering the impact of human and non-human actors to each other.

At this point, additional reference should be made to the further use of the two terms *umwelt* and *environment*. In cases where I mean a particular environment of the specified actor, I refer to “Umwelt,” the term described by Jakob von Uexküll. This term introduces a different experience of the environment than, for example, that of a microorganism. In other cases, I have used the term *environment*.

Timeline: Art and Maker Culture

Having highlighted related positions around art in Maker culture, it is time to draw a timeline to see how the positions lay down next to each other (Fig. 1). I have chosen to start my timeline with the first programable computing machine and to end it with a Generation M, the highlights of the merged physical matter and digital computation.

Not all positions shown in the chart are reflected in this study. Therefore, the references in the timeline should only help the reader to better understand my position in the argumentation. To orientate the reader in the politics of computation, I have included the Chaos Communication Congress and the release of the Netscape browser’s source code. And to orientate the reader in the Maker scene, I have added *The Whole Earth Catalog* with the focus on DIY culture and *Make:* a magazine with a focus on digital fabrication.

In the timeline, the reader will also find references to synthetic biology. These references are here to give the reader an idea of the possible future developments in science. For example, it took thirty-five years from the discovery of DNA structure until Joe Davis created *Microvenus*. And it might take another thirty-five years from the discovery of the CRISPR-Cas9 method to have “designer babies”[26] created in daily practice in medicine.

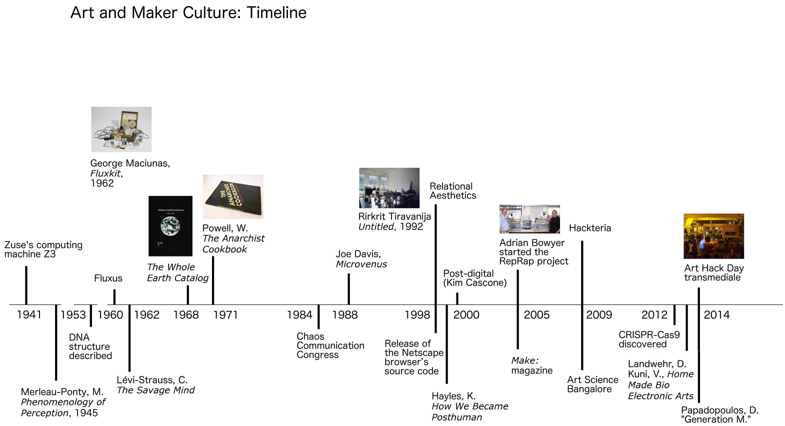

Fig. 1. Art and Maker Culture: Timeline

I have also included the public DIY biolab, Art Science Bangalore, in my timeline to give the reader an idea that other similar initiatives next to Hackteria were active elsewhere in the world. While these positions are important to the aesthetics of Maker culture, they are not necessarily the only ones to consider, and serve here only as references for a deeper research.

*26 As of January 2022, there is only one known case—Chinese twins Lulu and Nana were genetically modified. For more information, see Dyer (2018).

Setting Up Tools for the Research: *Introduction to Posthuman Aesthetics*

This chapter presents the base of the research: tools and references that will be used to explore the raised hypothesis—the necessity of the active participation of audiences in an artwork of Maker culture—within this thesis.

The tools presented in this research unfold as the *Introduction to Posthuman Aesthetics*[27] project. The project combines artistic toolkits, video tutorials, and manuals structured as separate research papers, and a set of instructions to implement artistic and scientific experiments. My assumption is that they should provide a framework for DIY experimentation and open up space for developing new artistic forms and experiences. While referring to technology, living organisms, contemporary media theory, and art practices, further questions should arise, ranging from abstract, philosophical examinations of creativity to global concerns about what forces dictate the organization of humanity and determine our future as a society. These questions should then be answered in subsequent discussions or materialized as new artistic works, including essays, drawings, installations, and performances.

The title of the project, *Introduction to Posthuman Aesthetics*, deserves additional attention. The title itself does not refer directly to either “introduction” or to “aesthetics.” Rather, I use the title to encourage the user of the tools to think about how the interaction between living organisms and computing machines can affect aesthetics, if we agree that aesthetics is concerned with experience, resulting in contemplation.

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*27 For more information, please refer to the website of the project. Available at http://triple-double-u.com/introduction-to-posthuman-aesthetics/ (Accessed 29 March 2020).

The project has been exhibited at the exhibitions under the title *Shared Habitats*,[28] which was carried out by a team from the Chair of Media Environments at Bauhaus University, Weimar. *The Introduction to Posthuman Aesthetics* featured four toolkits: "My Collaboration with Bacteria for Paper Production," "Mycorrhizal Networks, or How I Hack Plant Conversations," "Ultra-Low-Voltage Survival Kit," and "How I Prepare Myself to Be Cloned." Next to the toolkits on display were also manuals with a set of instructions to execute experiments provided and to refer them to related art projects. On the wall were attached video monitors displaying tutorials around the execution of experiments.

All these toolkits develop different discourses that I think are crucial for the discourses around posthumanism. These are the dynamics between different organisms including humans and microorganisms, the dynamics between machines and organisms, the role of electricity in matter, and genetic manipulation.

Although the toolkits themselves were designed in this project as aesthetic objects, they also include experimental settings which vary depending on who uses the toolkit and when. So for example the toolkit "Mycorrhizal Networks, or How I Hack Plant Conversations"[29] may be used with different organisms. If its tutorial uses grown mycelium, the next time it could be replaced by plants or by other organisms, including humans. Also, the coding for the Arduino microprocessor or Pd patch could be changed to another microprocessor, such as ATtiny or ESP8266, and another programming language, such as Max/MSP or TouchDesigner.

Another toolkit, "My Collaboration with Bacteria for Paper Production,"[30] provides tools to work around the interaction of microorganisms. In the broader context, it introduces the symbiotic relationships between living organisms and non-living things. Even if the tutorial and manual focus on the isolation of *Acetobacter* bacteria, next time it could be used for isolation *E. coli* or *Lactobacillus* spp. bacteria. The growth of isolated bacteria could be used for time-lapse photography or for therapeutic purposes.

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*28 The exhibition *Shared Habitats*, curated by Ursula Damm in collaboration with Mali Wu, was first installed in November 2017 at the Art Center NKNU, Kaohsiung, Taiwan, where eleven artists and scientists associated with the Media Environments department at Bauhaus University, Weimar, presented their works. The second version of the exhibition, curated by Ursula Damm in collaboration with Ugnė Paberžytė, was installed between May and July 2019 at the MO Museum, Vilnius, Lithuania. The last exhibition, curated by Ursula Damm, was installed as part of the Ars Electronica festival in Linz, Austria, in September 2019.
*29 For more information, see
http://triple-double-u.com/mycorrhizal-networks-or-how-i-hack-plant-conversations/ (Accessed 21 March 2020).
*30 For more information, see
http://triple-double-u.com/my-collaboration-with-bacteria-for-paper-production/ (Accessed 21 March 2020).

Toolkit #1.
"My Collaboration with Bacteria for Paper Production"

> I love the fact that human genomes can be found in only about 10 percent of all the cells that occupy the mundane space I call my body; the other 90 percent of the cells are filled with the genomes of bacteria, fungi, protists, and such, some of which play in a symphony necessary to my being alive at all, and some of which are hitching a ride and doing the rest of me, of us, no harm.
> — Donna Haraway (2008, 3–4)

This toolkit introduces symbiotic relationships between living organisms and non-living things. Symbiotic relationships are outlined with references to artistic projects and scientific research. It refers mainly to three different kinds of research: a theory of the origin of eukaryotic cells proposed by Lynn Margulis, formerly Lynn Sagan (Sagan 1967), the Human Microbiome Project carried out by the National Institutes of Health in the United States (NIH 2012), and a manifesto-like proposal of interspecies dependencies by Donna Haraway (2008).

Fig. 2. Toolkit "My Collaboration with Bacteria for Paper Production." Photo: Brigita Kasperaitė

In addition, the project provides a kit (Fig. 2) that includes tools to experience relationships between microorganisms: In the first case we will grow SCOBY (symbiotic colony of bacteria and yeast), and in the second we will isolate *Acetobacter*[31] bacteria from grown SCOBY in order to further cultivate colonies of single species. Altogether symbiotic relationships are experienced through experimentation with living microorganisms and non-living components, which enable the experimentation.

*31 The name of Acetobacter bacteria in SCOBY is sometimes used in scientific papers as a synonym for Gluconobacter and Komagataeibacter, sometimes as different bacterial species. In this study, I present the methodology for isolating bacteria from other bacteria, so the reader should not put too much emphasis on naming.

Related Artworks

Symbiotic relationships between organisms are questioned while discussing interaction among members of the same species, envisioning the influence of one species over the other, and proposing evolutionary contexts. Introduced below are four projects covering the discourse related to symbiotic relationships.

Objectivity [tentative]: Soundscapes[32] (2012-2013) by Nurit Bar-Shai contains a number of petri dishes hung on the wall, which together shape horizontal and vertical lines. The petri dishes are inoculated with dyed bacteria *(Paenibacilus vortex)* that have been grown on an agar medium with necessary nutrients (Fig. No. 3). In his book *Bio Design* (2012), Willem Myers described the artwork in the following:

> In visualizing biological systems of self-organization, it is possible to detect surprising complexity and to achieve dramatically varied results with only slight alterations in the initial environment… These pieces examine the decision making of living, performative objects that 'grow images' as a sculptural form… These microorganisms possess advanced social motility, employing cell-to-cell signaling to prompt activities such as attraction and repulsion under different environmental conditions… Once the bacteria have grown into patterns, prompted by the dispersal of nutrients, they are made visible with dye that also halts their growth. (Myers, 2012)

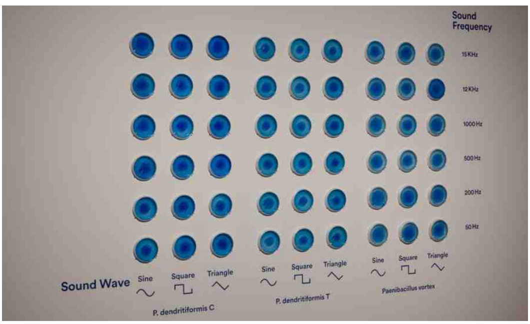

Fig. 3. Nurit Bar-Shai, *Objectivity [tentative]: Soundscapes* (2012–2013), in *Exo-Evolution*, ZKM, 2015 / © Photo: Jonas Zilius ZKM | *Zentrum für Kunst und Medientechnologie*

The work brings up the context of self-organization and collaboration between bacteria in *Paenibacilus vortex* bacterial colonies. The discourse introduced could be expanded to networks of bacteria sending signals from cell to cell while

*32 http://www.nuritbarshai.com/objectivity/ (Accessed 15 March 2020) searching for food. The artwork also introduces the bacterial species as "intelligent" through its ability to draw fractal-like patterns.

In the exhibition description of *The Unsettling Eros of Contact Zones*[33] (2015), Tarsh Bates wrote:

> An exhibition exploring what it means to be human when we recognise our bodies as multi-species ecologies, with a particular focus on the relationships between Homo sapiens and *Candida albicans*. I used scientific and artistic methodologies to explore physical, emotional, cultural and political relationships between humans and *Candida*. Works comprised sculptural, photographic and filmic works, dead and living organisms, and were developed during my PhD research at SymbioticA and the University of Western Australia.[34]

The installation (Fig. 4) uses a variety of materials, including organic artisanal white bread leavened with *Candida albicans* and *Saccharomyces cerevisiae* yeast strains, brie, blue cheese, and hummus. During the event, the public was invited to taste bread baked with traditional yeast and yeast that normally lives in human bodies.

Fig. 4. Tarsh Bates' exhibition *The Unsettling Eros of Contact Zones* at the Gallery Central Shopfront, 2015. Photo: Megan Schlipalius

Besides the discourse on symbiotic relationships between yeast and humans, Bates also raises ethical questions regarding the consumption of organisms, especially those living in close relationships with humans. It also questions borders between organisms of similar bacterial strains: If we consume bread without questioning the presence of the *Saccharomyces cerevisiae* strain, why would we then question eating bread with *Candida albicans*, another similar bacterial strain that lives in our bodies?

*33 https://tarshbates.com/portfolio/t-he-unsettling-eros-of-contact-zones-2015/ (Accessed 15 March 2020)
*34 https://tarshbates.com/portfolio/the-unsettling-eros-of-contact-zones-and-other-stories-2015/ (Accessed 15 March 2020)

The project *Selfmade*[35] by Christina Agapakis and Sissel Tolaas part of a larger exhibition in Dublin Science Gallery in 2013, curated by artist and designer Alexandra Daisy Ginsberg, Anthony Dunne (Royal College of Art), Paul Freemont (Imperial College), Cathal Garvey (bio-hacker), and Michael John Gorman (Science Gallery).

Fig. 5. Cheese made from human toe bacteria. Photo: http://cultofweird.com

Scientist Christina Agapakis (US) and scent expert Sissel Tolaas (NO) collected bacteria from noses, tears, and other parts of different bodies in order to produce cheese (Fig. No. 5). The artists described their project as follows:

> *Selfmade* is a series of "microbial sketches," portraits reflecting an individual's microbial landscape in a unique cheese. Each cheese is crafted from starter cultures sampled from the skin of a different person. Isolated microbial strains were identified and characterised using microbiological techniques and 16S ribosomal RNA sequencing. Like the human body, each cheese has a unique set of microbes that metabolically shape a unique odour. Cheese odours were sampled and characterised using headspnace gas chromatography-mass spectrometry analysis, a technique used to identify and/or quantifyn volatile organic compounds present in a sample.[36]

The idea behind the project goes back through hundreds and thousands years of history, when microorganisms from human bodies accidentally appeared in milk and milk products and fermented and hardened them into what we now know as cheese. Although symbiotic relationships between microorganisms are directly present in cheese production, cheese would not have become cheese without the microorganisms living on and inside the human body.

*35 http://agapakis.com/cheese.html (Accessed 15 March 2020)
*36 https://dublin.sciencegallery.com/growyourown/selfmade (Accessed 15 March 2020)

1000 Handshakes[37] by François-Joseph Lapointe was performed for the first time at the Panum Institute, University of Copenhagen, in 2014. Later the same year, it was repeated at the Medical Museion in Copenhagen, as well as during the Transmediale festival for media art and digital culture in Berlin (2016). For his performance, biologist and bioartist François-Joseph Lapointe from Montreal shook hands with 1000 people (Fig. No. 4). Being a scientist, Lapointe approached his work from a scientific research perspective as well, collecting bacterial samples from his hands and analyzing them in the laboratory. The result—visualized networks of bacterial species— was presented at the Art Laboratory Berlin gallery in 2016 within a larger series of exhibitions entitled *Non Human Subjectivities*.

Fig. 6. *1000 Handshakes* at the Transmediale Festival in Berlin, 2016. Photo: Art Laboratory Berlin[38]

According to Art Laboratory Berlin, "The performance raises awareness through physical and social engagement, through acts of participation and exchange on social, individual and microbial levels. The handshake, a basic and ancient act of networking forms the beginning of a social, scientific and artistic collaboration between the performer and the public."[39] It also extends the discourse on relationships between humans and bacteria into the symbiotic social network, adding an additional discourse of shared human and non-human networks.

*37 http://www.museion.ku.dk/whats-on/exhibitions/30119-2/30129/1000-handshakes/ (Accessed 13 August 2021
*38 http://artlaboratory-berlin.blogspot.de/2016/02/francois-joseph-lapointe-1000_4.html (Accessed 13 August 2021
*39 http://artlaboratory-berlin.blogspot.de/2016/02/francois-joseph-lapointe-1000_4.html (Accessed 13 August 2021).

Concept

The project provides tools that invite the user to explore their own relationships with organisms and to grasp invisible creatures surrounded by the outer world. By using SCOBY as a metaphor for the complex organization of microorganisms, the experimentation reflects on the role of a single organism in relation to its environment.

How to best understand the complex behavior between non-living things and living organisms? What is their interaction and how does it become symbiosis? The experienced symbiosis aims at further discussions of evolution, the diversity of organisms, and, finally, the interaction between chemical compounds of living organisms and non-living tissues.

Symbiotic Relationships

The idea introduced in this paper and the toolkit is wrapped around the interaction between different types of organisms. It also introduces interactions between chemical and organic elements, which, while interacting, trigger the appearance of newly shaped tangible or intangible elements and, on a global scale, trigger evolutionary processes. These interactions could be defined as symbiotic relationships, or, as Donna Haraway puts it, “companion species.”

While introducing the companion species idea, Haraway has talked about her sheepdog, Ms. Cayenne Pepper, with whom Haraway has shared interactions, exchanging, for example, saliva and, along with it, genes and bacteria, making them part of herself. In so doing, Haraway asked, “who ‘we’ will become when species meet” (Haraway, 2008) and proposed the uniqueness of an organism as being shaped via the processes of various interactions with different species. The discourse here goes far beyond a traditional, let's say, Cartesian (Cogito ergo sum) or Nietzschean (the Übermensch) understanding of the human, wherein the former defines human existence by the ability to think and the latter defines the human as striving to overcome their own limitations. In Haraway's case, the human is defined by collaboration with other species. This idea has been developed by Haraway while referring to evolutionary theorist Lynn Margulis. Meanwhile, research on human microbiota has been carried out by the National Institutes of Health.

As an evolutionary theorist, Lynn Margulis criticized the traditionally accepted theory of evolution proposed by Charles Darwin; she introduced evolution as merely a collaborative interaction rather than a struggle for existence. If the struggle for existence in Darwin's theory led to natural selection and survival of the fittest (Darwin, 1859), Margulis introduced a theory of symbiotic organisms wherein, through interaction and collaboration, prokaryotic organisms evolved into more complex eukaryotic cells (Sagan, 1966). In her article "On the Origin of Mitosing Cells," the theory is introduced through the interaction of three ancient organelles: mitochondria, photosynthetic plastids, and flagella, which, over the course of changing weather conditions during Earth's history, were impelled to mutate into one organism. This process was possible due to vapor and the escape of free hydrogen into the upper atmosphere, which led to the production of molecular oxygen. The increasing amount of oxygen, in turn, was consumed by other organisms that had to survive in the changing conditions: An aerobic prokaryotic mitochondrion was ingested into the cytoplasm of a heterotrophic anaerobe, while symbiotic cilium attached to other bacteria and formed a flagellum. Further evolution resulted in eukaryotic blue-green algae:

> During the course of the evolution of mitosis, photosynthetic plastids (themselves derived from prokaryotes) were symbiotically acquired by some of these protozoans to form the eukaryotic algae and the green plants. (Sagan, 1967: 225)

The idea of evolutionary change via interacting organisms suggests that we humans are not humans because we "think," but because we interact with other organisms and we evolve with other organisms. Therefore, the discourse opens up awareness of whom we interact with and how we interact. This awareness brings us closer to acknowledging symbiotic processes within and around other organisms.

The National Institutes of Health carried out a project analyzing and sequencing the variety of DNA in the human body, coming to the conclusion that the ratio of human cells to other cells within the body is one to ten. The cells belonging to humans have one DNA strand, and those of other organisms have the other. Those other organisms carrying different DNA are various fungi, bacteria, and protists that live on the skin, in the guts, or in the nose:

> Microbes inhabit just about every part of the human body, living on the skin, in the gut, and up the nose. Sometimes they cause sickness, but most of the time, microorganisms live in harmony with their human hosts, providing vital functions essential for human survival. (NIH 2012)

To define the human microbiome, researchers at the National Institutes of Health analyzed 242 people by taking samples from different parts of the body and analyzing them with DNA sequencing machines, instead of by growing microorganisms in a medium under laboratory conditions. This way they ended up with more accurate results. It follows that the more than ten thousand other microbial species occupying the human ecosystem must have a function that is more than just to lurk around the body and consume energy provided by digested food. Microorganisms break down proteins, lipids, and carbohydrates, readying them to be absorbed by the human organism. They also produce vitamins and anti-inflammatories that regulate the immune system and keep the human body safe from diseases (NIH 2012). In short, microorganisms have been collaborating with humans for survival for time immemorial over the course of evolution.

So, what is crucial to evolution is the interaction over time between organisms, including the smallest and the biggest: bacteria, fungi, protists, plants, and animals. Some of them produce oxygen and some consume it, some of them break down compounds and some absorb broken down chemical elements. Everything is in constant interaction and symbiotic relationship, including living organisms, chemical compounds, and inorganic elements.

SCOBY

To introduce symbiotic relationships between organisms, I use SCOBY. The culture is comprised of mixed strains of bacteria and yeast present during the fermentation process within a kombucha tea. The DNA sequencing analysis of the bacterial and fungal populations of five distinct SCOBY samples introduced in "Sequence-based Analysis of the Bacterial and Fungal Compositions of Multiple Kombucha (Tea Fungus) Samples" (Marsh et al. 2013) resulted in a number of *Acetobacter* and *Saccharomyces* species, or more specifically: *Gluconacetobacter* (in some papers, also referred to as *Komagataeibacter* or *Acetobacter*) was present in more than 85% of all samples, *Lactobacillus* was present in up to 30% of the samples analyzed, *Zygosaccharomyces* was present in more than 95% of the SCOBY samples, and *Acetobacter* was detected in less than 2% of samples. A great variety of other microbial bacteria and yeasts, including *Candida*, *Saccharomyces*, and *Saccharomycoides*, were also present (Marsh et al. 2013).

Toolkit

The toolkit has been designed to enable the discussion of symbiotic relations between living organisms and non-living things. At the same time, its aim is to develop an awareness of interspecies dependency, including with the user of the kit. The toolkit includes jars with chemical elements and ingredients, along with a sample of SCOBY in kombucha tea. It also has a set of the tools necessary for isolating *Acetobacter* bacteria from SCOBY (Fig. 2).

Within the two experiments introduced, I show how to grow microorganisms. While the first experiment presents the growth of the SCOBY in tea (Annex I), the second explains how to isolate a bacterium from the SCOBY (Annex II). Having introduced the techniques, one could use them for individual experimentation, which may further lead to new outcomes, including hypotheses, ideas, and artworks (see section "Workshop #1. SCOBY, Shit, and Humus" and chapter "A Shift in the Role of an Artist"). This toolkit presents a time-lapse video of the interaction (and at the same time symbiosis) between bacterial colonies included in the video tutorial for executing the experiments (Fig. 7).[40] A viewer may also notice that the interaction between bacterial colonies is presented through the technological lenses (the reflection of the camera on the screen), the surface of which is a home and food source for other microbial species.

Fig. 7. Interaction between bacterial colonies. Video still

After carefully thinking about each element of the toolkit, this project can be viewed from the perspective of discourses on symbiosis, learning about the care of microorganisms, and artistic practices within Maker culture.

Conclusions and Further Discourses

Through the philosophical insights of Donna Haraway, an alternative approach to evolution by Lynn Margulis, the results of DNA sequencing of the human microbiome by NIH, the aesthetic outcomes of a number of artists, the video tutorial, and practical step-by-step instructions for working with microorganisms, this project has introduced symbiotic relationships between living organisms and non-living things. Although the title proposes "collaboration" with bacteria for paper production, the goal of the project is to lead the reader toward the imagining of possible interactive settings—in this case, growing symbiotic SCOBY cultures and isolating Acetobacter bacteria strains. While learning is pursued through the use of the toolkit, the artistic nature of this project consists of the toolkit itself, the potential of experimentation, and bacterial growth aesthetically represented in the time-lapse video.

Introducing symbiotic relationships through experimentation, the project opens up further discourses. One of these discourses is, for example, mutation, which would occur while experiencing the grown microorganisms. If put in broader terms—over the course of evolution, mutation has played an important role for organisms in becoming slightly different from their parents. While self-replicating, interacting with each other, and mutating according to changing environmental conditions, early prokaryotic organisms were able to evolve into what is now a variety of living species. Another discourse is the impact of living organisms and non-living things to each other, presented in this toolkit as an imaginary setting. To experience it practically I developed the "Mycorrhizal Networks, or How I Hack Plant Conversations" toolkit and a set of new experiments.

*40 See video tutorial at http://triple-double-u.com/my-collaboration-with-bacteria-for-paper-production/ (Accessed 13 February 2021).

Toolkit #2.
"Mycorrhizal Networks, or How I Hack Plant Conversations"

In this project, I introduce the idea of interaction between elements of different kinds, which includes transport of information passed during the interaction process. In one case, the interaction appears in a natural environment where fungi act as an interface between the interacting plants; in the other case, I introduce an electronic interface between organic elements and a computer to translate chemical activity into digital information, and vice versa. The idea of intermediary interfaces is that, while passing information, they act as proxy servers, being able to change the information that is passed and send it further to the target destination. The idea is represented within a kit that includes diverse organic and inorganic elements, along with tools to execute the experiments described (Fig. 8).

Fig. 8. Toolkit "Mycorrhizal Networks, or How I Hack Plant Conversations." Photo: Brigita Kasperaitė

Within the scientific context, the kit introduces two discourses around communication. First of all, I refer to Claude Shannon's idea of a noise source being in between the transmitted and received signal. Second, I introduce the idea of allelopathy, a phenomenon by which an organism, while producing and signaling biochemicals, influences the growth of other organisms. In addition, although not directly introduced, other essential topics for discussion around fungi could come up while executing the experiments provided. These topics include the DIY production of antibiotics, such as penicillin (Inglis-Arkell 2013), the ability to use space radiation as a food source (Dadachova et al. 2007; Dadachova, Casadevall 2008), and the ability of fungi to biodegrade organic and inorganic elements, including slowly degrading elements such as cellulose, toxins, and heavy metals (Stamets 2005; Singh 2006).

The title "Mycorrhizal Networks, or How I Hack Plant Conversations" is a direct reference to the use of fungal mycelium for interaction between plants. This interaction is introduced through an electronic interface that translates chemical signals into electronic signals and vice versa, opening up a playground for the feedback loops between organic and inorganic elements—in this case, plants, mycelium, and a computing machine.

Related Artworks

There are a number of artists and artworks worth mentioning. Among other artists working with plants, fungi, and/or electronic interfaces, bridging these subjects are Martin Howse, Saša Spačal, Laura Popplow, Gediminas and Nomeda Urbonas, Leslie Garcia, and Miya Masaoka. For the sake of diversity, I have chosen to introduce four artworks: *Pieces for Plants* by Miya Masaoka, *Radio Mycelium* by Martin Howse, *Fungutopia* by Laura Popplow, and *Life Box* by Paul Stamets.

Because of the methods used, Miya Masaoka's project *Pieces for Plants*[41] from 2007 is probably the most direct reference to "Mycorrhizal Networks, or How I Hack Plant Conversations". In her piece, Masaoka uses electronic interfaces attached to the plants to generate sound (as well as text, appearing in a video performance) (Fig. 9). While changing her body position in relation to the plants (approaching, touching, retreating), Masaoka changes the physical properties of the space, which, in turn, affects the plants. Plants sense the changing environment and further transport the captured changes in the form of electrical signals to the electrodes attached to them. The electrical signals captured are then translated into digital signals and transferred into the computer for further manipulation.

*41. http://www.youtube.com/watch?v=1AHOEcAprc8 (Accessed 23 February 2017).

Fig. 9 Miya Masaoka. *Pieces for Plants* (2007). Photo: Donald Swearington[42]

Using the measurements captured from the interaction between herself and the plants, Masaoka, on the one hand, acts as a performer and, on the other hand, lets the machine generate sounds. Here, the machine becomes an interface between the plants and the performer, while, at the same time, a collaborator for the artistic piece. The final performance could be described as a translation of physical environmental properties into sonic, visual and haptic experience.

As in Miya Masaoka's *Pieces for Plants*, Martin Howse's *Radio Mycelium*[43] (2011) introduces interaction between the physical properties of an environment and living organisms. In both cases, living organisms and electronic elements are enclosed in a system. On the other hand, the artworks are of different approaches and narratives. While Masaoka explores, from a poetic perspective, the ability of plants to sense the environment, Howse examines connectivity and interaction between the physical properties of the environment and mycelium networks from a scientific, cultural and technical perspectives. Moreover, Masaoka "performs" her piece, whereas Howse holds a "workshop" (Fig. 10). This is how he describes *Radio Mycelium*:

> The *Radio Mycelium* workshop aims to actively examine the cross-spore-germination between two parallel wide area networks; between radio-based communication technologies and the single organism network

*42 http://www.miyamasaoka.com/media_files/photos/ (Accessed 26 February 2017).
*43 http://libarynth.org/parn/radio_mycelium (Accessed 23 February 2017).

of the mycelium. Fungal transceivers sprouting mycelial antennas form an imaginary underground network. Diversity of human networks is mapped across fungal diversity in the urban environment. The influence of electromagnetic carrier wave on the mycelial network is to be examined.[45]

Fig. 10. Martin Howse, *Radio Mycelium* (2011). Photo: Nik Gaffney/foam[44]

Proposing the workshop format as artistic means, Howse also proposes research and educational frameworks. Howse and the participants seek understanding of how the environment functions, how species interact with their surroundings, how much cultural charge there is in what is being approached (Howse gives references to Terence McKenna, Paul Stamets, Charles Darwin) and how science and cultural charge complement each other. Through research, doing, sharing, and envisioning, Howse's artwork becomes multilayered.

Laura Poplow's *Fungutopia*[46] from 2011 is an installation, a workshop, a prototype kit and a community project (Fig. 11). Being a multifaceted artwork, it also serves as an educational platform. The artist herself describes the project in the following way:

> As an installation fungutopia shows the different possibilities that mushrooms offer to help to make the world a better place: Mushrooms are open source medicine, food, fertilizer and soil-recovery-method.

*44 https://www.flickr.com/photos/foam/6459095083/in/album-72157628288022139/ (Accessed 26 February 2017).
*45 http://www.psychogeophysics.org/wiki/doku.php?id=mycelial (Accessed 25 February 2017).
*46 http://www.fungutopia.org/ (Accessed 23 February 2017).

They can be cultivated quite simply even indoors and are perfect for urban fungiculture. The workshop shows simple techniques to grow mushrooms in cities, whereas the prototype *MUSHroom* tries to combine Open Source Electronics with Biology to grow even more rare medicinal species year round indoor. As a community-project fungutopia tries to bring together people for urban fungiculture and share knowledge and experience. The Online Community grow.fungutopia.org is the web equivalent of the f2f experience.[47]

Fig. 11. Laura Popplow, *Fungutopia*, 2011. Photo: Martin Schlecht[48]

As a very complex project, *Fungutopia* becomes a platform to discuss a variety of topics related to posthuman aesthetics. Along with the reference topics covered by Paul Stamets, *Fungutopia* is also about cooking, DIY electronics, open-source initiatives, sustainability, social practices and, of course, contemporary aesthetics.

Related to "Mycorrhizal Networks, or How I Hack Plant Conversations" is the project *Life Box*[49] by mycologist Paul Stamets, started in 2010. Although not exactly an artwork, but rather a commercial product, the project deserves to be listed among other related artworks. First of all, Stamets' ideas regarding mycelium and fungi are often referred to by artists working with fungi (Gediminas and Nomeda Urbonas, Laura Popplow, Martin Howse, TARO). Furthermore, the idea behind the project is well shaped conceptually.

*47 http://www.fungutopia.org/index.php?/about/ (Accessed 23 February 2017).
*48 http://www.fungutopia.org/index.php?/ppp/test/ (Accessed 26 February 2017).
*49. https://www.youtube.com/watch?v=Q8CMsB4jLLc (Accessed 23 February 2017).

In 2010, Stamets came up with the idea of producing cardboard boxes that could be used for at least two purposes: as packaging material and for the collection of plant seeds. Cardboard boxes of different sizes (Fig. 12) can be purchased and used for shipping goods. At the same time, these boxes also serve to combat deforestation and climate change.

The idea behind *Life Box* is simple: Cardboard, which is made of cellulose, is a good source of nutrients for mycelium and fungi. Through biodegrading processes, the cardboard will turn into soil, and soil containing decomposed chemical elements will, in turn, become a basis for plant growth. The cardboard from a *Life Box* is filled with plant seeds and fungal spores, which, if watered, will begin to germinate and grow.

Interesting in this project is the process of learning how plants grow. The project also involves taking care of living organisms –in this case, fungi and plants. Finally, if trees are nurtured and continue to grow, they could grow into a forest, consuming carbon dioxide and producing oxygen, and, in such a way, again making the environment user-friendly.

Fig. No. 4. Paul Stamets, *Life Box*, 2010.
Courtesy: Life Box Company[50]

*50 http://www.thalo.com/thumbnail/040212_1efa29d-586244594-4f79e58e-a7f0-b1c6d6db/o.jpg (Accessed 26 February 2017).

Concept

One of the scientific terms defining plant interaction is allelopathy, a phenomenon wherein compounds produced by one plant affect the growth of surrounding plants. The compounds produced are released into the soils or taken in by symbiotic fungi and further transported over mycorrhizal networks to the target plants within the same community in order to resist invasive species. Why would fungi and plants interact with each other? How would that happen? And what further picture could be drawn from this interaction?

Using allelopathy as a metaphor for plant interaction, this project suggests interference in this interaction by adding an electronic interface to plants that captures biochemical signals and translates them into digital values and vice versa. The electronic interface acts as a proxy server, able to change the information passed and influence the target destination.

All the organic and inorganic components, as well as the electronic parts, are provided in the project toolkit, which is an artistic framework and a basis for executing the experiments described. To support the experiments, the manual and the video tutorial are supplied.

Interaction Between Elements of Different Kinds

This chapter provides an introduction to methods for transmitting information between elements of different kinds, in particular, fungi, plants, and electronic parts, which might impact the information transmitted.

Fungi and plant kingdoms belong to the Eukaryota domain and have eukaryotic-type cells that differ from prokaryotic cells (bacteria and archaea) in membrane-bound organelles, which contain genetic material enclosed by a nuclear envelope. According to Nic Fleming, around 90 percent of land plants are in mutually-beneficial relationships with fungi. These partnerships are usually described as "mycorrhiza," where the fungus colonizes the roots of the plant (Fleming 2014). The colonization is either intracellular (arbuscular mycorrhizal fungi) or extracellular (ectomycorrhizal fungi), where both sides interact with each other, exchanging chemical elements as well as differently charged protons and electrons.

Most fungi grow as mycelium, consisting of a mass of branching, thread-like hyphae, which are cylindrical, thread-like structures 2 to 10 µm in diameter and up to several centimeters in length. Together, hyphae may form extremely large organisms, such as, for example, Armillaria ostoyae, which occupies 965 hectares of soil found in Oregon's Blue Mountains in the US (Casselman 2007). While able to form net-like structures, this fungus has been called "Earth's natural Internet" (Stamets 2008). Fungi expert Paul Stamets has even compared mycelium to ARPANET, the US Department of Defense's early version of the Internet (Stamets 2008).

On the other hand, allelopathy, the exchange of chemicals within mycorrhizal networks, has been explored by Kathryn Morris, formerly Kathryn Barto (Barto et al. 2011), Nancy Stamp (2003), and Rick Willis (2010). Morris and her team tested, for example, the soil for two compounds made by marigolds. In the samples where the fungi were allowed to grow, levels of the two compounds were two to three times higher than in samples without fungi (Barto et al. 2011). That suggests that the mycelia transport chemical compounds.

As a result of this growing body of evidence describing the communication services that fungi provide to plants and other organisms, many biologists have started using the term "wood wide web" as a reference to the World Wide Web, or simply the Internet (Fleming 2014).

Communication Systems and the Source Noise

The visual similarity of mycorrhizal networks to computer networks and proofs that mycorrhizal networks are able to transport chemicals brings us to Claude Shannon's communication theory. The communication theory could be symbolically represented through the information source that selects a desired message, a transmitter that changes the message into a signal to be sent through a communication channel, a noise that interferes with it, a receiver that converts the signal into a message, and a destination (Shannon, Weaver 1964) (Fig. 13).

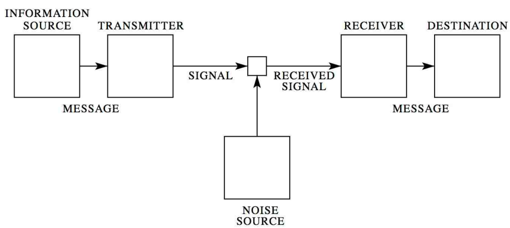

Fig. 13. Schematic diagram of a general communication system (Shannon, Weaver 1964)

Related to this project is the source noise as part of a communication system, which always impacts it. While Shannon has proposed a way to reduce the source noise in order to have the least possible impact on the transmitted signal, the interest in source noise in this project lies elsewhere. Say, if we "employ" the source noise to generate false signals, the ability to impact the transmitted signal becomes higher, and, in turn, the message received at its destination point could have a higher impact. This higher impact is often seen, for example, in translated texts, because of the mismatch of languages used at their source and destination points, and the translator, who acts as a noise source in the setting.

While offering an electronic interface attached to a mycorrhizal network, the impact of the transmitted signal in a mycorrhizal network could be manipulated by the different electric potentials provided.

Electrical Potentials in Living Organisms

As in all matter, the differently charged protons, neutrons, and electrons of atoms generate electrical potentials. Electrical signals, according to Nick Lane, are the basis for all living organisms and life forms (Lane 2015, Szechyńska-Hebda et al. 2017). How does that work?

The cytoplasm of plants have, among other chemical elements, potassium (K) salts, which provide the correct ionic environment for metabolic processes and, as such, function as regulators of various processes, including growth regulation. Potassium ions (K+) provide protein synthesis and interaction with the external environment, for example, the exchange of gas or nutrition (Leigh et al. 1984). For example, in animals, positively charged sodium (Na+) and potassium (K+) ions are generated by interacting with negatively charged chlorine (Cl-) ions in neural cells (Davies 2006). Differently from animals, in plants, electric potentials are generated by potassium (K+), calcium (Ca2+), and chloride (Cl-) ions, which are passed through the cell membranes and ion channels (Fromm, Lautner 2007; Davies 2006; Lane 2015). Electric potentials are usually measured with the help of a weak electric current, which is passed through the organism between two electrodes. The difference of the electric signal is compared with the third electrode, which is attached to the ground or placed further away from the electrodes, through which the electric current passes (Davies 2006).

Electrical charges could be captured by intracellular or extracellular measurements. Both methods have their positive and negative sides. For example, the intracellular measurements are localized and can perform measurements within one cell. At the same time, intracellular methods wound the plant. Extracellular measurements sum up the total of bioelectrical activity in large groups of cells at the surface of a leaf or stem and do not wound the plant (Fromm, Lautner 2007). Within this project, the use of extracellular measurements is suggested because the experiment can be performed for a longer period of time. Meanwhile, the plant will not be damaged by invasive electrodes.

To sum up, the interaction between symbiotic fungi and plants is an exchange of electrical signals and chemical elements between different species. The next question concerns the interpretation of the signals as forms legible to humans, and further manipulation of electric signals that might, for example, impact the growth of the plants and fungi.

Interfaces Between Plants and Computing Machines

Noting that differently charged protons, neutrons, and electrons of atoms within organisms generate electrical signals, and knowing that electronic circuits and computing machines operate on electrical signals as well, the next step is to combine organisms with electronic elements into an interface and to translate electrical signals passed into digital signals or humanly perceptible sonic, visual, and haptic outputs.

The interface between plants and machines within this project consists of electrode pads for capturing extracellular activity, an electrical circuit for high accuracy, an instrumentation amplifier AD620 for amplifying the electrical signals captured, and an Arduino microcontroller for the conversion of electrical signals into digital information (Fig. 14). The endpoint of the interface is a Windows, Mac, or Linux computer.

Fig. 14. The interface between plants and computing machines. Photo: Brigita Kasperaitė

The electrical signals captured with electrodes are further directed to an electrical circuit in order to amplify those signals and to further deliver them for conversion into digital information. The digital data received by the computer is further manipulated with a Pure Data programming environment for audio, video, and graphical processing.[52] While converting digital data back into an electric current, and sending the electric current further to the plant, the proposed interface is completed. It is ready to be used as a source noise for the plant-to-plant, plant-to-fungi, or similar interactive setting.

*52 https://puredata.info/ (Accessed 25 February 2017).

Toolkit

The kit (Fig. 8) contains tools to experience interaction between interconnected elements of different natures. It includes: electronic components for building a sensor and a radio transmitter, both developed by Martin Howse, a petri dish full of coffee grounds, a few dowels with dried samples of oyster mycelium, different plant seeds, a digital microscope, an Arduino microcontroller, and software to bring the tools into action. The experiments introduced in the toolkit will give an idea of how to grow mycelium, how to make electronic tools and attach them to living organisms, and how to use the tools for audiovisual expression.

The use of the kit is divided into an array of different phases. The first phase introduces the cultivation of mycorrhizal networks and plants using the provided mycelia samples and plant seeds, and some coffee grounds. This phase should last for some weeks, until the mycelia have grown on the coffee grounds. The next phase is to grow plants next to the mycelia. Depending on the plant seeds used, the phase could take months or years, until the plants are big enough to attach to the electrodes provided. During the third phase, the user is invited to build an electronic interface and bridge it with the plants, the mycorrhizal fungi, and the computer in order to hack the interaction between them.

Fig. 15. A collaborative performance between Martin Howse and myself in the Brandenburg Forest. Video still

The first experiment introduces how to grow mycelia on coffee grounds (Annex III). The second experiment shows how to sense electric potentials in living organisms (Annex IV). The third experiment explains how to assemble and test the mycelial radio transmitter (Annex V). The fourth experiment explains how to use built tools and the Pd patch provided for audiovisual expression and electric-current manipulation (Annex VI). Overall, the user of the toolkit learns techniques to deal with the transport of information passed during the interaction process between elements of different types and comes with new ideas and new results.

One of the results presented in the attached video tutorial is a collaborative performance between Martin Howse and myself in the Brandenburg Forest (Fig 15).[53] In this performance, Martin Howse uses mycelium as an antenna to send out radio signals and a radio receiver to receive them, while I record the signal from the plants, digitally alter it, and feed it back into the plants as an electrical signal. The process results in sonic and visual expression. In reference to allelopathy, a phenomenon where one plant influences the growth of surrounding plants, one could think of technologies that influence the environment.

Conclusions

While providing a set of organic elements (plants, mycelia, coffee grounds) and inorganic elements (electronic elements to bridge the organic elements with the computer), I have laid the practical foundation to work with the interactive setting of plants and computing machines. Along with the practical experiments, I have briefly introduced the discourse in relation to the interaction between elements of different kinds and the idea of transport of information between these elements. Biochemical processes happening within living organisms could be altered and manipulated digitally by picking up an electric signal at its source location, translating it into a digital signal, altering it, and sending it to the destination. In so doing, the growth of the plants, for example, could be altered by themselves through the electronic interface. Furthermore, the signal captured could be sonified or visualized with software such as Pd. These ideas push further to explore the nature of the electrical signal, expanded in the toolkit "Ultra-Low-Voltage Survival Kit."

*53 See video tutorial and the performance at http://triple-double-u.com/mycorrhizal-networks-or-how-i-hack-plant-conversations/ (Accessed 13 February 2021).

Toolkit #3.
"Ultra-Low-Voltage Survival Kit"

Given that the human state of today is indivisible from technological achievements or, to be more precise, indivisible from a computing machine, this section refers to the nature of the electric signal as the base for digital computation and invites the reader to experience electricity with their own bodies. To start with, the section references two artistic projects related to the theme, suggests a conceptual framework for experiencing electricity, introduces the scientific basis for the experiments, and provides a step-by-step manual for the use of the tools for experiencing electricity. Focusing on information processing between organic and inorganic matter, the toolkit (Fig. 16) introduces two experiments: (1) an LED lit up by energy generated by the human body and (2) sound generated from a difference in temperature between a human and their environment. Proposing the building of simple interfaces between living organisms and machines without using a battery, the user becomes independent of the electricity supply.

Fig. 16. Toolkit "Ultra-Low-Voltage Survival Kit." Photo: Brigita Kasperaitė

Related Artistic Projects

The Workshop and participatory installation with DIY audio devices *Fresh Music For Rotten Vegetables*[54] by Karl Heinz Jeron (Fig. 17) is about generating sounds from vegetables and fruits that are past their best and unsellable in supermarkets. In the description of the project, the author wrote:

> The electronic devices built by the participants are controlled and fed by current generated by use of the collected vegetables. According to the state of the vegetables, the sound, the colour of the sound, and the volume of the sound are varied. Thus, an improvised piece of music is created from the most simple parts, and a garnish. (Jeron, 2011)

The project is a direct reference to a "lemon battery," that is, a battery built from lemons. Interesting in this project is that the sound generated varies as the vegetables and fruits change state over time.

Fig. 17. Karl Heinz Jeron, *Fresh Music For Rotten Vegetables*. Source: http://jeron.org/

Bacterial Radio[55] by Joe Davis (Fig. 18) uses a crystal radio mechanism, allowing for the capturing and conversion of AM radio waves. Besides being a radio, crystal radio evokes the idea of a living organism that is able to naturally generate electric current through interaction with its environment.

The technical description of *Bacterial Radio* reads as follows:

*54. http://jeron.org/fresh-music-for-rotten-vegetables/ (Accessed 5 November 2017).
*55. http://prix2012.aec.at/prixwinner/7023/ (Accessed: 14 May 2016).

In spring 2011, I created a flat circuit design that could be constructed in a Petri dish. This circuit was then cast in negative relief in PDMS (polydimethylsiloxane) gel. Cells and growth media were then applied to circuit impressions in the gel. The cells used were *E. coli* modified with a gene for silicatein, a ubiquitous protein native to many different marine organisms. These organisms use silicatein to polymerize silica from seawater in order to create glass endoskeletons and exoskeletons in a fantastic variety of forms. The silicatein gene used in the Bacterial Radio experiments was isolated from the marine sponge Tethya aurantia.

Silicatein is a promiscuous protein, so that if growth media is starved of silica and instead provided with metal salts or semiconductors, then the protein will try to polymerize those materials instead. In this way, electrical characteristics were imparted to the two respective cultures of bacteria used with *Bacterial Radio*. Bacteria were fixed and immobilized in the

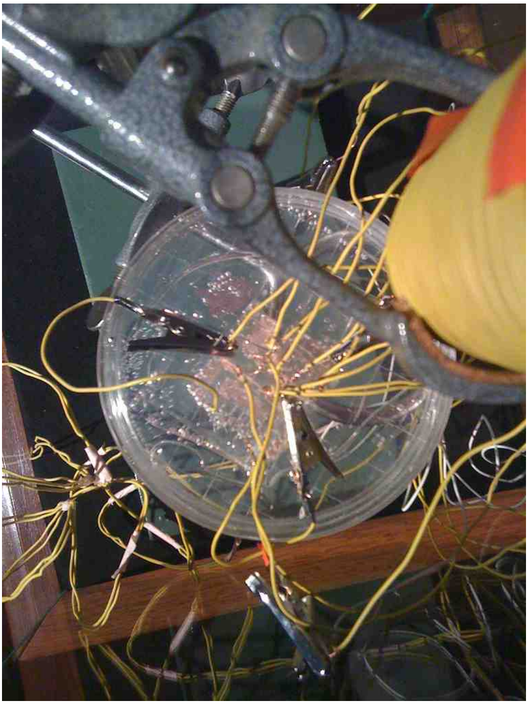

Fig. 18. Joe Davis, *Bacterial Radio*. Source: https://c1.staticflickr.com

PDMS gel. Pins and wires were used to connect elements of the gel-embedded circuit to each other and to external components such as the antenna, the ground and headphones (Davis, 2012)

The project *Bacterial Radio* is compelling from different perspectives. First of all, it uses crystal radio, a radio mechanism that is able to catch and convert AM radio waves with no additional electricity supply. Secondly, Davis has introduced modified *E. coli* bacteria, which might replace traditional wires.

Concept

All matter has electrical properties. Given that electric signals in carbon-based organic matter and silicon-based computing machines are of the same nature, the "Ultra-Low-Voltage Survival Kit" explores the idea of generating electricity with the human body. While practically letting the user of the toolkit move subatomic particles in and out of the body, the project invites one to experience electricity. Proposing to power computing machines by one's own body, the project also suggests critical evaluation of the possibility of technology further becoming part of human bodies.

Ultra-Low Voltage and Organic Matter

Every solid, liquid, gas, and plasma is composed of neutral or ionized atoms that have differently charged subatomic particles, which, while interacting with subatomic particles of another atom, generate electric current. The related artistic projects referred to earlier in this section trigger our imagination and invite us to think of scenarios that could bring computing machines and organisms together into a single entity. Applying features of computing machines on humans, including retinal implants and brain pacemakers, one could think of enhanced humans or, even, non-human humans. Here, critical thought provides different traditions, which could be described under one posthumanist umbrella.

In Katherine Hayles's terms, the posthuman is a state wherein the human seamlessly integrates with intelligent machines and approaches his or her body as a prosthesis. To be more precise, in Hayles's posthumanism, there are "no essential differences or absolute demarcations between bodily existence and computer simulation, cybernetic mechanism and biological organism, robot teleology and human goals" (Hayles 1999, 2). In such a tradition, questioning all matter as having the same electrical properties becomes crucial.

Historical Context of Electricity

Organisms can be characterized by their ability to conduct electricity, which has been known since the second half of the 18th century. Edmund Whittaker (1910) mentioned Luigi Galvani's and his assistants' experiments in the 1780s, which demonstrated convulsions in frog legs when attached to an electrical machine, and which were considered "animal electricity." A slightly different approach to electricity was presented by Alessandro Volta, who, in 1800, built his Voltaic Pile, known as the first electrical battery (Russel 2003). Described as a reaction between chemical elements, the Voltaic Pile had two electrodes of different metals placed between pads made of moist material. Such a setup made it possible to demonstrate interaction between organic and non-organic matter.

The characterization of organisms capable of electrical conductivity in reference to reactions between nerves (organic) and metals (non-organic) instead of "animal electricity" was introduced by Johann Wilhelm Ritter (Berg 2008) after a number of experiments shortly before his death in 1810.

Electric Current Generated by Organic Matter

The simplest interaction between organic and non-organic elements could be demonstrated with a lemon battery, which generates electricity from a chemical reaction between acids and two electrodes of different metals—zinc and copper (Fig. 19). Placed within one small or several normal-sized lemons, the setup is identical to Volta's electrical battery. In the lemon battery, the copper serves as the positive electrode, while a piece of zinc acts as the negative electrode. Citric acid triggers the chemical reaction between the negative and positive electrodes, generating a small potential difference, which, in turn, becomes the electrical current (Edinformatics 2015). The electric current could also be produced by, for example, potatoes or humans.

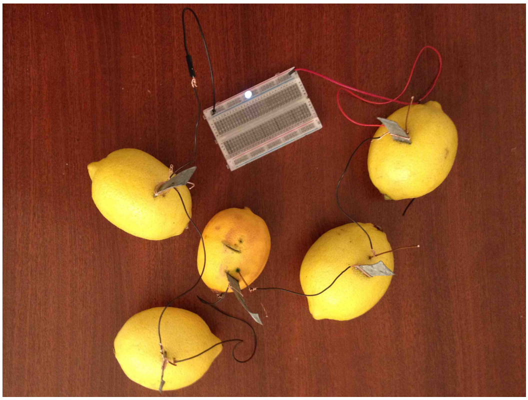

Fig. 19. Mindaugas Gapševičius, *Prototype for a Posthuman Game*. Installation detail. Lemons connected with copper and zinc electrodes produce electricity that can light up an LED. Photo: Mindaugas Gapševičius

During the workshop held in Vilnius in 2015, the workshop participants and I tried to experiment with different matter.[56] All the vegetables and fruits brought for the workshop generated up to 1 V of electric potential through the attached copper and zinc electrodes. The human body generated 0.4 V electric potential. During further experiments, while connecting five fruits and vegetables in sequence, the 4 V of electric potential generated was able to light up an LED. Similarly, connecting seven workshop participants to the sequence produced 2 V of electric energy.

*56 "Do-It-Yourself" series workshop *How To Light Up LED With Your Body* with artist Mindaugas Gapševičius. Available at http://www.letmekoo.lt/en/pasidaryk-pats-dirbtuves-kaip-iziebti-led-savo-kunu-su-menininku-mindaugu-gapseviciumi/ (Accessed 11 August 2015).

Although the amount of voltage might have been enough to light up an LED, a lack of current prevented the lighting up of the LED during the workshop.

Nevertheless, an LED can be lit up with one human body by combining several electronic components in the circuit. An example showing such an experiment was published on YouTube by the user slider2732 in 2013.[57] Here, the "battery" consists of a human body, two capacitors, a resistor, a semi-conductive stone (such as ferrite or pyrite) with copper wire, and a piece of aluminum.

Toolkit

The toolkit (Fig. 16) includes electronic components for building circuits for audiovisual performances (Fig. 20) that use a human body as a replacement for an energy source. The manual proposes that we reconsider properties of our bodies that could become an essential source for powering up bionic implants or external devices.

To generate energy we will use (in the first experiment) a reaction between zinc and the human body to make a battery and power up an LED with it (Annex VII). In the second experiment we will use body temperature (to be exact, the temperature between a body and its environ-

Fig. 20. Wolfgang Spahn and Mindaugas Gapševičius perform with their devices at TOP project space. Video still

*57 https://www.youtube.com/watch?v=STPej7VQNzI (Accessed 13 May 2016).

ment) to generate energy (Annex VIII). With that, we will power an audible synthesizer that is controlled by temperature and light.

Conclusions

The project aimed to introduce a framework for experiencing electricity. Chemical reactions between organic and non-organic matter and difference in temperature between a human body and its environment generated enough electricity to light up an LED and to play sound. Therefore, the use of a human body in connection with a silicon-based computing machine need not be considered fantasy or a faraway future. Moreover, discussions around ultra-low voltage should garner more attention because machines powered by ultra-low voltage might reduce energy use and, also, could make humanity less dependent on the production of electricity; for example, small-sized computer chips or nanorobots could be powered directly by the human body.

This section's introduction of circuits that produce light and sound without an additional battery or voltage supply questions the posthuman state, defined by Katherine Hayles as the merging of the human body and silicon-based technology.

Toolkit #4. “How I Prepare Myself to Be Cloned”

This toolkit introduces tools to analyze organisms at the molecular level and questions cloning and manipulations in a genome at the DIY level. Although cloning animals in scientific research has been explored for decades,[58] it is still considered by many as unethical, especially when it comes to cloning humans.[59] Nevertheless, the possibility exists, and it is only a matter of time until the first human will be cloned. The section entitled “How I Prepare Myself to Be Cloned” is a provocative reference to the possibility of cloning my own body, but is not necessarily the goal of the section. This section, however, looks into scientific and artistic projects that have used the cloning of animals or the modification of their genetic code, and invites one to experience the manipulation of the human genome at practical and aesthetic levels. The toolkit (Fig. 21) enables the analysis of a genome at home.

Fig. 21. Toolkit “How I Prepare Myself to Be Cloned.” Photo: Brigita Kasperaitė

In nature, identical plants, for example, grow from a single cell or from a number of seeds matured in the plant. Unicellular organisms or cells of multicellular

*58 See “Cloning” entry on Wikipedia. Available at https://en.wikipedia.org/wiki/Cloning (Accessed 27 October 2017).

*59 See “Human cloning” entry on Wikipedia. Available at https://en.wikipedia.org/wiki/Human_cloning (Accessed 27 October 2017).

organisms start their division by splitting their genetic code and making out of it two identical copies, which, in turn, would trigger the division of the cell into two identical copies.

Historically, humanity has noticed similarities in a variety of organisms that trigger its fantasy. On one hand, organisms have been depicted in repetition in historical imagery, as in slaves in Egyptian murals or animals in Mesopotamian reliefs. On the other hand, organisms have also been presented as hybrids. In ancient spoken and written stories or depicted scenes, we meet a number of mythological hybrids carrying parts of different organisms: Pegasus was imagined as a horse with wings, centaurs appeared as half-human and half-horse, mermaids were composed of fish and women. Although practically these hybrids didn't exist and were achieved through an inherent faculty of divine intervention, during the course of evolution hybrids of a certain level were also bred in the real world: Mules came into being while breeding a female horse with a male donkey, and shoats came about while breeding a sheep with a goat.

Donna Haraway's question of "who 'we' will become when species meet" (Haraway 2008, 5) is rather philosophical, projected into the future and further evolution. If I think of contemporary biotechnologies and CRISPR-Cas9 as methods for modifying organisms, the metaphor proposed by Haraway becomes very important within the discourse of cloning and transgenic species, especially those within the animal kingdom. What will happen over the course of future evolution if organisms are programmed and reprogrammed? After this intentioned human (re)programming, how far will the newly shaped organisms continue to mutate over new generations in order to adapt to changing environmental conditions?

*60 https://en.wikipedia.org/wiki/Dolly_(sheep) (Accessed 29 October 2017).
*61 http://www.sciencemag.org/news/2015/12/and-science-s-2015-breakthrough-year (Accessed 29 October 2017).

While cloning is a natural process of reproduction in an organism, advances in molecular biology at the end of the 20th and at the beginning of the 21st century have completely changed the understanding of cloning, including the mastering of modifications of a cloned organism. The year 1996 is marked by the cloning of a sheep from an adult somatic cell,[60] and 2012 became a breakthrough year in genome-editing, allowing one to “cut” and “paste” specified DNA targets into the genome of an organism.[61] Since the end of the 20th century, genetically modified organisms, or GMOs, have become a standard in the food industry.

In artistic practice, the manipulation of a genome is rather an exception. At the same time, working with a genome and questioning its manipulation at an aesthetic level is a challenge because of limits in its (re)presentation.

The first part of the section introduces artistic and scientific projects related to cloning and genetic manipulation. The second part of the section lays out three experiments, guiding the reader and the toolkit user to practical work with molecular biology. Able to experience the basic idea of life while using the tools provided, the toolkit user should be able to participate in discussions around issues of cloning and the genetic modification of animals.

Related Projects

Dolly is a sheep that was cloned at the Roslin Institute in Scotland in 1996 (Fig. 22). A cell taken from a mammary gland in a six-year-old sheep was altered and implanted into an egg from a surrogate Scottish Blackface sheep, which, through a normal pregnancy, gave birth to a healthy offspring.[62] Interestingly, Dolly was born from a somatic and not a reproductive cell, meaning that at any time any cell taken from an adult could be reprogrammed into a reproductive stem cell.

The idea of being able to clone a mammal from an adult cell gives way to the idea of cloning a human, which is banned by civil law all over the world. Nevertheless, the research is still being done at the embryo level to gain further scientific knowledge. The technique used—somatic cell nuclear transfer (SCNT) combined with the CRISPR-Cas9 gene-editing technique—might change expectations for cloning mammals, including humans.

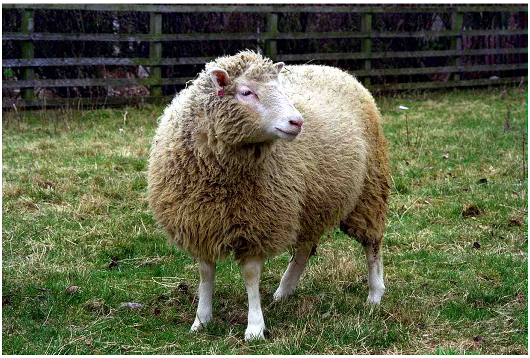

Fig. 22. *Dolly*. Photo courtesy by the Roslin Institute, University of Edinburgh. Source: http://dolly.roslin.ed.ac.uk/

At least seventy-four attempts at animal modification were counted in 2015 by A. Lievens and colleagues (2015). While genetically modified animals are not yet produced for human consumption on a large scale, news associated with them still comes up. In 2015, genetically modified salmon were approved for consumption in the US by the Food and Drug Administration and showed up on the market in 2017.[63] *GloFish* (Fig. 23), the first genetically modified pet, have been around in pet shops in the US since 2004 (Nash 2004).

*62 http://www.nature.com/articles/ncomms12359 (Accessed 29 October 2017) and http://dolly.roslin.ed.ac.uk/facts/the-life-of-dolly/index.html (Accessed 29 October 2017).

*63 https://www.cnbc.com/2017/08/09/salmon-becomes-worlds-first-genetically-modified-animal-to-enter-food-supply.html (Accessed 29 October 2017).

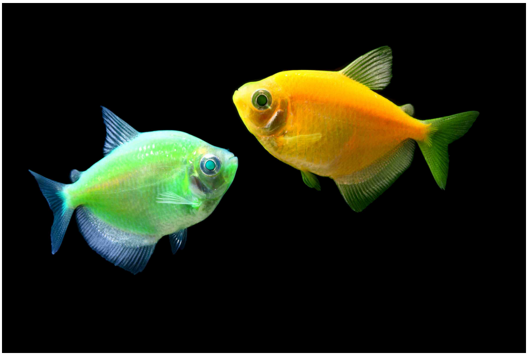

Fig. 23. GloFish, orange and green tetra. Source: http://glofish.com

The GloFish is interesting because of its aesthetic value. Being a pet, its function is to entertain its host. The GloFish includes the green fluorescent protein (GFP), which is widely used in scientific research. GFP modification is also used for educational purposes in high schools and colleges to teach students about recombinant DNA and protein purification techniques. Even if genetic modification is restricted for domestic experiments, GFP modification was legalized by Berlin authorities in 2016 for educational purposes for use in home environments.[64]

Originally isolated from the jellyfish Aequorea victoria, scientists use the protein as a marker within a DNA sequence or as a concept of proof for genetic modification. Although GFP modification is considered harmless in organisms, some studies suggest its influence on animal aging, locomotive ability, and eye morphology. Therefore, it is suggested that GFP be used cautiously for genetic modifications (Mawhinney, Staveley 2011).

The transgenic artwork *GFP Bunny*[65] by Eduardo Kac was completed in February 2000 with the birth of a rabbit named "Alba" (Fig. 24). The project was an outcome of Kac's collaboration with zoosystemician Louis Bec and scientists Louis-Marie Houdebine and Patrick Prunet. The rabbit had altered genomics, carrying

*64 In 2016 Rüdiger Trojok was using GFP for modifying E. coli bacteria in his home laboratory. For more info, see https://www.meetup.com/Biotinkering-Berlin/events/235107360/?_cookie-check=zc-l_hyy9qe64U94 (Accessed 29 October 2017).
*65 http://www.ekac.org/gfpbunny.html#gfpbunnyanchor (Accessed 29 October 2017).

a fluorescent GFP, the same protein that was used to modify the GloFish. Genetically modified Alba was an albino rabbit with no skin pigment and with pink eyes. In daylight it would look white, while under blue light with a maximum excitation of 488 nm the rabbit would glow with a bright green light (Kac 2000).

Fig. 24. GFP Bunny. Source: http://oslolux.wordpress.com/eduardo-kac

In the description of the project, Kac wrote:

> My transgenic artwork *GFP Bunny* comprises the creation of a green fluorescent rabbit, the public dialogue generated by the project, and the social integration of the rabbit.[66]

While the project generated huge attention in the media and was followed by a number of interpretations,[67] the social integration of the rabbit has failed, as it was never released from the laboratory.[68] This is despite the fact that Alba, like any other rabbit, sought interaction and, for example, sat comfortably in Kac's hands (Kac 2000).

For the genetic modification of Alba, scientists integrated GFP into the genome through zygote microinjection, the method most extensively used in the production of transgenic animals, including rabbits. The method suggests in vitro fertilization, which is done outside of the organism and therefore could be easily combined with the SCNT method used to clone Dolly.

*66 Ibid.
*67 See http://www.ekac.org/gfpbunny.html (Accessed 29 October 2017).
*68 https://today.duke.edu/2000/11/bunnyn03.html (Accessed 29 October 2017).

There are a number of controversial discussions around the *GFP Bunny* project. Firstly, the photo of the fluorescent rabbit has been digitally manipulated. Secondly, there are different versions of the story of how long the rabbit was alive. Finally, according to *Wired* magazine, it is not clear if the rabbit was genetically modified as an artistic project from the beginning.[69] Nevertheless, the project gained enough attention from the media to be considered one of the most influential in Bioart.

Sterile[70] is a project by Revital Cohen and Tuur Van Balen that is a genetically modified Albino goldfish (Fig. 25). At the Schering Foundation exhibition space in Berlin, it was shown alongside other works, including the video *Kingyo Kingdom*, which follows fish breeders in Japan while at the same time contextualizing the genetically modified fish, and *Sensei Ichi-gō*, a machine capable of reproducing sterile goldfish. Within the project description, *Sterile* is described as follows:

> Albino goldfish engineered to hatch without reproductive organs. They were not conceived as animals but made as objects, unable to partake in the biological cycle. An edition of 45 goldfish was produced for the artists by Professor Yamaha Etsuro in his laboratory in Hokkaido, Japan, following an intricate collaboration process, which began in 2011.[71]

Fig. 25. *Sterile*. Source: http://containerartistresidency01.org

*69 See the article at https://www.wired.com/2002/08/rip-alba-the-glowing-bunny/ (Accessed 29 Oct 2017).
*70 http://www.cohenvanbalen.com/work/sterile (Accessed 29 October 2017).
*71 http://www.artscatalyst.org/sterile-sensei-ichi-go (Accessed 29 October 2017).

The important part of the project is that the fishes were not sterilized after they were born, but were genetically modified in order to not have reproductive organs. In such a way, the artists showed their responsibility in front of the whole ecosphere, because the genetically modified animals will not continue breeding later. Having the fish born sterile, the project questions genetic modification done by humans in relation to a naturally evolving environment.

Moreover, an important message in *Sterile* is the blurring of the borderline between object and subject: whether it be a fish being technically engineered to become an object or a machine being programmed to become similar to a living organism. The idea of an object becoming a subject and vice versa has been conceptualized around the machine-human rhizome within the context of the umbrella project of this section, *Introduction to Posthuman Aesthetics*, which proposes a subjective perspective on discourses in contemporary aesthetics.

Microvenus by Joe Davis is a genetically modified *Escherichia coli* bacteria strain carrying a piece of a synthetically composed sequence of amino-acid molecules. It was first cloned into several laboratory strains of *E. coli* in collaboration with molecular geneticist Dana Boyd at Jon Beckwith's laboratory at Harvard Medical School in 1988. As bacteria are small and invisible to the human eye, the artwork, instead of being visually "aesthetic," is instead left to the imagination. Davis introduces the *Microvenus* as follows:

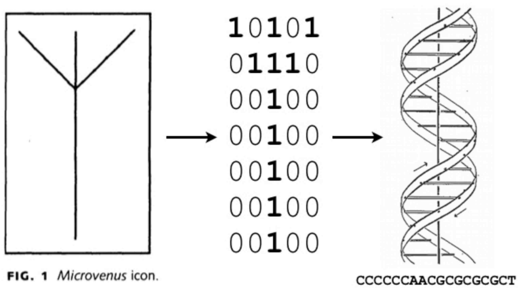

Fig. 26. *Microvenus*. Source: http://unmondemoderne.wordpress.com

*70 http://www.cohenvanbalen.com/work/sterile (Accessed 29 October 2017).
*71 http://www.artscatalyst.org/sterile-sensei-ichi-go (Accessed 29 October 2017).

> Each Microvenus organism contains many copies of a special molecule designed by the artist and his colleagues. The artistic molecule is a short piece of synthetic DNA containing a coded visual icon that has been incorporated into a living strain of bacteria *(E. coli)*. (Davis 1996, 70)

The coded icon is the symbol for "life" from a Germanic rune. Resembling the letter Y, it also represents a female Earth in different mythologies. The graphical image was converted into the bit-map image and further into DNA base pairs in order to synthetically program and be attached to the original DNA code of the plasmids carried by bacteria (Fig. 26). Davis has imagined that the code could be interpreted by extraterrestrials, as the final stage of the project was supposed to include shipping of the modified bacteria into the universe.

Microvenus is compelling from different perspectives. First of all, it is the first genetically modified artwork. Secondly, Davis's idea to encode and store data in DNA in the late 80s was a couple of decades ahead of a scientific project presented by the CUHK team at the iGEM competition in 2010.[72] Finally, thinking of extraterrestrial intelligence, it probably makes sense to consider communication happening at the very basis of life, within the chemical interactions between different molecules. So, encoding and reading genetic information could potentially provide many answers about different life forms.

Concept

Cloning is a complex issue involving scientific knowledge, civil law, and ethical questions yet to be solved by humanity. On the other hand, the methodology

*72 http://2010.igem.org/Team:Hong_Kong-CUHK (Accessed 29 October 2017).

used for cloning animals is not that complex and could be easily imagined with the use of simple tools.

Referring to mythological hybrids (like centaurs, mermaids, and minotaurs), the toolkit, the tutorial, the paper (this section), and a number of experiments associated with the manipulation of a genome, the project aims at envisioning possible shapes, functions, and needs of non-human humans. While practically "disassembling" the cells, amplifying the genetic code of cells' DNA, and analyzing DNA, the user of the kit is invited to experience life at a molecular level.

Along with a manipulated genome, the question raised in this project is of the engineered self. To what extent could it be possible to modify one's own DNA, or, even, to give birth to a modified self? How much self will remain?

Cloning Mechanism of Animals and Modifications of Genome

In the section "My Collaboration with Bacteria for Paper Production," which is devoted to symbiosis, I have briefly introduced interactions between chemical and organic elements, which, while interacting, trigger evolutionary processes. These processes wouldn't have been possible without the organism's ability to self-replicate and mutate while adapting to changing environmental conditions. While self-replication is just another term to define cloning processes, the mutation of the organism in the natural environment could be compared to natural breeding or to engineered genetic code.

While self-replication is a natural process in unicellular organisms, cell division, and spore formation, within this research, importance is laid on cloning animals that sexually reproduce or, to be more precise, the method for mammal cloning that was used to clone the sheep Dolly.

Dolly was cloned using the SCNT mechanism, a technique for creating an ovum with a donor

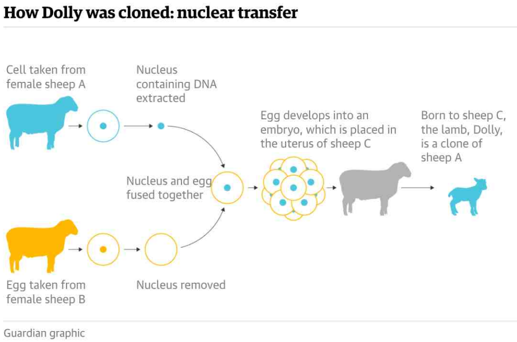

Fig. 27. Somatic cell nuclear transfer to clone Dolly. Source: The Guardian

nucleus. The mechanism was rather simple: A cell from one sheep was used for the extraction of the nucleus, and an egg cell without a nucleus from another organism was used for the implantation of the extracted nucleus. In vitro fertilization and a microinjection technique were used to insert the nucleus into the donor sheep, causing the further development of the embryo and, finally, the birth of Dolly (Fig. 27).

The SCNT mechanism for cloning Dolly was also used to clone other mammals, including dogs and cats. The owner of the patent, the Korean company BioArts International, stopped providing its commercial service in 2008 because of lack of interest and competition in the black market.[73] The company's cloning vendor, the Sooam Biotech Research Foundation of Seoul, still offers the service. On the other hand, their last competition, to clone a beloved dog, was announced on 25 November 2013. According to the foundation, the biggest hurdle to cloning mammals from an adult cell is still the low rate of pregnancy, reaching as low as 2 percent,[74] and the price, reaching 100,000 US dollars per clone.[75] Other sources also report a high number of abnormal fetal developments.[76]

*73 https://www.petwellbeing.com/blog/news/worlds-first-pet-cloning-company-discontinues-service (Accessed 19 April 2019).
*74 http://en.sooam.com/dogcn/sub03.html (Accessed 29 October 2017) and http://dolly.roslin.ed.ac.uk/facts/cloning-faqs/index.html (Accessed 29 October 2017).
*75 http://en.sooam.com/dogcn/sub06.html (Accessed 29 October 2017).
*76 https://www.ncbi.nlm.nih.gov/books/NBK215769/#!po=26.9912 (Accessed 29 October 2017).

Genetic Engineering

Genetically modified organisms, or transgenic organisms, are able to express foreign genes. This means that the genetic code is similar for all organisms, and a specific DNA sequence will code for the same protein in all organisms. Cutting out a gene responsible for reproduction, as was done in Revital Cohen and Tuur Van Balen's *Sterile*, will not code related protein and thus will disable a function that the DNA sequence was supposed to code. While adding a GFP gene, as was done in Eduardo Kac's *GFP Bunny*, would add the ability of the organism to glow under a UV light.

Although the genetic code in different organisms is similar, different organisms carry different cellular structures and can be genetically engineered differently. For example, unicellular prokaryotes like *E. coli* bacteria are engineered under electric or heat shock, while multicellular eukaryotes like plants might be engineered naturally using *Agrobacterium tumefaciens* or in the lab using the same microinjection as was used to clone Dolly, or other mechanisms, including a gene gun, electroporation, and CRISPR-Cas9. Multicellular eukaryotes (such as animals) have an even more complex system for engineering, though, as in plants, they could be engineered using both lab and natural methods. On one hand, engineering could be done with the help of viruses that are able to carry the genetic code attached to them. On the other hand, animals could be engineered using lab methods, likewise including microinjection, a gene gun, and CRISPR-Cas9. Depending on a specific DNA sequence, the methods could be combined. For example, the GFP gene could be amplified in the plasmids of *E. coli* bacteria and then, while using microinjection, attached to the chromosome of a multicellular organism. The GFP gene could also be amplified using the polymerase chain reaction (PCR) technique and inserted into a cell using the gene gun technique.

Although the methods introduced are used for cloning and genetic modification, this section will not introduce how to clone oneself. Instead, the experiments introduced below will give an idea of the DIY methods for genetic analysis and manipulation. Altogether, the project remains an artistic framework for experiencing life at a molecular level and raises a number of questions related to molecular biology.

Toolkit

The DIY tools provided (Fig. 21) help to look at genetic code and to diagnose mutations in a genome, if any. While mutations could vary and result in different diseases, I suggest focusing on a gene sequence that is responsible for breaking down lactose. Three experiments introduced (a polymerase chain reaction, a gel electrophoresis, and a DNA fingerprinting) give an idea if the inspected person tolerates lactose, found in milk and other dairy products (Annex IX–XI).

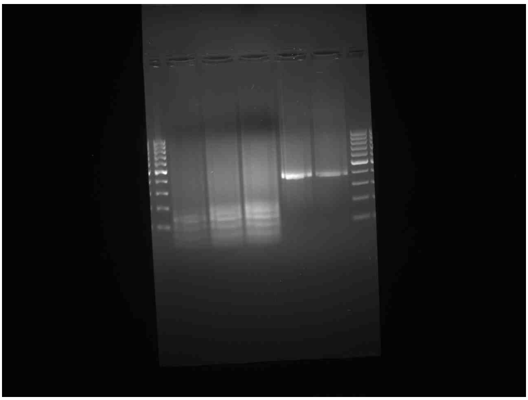

Fig. 28. Gel electrophoresis and DNA fingerprinting. In our experiment we used a 2% agarose gel with 1 kb pairs DNA ladder, located on the left and on the right sides of the gel. The first, second, and third tracks are loaded with the treated DNA samples, with 20, 30, and 50 ul of the sample, respectively. The fourth and fifth tracks are loaded with the untreated DNA sample: in the fourth track, the sample was amplified with the professional PCR, and in the fifth with the DIY PCR provided in the toolkit. Photo: Auksė Gaižauskaitė

After implementing all the experiments, the user of the toolkit will come up with new ideas of what other analyses may be done, or how to approach tools otherwise. My proposal was to compare professional and DIY tools for the analysis of the DNA and to show the results as a photo, something of what scientists use in their daily practice (Fig. 28). After the aesthetic presentation of the photos, scientists are invited to think about how science can become artistic (Fig. 29).

Fig. 29. Aesthetic presentation of the photos with gel electrophoresis and fingerprinting results. Photo: Brigita Kasperaitė

Conclusions and Discussion

While referring to mythological hybrids, artistic, and scientific projects, this section aimed to provide a framework for experiencing life at a molecular level. Practical experimentation should have opened up space for dreaming and imagination. For example, I discovered that cloning mammals that sexually reproduce requires a donor organism. In theory, there is the possibility to clone oneself without having a donor organism. In this case, the imagined condition would be a manipulated cell from the same female mammal, as only a female mammal would be able to deliver an offspring. A yet another idea would be the modification of an offspring's DNA code with a GFP gene. While in a casual setting the offspring wouldn't differ from a non-modified offspring, under a UV light it would potentially glow.

There are many questions still to be raised and answered, including those that concern ethical issues: How will genetically modified humans share their lives with non-modified ones? Why would I need to clone myself? How do I make sense out of cloning humans? Whatever the answers, the process of genetically modifying humans has already begun,[77] and humans will need to learn how to interact with non-human humans.

The other challenge is the use of DIY tools and experiments at a molecular level in private homes. If the genetic modification of organisms is simple, and if it is accessible to wider audience, what is at stake here for artists? Is there anything new in artistic expression?

*77 See MIT Technology Review on China's CRISPR twins. Available at https://www.technologyreview.com/s/613007/chinas-crispr-twins-a-timeline-of-news/ (Accessed 16 April 2019).

Conclusions and Discussion

In the *Shared Habitats* exhibitions, the audience saw mainly manuals and video tutorials that were part of the toolkits. Furthermore, the toolkits, manuals, and video tutorials invited the audience to experiment right in the exhibition.

The format of an artistic manual is not a new one. Besides *The Fluxus Performance Workbook* compiled by Friedman (2002), which provides step-by-step instructions for performing a work of art, other similar manuals include *The Anarchist Cookbook* (Powell 1971), *Creative Biotechnology: A User's Manual* (Thacker, Jeremijenko 2004), and *Home Made Bio Electronic Arts: Do-it-yourself: Microscopes, Sensors, Sonifications* (Landwehr, Kuni 2013). If manuals in *The Anarchist Cookbook* and *Creative Biotechnology* serve questions important to a biotech hobbyist, and the manuals in the book *Home Made Bio Electronic Arts* serve as a roadmap for the artistic study of electronics, the manuals of *Introduction to Posthuman Aesthetics* aim at a full range of research regarding the chosen theme and function as separate scientific papers. My additional contribution to the artistic format of the manual is also an aesthetic one, as I published them as individual handmade booklets.

Next to the manuals, *Introduction to Posthuman Aesthetics* also provided toolkits for individual experimentation. Four toolkits have been presented. While the toolkit "My Collaboration with Bacteria for Paper Production" focused on symbiotic relationships between living organisms and non-living things, "Mycorrhizal Networks, or How I Hack Plant Conversations" gave an idea of the interaction between elements of different kinds. The toolkit "Ultra-Low-Voltage Survival Kit" then explored the nature of the electrical signal, and the toolkit "How I Prepare Myself to Be Cloned" questioned the possibility of cloning one's own body.

One note is that toolkits as an artistic format are also not necessarily new. Mention should be made of "Fluxkits" (or "Fluxboxes"), conceived by Georg Maciunas and produced by invited artists.[78] Mention should be also made of toolkits in *PSX Consultancy* by Špela Petrič and collaborators.[79] Both art projects used the toolkits rather for aesthetic purposes and not really for practical use. I would also like to mention the toolkits of

*78 See, https://www.moma.org/interactives/exhibitions/2011/fluxus_editions/category_works/fluxkit/index.html (Accessed 1 January 2022).

Hackteria initiative,[80] whose primarily function was their use during the workshops. I would mention also the *Free Universal Construction Kit* by Golan Levin and collaborators, which functioned as a set of instructions for products available in the market.[81] Differently to mentioned toolkits, I tried to combine the use and their aesthetic form. All included tools were also given meaning in terms of size, materiality, and use.

Part of the *Introduction to Posthuman Aesthetics* were also video tutorials presented as instructions for conducting experiments. Among the artistic video tutorials, worth mentioning are *How Not to Be Seen* by artist and critic Hito Steyerl and the video series *A Side Man 5000 Adventure* by Harsha Hewitt. Even in my video tutorials, instructions are given for conducting experiments, and the aesthetic results of the use of the toolkits were also integrated. For example, the video tutorial of the toolkit "Mycorrhizal Networks, or How I Hack Plant Conversations" begins and ends with a performance in the Brandenburg Forest.

In the *Shared Habitats* exhibitions where I have installed *Introduction to Posthuman Aesthetics*, the audience often did not dare to touch the objects or use tools unless invited to do so. Perhaps this state of the audience is similar to that described by Varvara Guljajeva in her dissertation on the passive audiences, and is more reminiscent of a conventional approach to artistic works. My intention was rather to introduce a different format into the exhibition, a format similar to a Fluxus performance or a relational aesthetics type. However, instead of offering a performance or relational aesthetics event, I decided on a specific setting for the use of the toolkits, the DIWO (Do-It-With-Others) format, which would be reminiscent of Maker culture and different from the formats already seen in previous artistic expressions. Therefore, next to the individual use of the toolkits within the *Introduction to Posthuman Aesthetics*, I have also conceptualized the use of the toolkits for the collaborative setting as a *Self-Repair Lab* workshop series. Since I could not imagine beforehand what such a setting would bring in terms of outcomes, I was curious to implement the setting and reflect on it from an artistic point of view. Therefore, in the following chapter, I will present the results of the *Self-Repair Lab* workshops conducted as part of the exhibition.

*79 See, https://peiyinglin.net/psx.html (Accessed 1 January 2022).
*80 See, for example, https://www.hackteria.org/wiki/Ekalavya_Toolkit (Accessed 1 January 2022).
*81 See, http://www.flong.com/archive/projects/free-universal-construction-kit/index.html (Accessed 1 January 2022).

Collaborative Experience in the Self-Repair Lab

The idea of the collaborative experience was realized in the collaborative setting of the *Self-Repair Lab*,[82] where the audience was invited to join the artist in using the toolkits. So here I propose what would traditionally be called a "workshop": a room and tools provided to make or repair goods.

The *Self-Repair Lab* was conceptualized as a continuous DIWO experience that I have installed temporarily in public spaces and permanently in Berlin and Vilnius (Fig. 30–32).[83] The version which is referred to in this section was installed at the *Shared Habitats* exhibition at the MO museum in Vilnius. While the permanent installations were equipped with laminar flow hoods for a sterile work, centrifuges for separating denser substances and particles from the low-density substances, PCR thermocyclers for DNA manipulation, and 3D printers for a quick

*82 For more information, please refer to http://triple-double-u.com/self-repair-lab/ (Accessed 30 March 2020). Collaborators include Julian Chollet, Martin Howse, Wolfgang Spahn, Jan Glöckner, Auksė Gaižauskaitė, Miglė Kalvaitytė, and Juan Pablo Díaz among others.
*83 See TOP project space in Berlin, available at http://www.top-ev.de/ (Accessed 27 September 2019) and Institutio Media Alt lab, available at http://www.o-o.lt (Accessed 27 September 2019).

small-scale digital fabrication, the *Self-Repair Lab* at the MO museum included only the tools which were needed for experimentation during the *Shared Habitats* exhibition. The experimentation with audiences was contextualized next to toolkits, video tutorials, and manuals of the *Introduction to Posthuman Aesthetics* artwork, introduced in the second chapter.

Fig. 30. *Self-Repair Lab* at the MO Museum. Video still

Fig. 31. *Self-Repair Lab* at the TOP project space, Berlin 2019. Photo: Brigita Kasperaitė

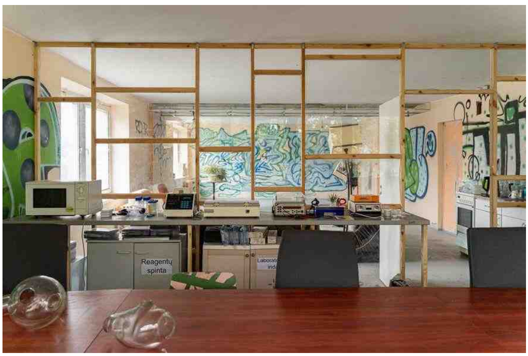

Fig. 32. *Self-Repair Lab* at the Alt lab, Vilnius 2020. Photo: Andrej Vasilenko

The *Self-Repair Lab* resembled a DIY biological-experiment laboratory where artifacts, lab equipment, people, and events were brought together in order to take a scientific detour and to understand the self-organization of the ecosystem, to reflect the posthuman state, and to critically evaluate up-to-date discourses circulating among artists, scientists, and engineers. It is worth mentioning similar events from the 1990s: Rirkrit Tiravanija's series of cooking sessions *Untitled*, where the public were invited to watch the artist cook and were then served a meal,[84] or Christine Hill's *Volksboutique* stores, where people were invited to drink tea and buy clothes.[85] If in many performances, including interactive installations described by Varvara Guljajeva as post-participative, the artist had agency while the audience was largely passive, in the *Self-Repair Lab*, as in the works of Tiravanija or Hill, the audience took the place of the active participant, influenced primarily by the artist and the proposed setting, including the given tools and theoretical context.

While in conventional art terminology, "laboratory context" would be "performance," and "toolkits" would be "installation," the *Self-Repair Lab* suggested a dissolution of borders between technology, science, and art, and called the laboratory a laboratory and the toolkit a toolkit. In contrast to a science lab where scientists would raise hypotheses and, while experimenting, prove or disapprove them, in the *Self-Repair Lab*, participants would question science and technologies while getting into the direct interaction with other people, non-human organisms, tools, and matter.

In order to make science more accessible, the participants (and the rest of the audience) were also provided with toolkits, tutorials, and manuals from the *Introduction to Posthuman Aesthetics*. Similarly to *Thames & Kosmos* kits (popular consumer products targeted at children and young adults),[86] participants were introduced to practical experimentation and thematic context, which was directly linked to the toolkits from the *Introduction to Posthuman Aesthetics*.

The temporary *Self-Repair Lab* at the MO Museum in Vilnius suggested a social event where artists, scientists, and laypeople collaboratively explored the up-to-date artistic questioning, scientific inventions, technological innovations, and life challenges associated with those inventions and innovations. While the prerogative of the artists and scientists was to execute the conceptualized

*84 See catalog text from the exhibition Performance Anxiety, http://web.mit.edu/allanmc/www/rirkritmca.pdf (Accessed 15 February 2021).
*85 See interview with Christine Hill, https://we-make-money-not-art.com/interview_with_20/ (Accessed 15 February 2021).
*86 See https://www.thamesandkosmos.com/ (Accessed 28 September 2019).

experiment, laypeople contributed in pivotal ways by asking questions, suggesting answers, tinkering with matter, and, finally, providing new artifacts.

The collaborative nature of the workshops at the MO Museum was based on the introduction of tools and thematic context during the first day, the collaborative experimentation with other workshop leaders and other participants during the second day, and artistic outcomes from participants during the third day. In addition to the workshop leaders, nine other participants took part in each workshop. The results included new audiovisual performances, artifacts, installations with microorganisms, and ideas that were spoken, written down, or sketched on paper for further experimentation. These results contextualized up-to-date discourses, re-drew ethical borders between humans and non-humans, and materialized imaginations.[87]

The *Self-Repair Lab* was conceptualized as follows:

> *Self-Repair Lab* refers to an organism's ability to identify and fix its own system. A well known self-surgery under "real-life conditions" was performed by Leonid Rogozov. In 1961, during his expedition to the Antarctic, which, at that time, was not really an inhabited place, Rogozov performed an appendectomy on himself. While humanity dreams about space travel, humans often neglect certain "what if?" questions: What if it is not possible to ask others for help, to fulfill one or another task? What if certain experimentation is restricted by law? What, in fact, is "law"? There are also other questions that arise, such as: How far can one experiment with one's own body? Or, to whom do parts of one's body belong if they are detached from the body? To put it simply, "self-repair" relates strongly to the adaptability required to live in a changing environment: when humans talk about evolution, they say that life has survived due to its ability to adapt to changing conditions (for example, Lynn Margulis' theory of evolution). With the aim of "self-repair" being to adapt to present conditions, there is a need to reflect on developing technologies, scientific discoveries, and the changing understanding of humans as beings.[88]

Four three-day-long workshops were held: *SCOBY*, *Shit and Humus*, *I*, *Machine*, *and Energy Harvesting*, *Lactose-Intolerance DNA Portraits*, *and Radio Mycelium & How I Hack Plant Conversations*, all introduced bellow.

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*87 I refer here to Georg Trogemann's comments during the lecture "Material Fiction," given on 14 June 2018 at Bauhaus University, Weimar, as well as to the personal email written on 20 July 2018. While eschewing the term "creativity," Trogemann defines things through different terminology, for example "fictions," which suggest linking material and imagination. The different strategies of employing fictions between science and everyday culture can materialize the imaginary and may provide invaluable insight to the discussion on contemporary artistic practices.
*88 http://triple-double-u.com/self-repair-lab/ (Accessed 20 February 2022).

Workshop #1.
SCOBY, Shit, and Humus

The setting[89] provided experimentation around a symbiotic colony of bacteria and yeast (SCOBY) and soil samples, with artists Juan Pablo Díaz and myself, molecular biologist Julian Chollet, and participants ranging from an eleven-year-old boy to art students to curators. It was the extended version of an individual experimentation introduced in the toolkit "My Collaboration with Bacteria for Paper Production," which invited users to think of the symbiotic relationships between humans and non-human organisms while examining SCOBY and soil samples (Fig. 33).

Fig. 33. Workshop *SCOBY, Shit, and Humus*. Video still

To start contemplating the theme of the workshop, I stimulated participants by asking: What does symbiosis really mean? How can we understand the complex interaction between microorganisms, plants, and animals? How is self-organization related to being alive? And how could symbiosis unfold from an aesthetic perspective?

The collaborative nature of the work unfolded through the allocated tasks. While Julian Chollet introduced microscopy and a subjective method to grasp interaction between invisible microorganisms, Juan Pablo Díaz added a subjective analysis of soil samples while using a bittercress plant, and I introduced the preparation

*89 The workshop was executed during the Shared Habitats exhibition at the MO Museum, between 4 and 6 May 2019.

of medium for the isolation of microorganisms. The task for the participants was to come up with a new idea and to realize it while using a setting proposed by the core team.

During the time allocated for the experimentation, participants isolated bacteria, did microscopy, analyzed soil samples, discussed spontaneous ideas, and worked on documentation, time-lapse photography, maps, and manuals. Two interesting results came up.

One of the results came up while mapping an ecosystem (Fig. 34), something that Díaz, Chollet, and I had been developing for longer time at the

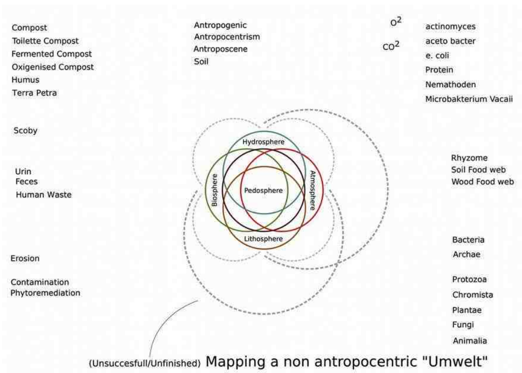


Fig. 34. The map of an ecosystem. Sketch: Juan Pablo Díaz

TOP project space during the residency of Chollet and at the Kunsthaus ACUD MACHT NEU during the Transmediale festival Vorspiel program. We started with an idea of an ecosphere comprised of lithosphere, atmosphere, hydrosphere, and biosphere. While mapping interactions of microorganisms around soil, Díaz proposed that all earlier versions of our attempt to map the soil represented an anthropocentric vision of interactions, which was incorrect thinking along the proposed flat interaction between different actors in the system. So the idea of mapping as one of the possible outcomes of the workshops came about with a striking through of the previous collaborative work. The result has shown that mapping is interesting as a process, but not necessarily interesting as a result.

Another unexpected result came up with a workshop participant Akvilė Paukštytė, who was busy isolating bacteria and doing time-lapse. While working on one overnight time-lapse, Paukštytė noticed a bacterial colony that was visually different from the other ones. Chollet, while analyzing it, presumed it was *Paenibacillus vortex*. Isolation of this bacteria was one of the goals with my students at the Bauhaus University in 2015. Then, we didn't succeed in isolating the bacteria. Therefore, the unexpected result was even more inspiring. And knowing that this bacteria was used by Nurit Bar-Shai in her *Objectivity [tentative]: Soundscapes* project in 2012, which was featured during the workshop, Paukštytė ended up additionally motivated. The final result of Paukštytė became a two-channel animation on *Paenibacillus vortex* and human compost (Fig. 35).

Fig. 35. Still of the two-channel animation by Akvilė Paukštytė

Interestingly, in this workshop, the mapping provoked a new idea that hadn't been thought at any earlier stage of the development: the inability to map a non-anthropocentric umwelt. Also, Paukštytė succeeded in combining the input from all the workshop leaders—I introduced the isolation of bacteria and time-lapse photography, Díaz provided and explained the different samples of soil, and Chollet introduced microscopy and shared his knowledge on bacteria—which led to the emergence of a new artistic outcome.

Workshop #2.
I, Machine, and Energy Harvesting

This workshop provided a setting to experience electricity with our bodies at the MO Museum.[90] While the conceptual part of the workshop that uses our own bodies as batteries was developed by myself over the last three years around the toolkit "Ultra-Low-Voltage Survival Kit," the practical part of this workshop emerged from collaborative work with Wolfgang Spahn. Spahn had been invited to contribute to the development of an electronic interface that generates sound from a human body. The experiments introduced during the workshop proposed the employment of a magnetic field,[91] which could perhaps boost some additional volts in the generated electric power.

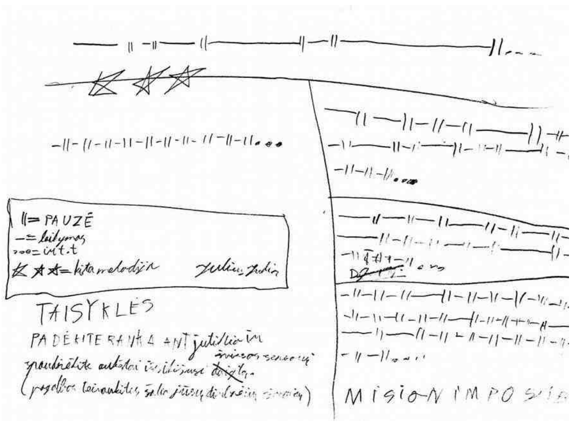


Fig. 36. Notation by Julius Judin

During the workshop I explained how to build a circuit for lighting up an LED using one's own body, and Spahn showed how to build a synthesizer that uses electric current generated from the difference between a body's temperature and its environment. Participants of the workshop were invited to build the devices introduced and to spend some time in developing new ideas. The developed ideas ranged from speculations on charging cell phones, to meditative

*90 The workshop is executed in collaboration with Wolfgang Spahn, and participants at the MO Museum, between 25 and 27 May 2019.

*91 The experiments used a self-oscillating voltage booster, also known as a joule thief.

performances, to sophisticated sound pieces. These included the notations by eleven-year-old Julius Judin and art student Tanya Frenkel for the built synthesizer, a device for blind people proposed by Aistė Marija Stankevičiūtė, a visualization of the generated sound by Mindaugas Dudėnas, and an interactive doorbell by Paulina Bradūnaitė. Following, I will briefly introduce three outcomes.

Judin made a drawing with Morse-code-like notations for the built device to play generative sound (Fig. 36). It was fascinating how this young boy picked up ideas and communicated to other people. He was the first to learn soldering and to help others to solder electronic parts. He was one of the participants to pick up an idea of drawing notations and to find a way to express them on paper. He was also the first one to try playing his notations.

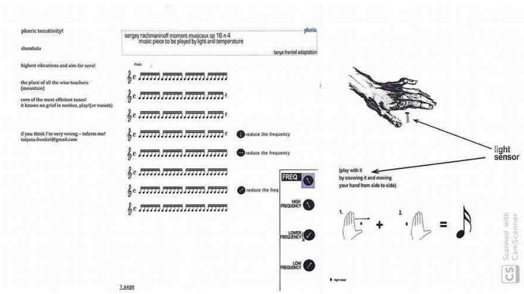


Fig. 37. Notation by Tanya Frenkel

Frenkel created an adaptation of Sergey Rachmaninoff's piece Opus 16 No. 4, played by two hands for the two constructed devices. Similar to Judin, Frenkel came up with drawing notations. The difference was that the notations by Frenkel were similar visually to the notations of Steve Reich, Philip Glass, and other composers combining traditional notations and drawings (Fig. 37). Also, whereas Judin proposed simple melody, Frenkel came up with an idea to adapt to a built device a very intense and difficult piece (Opus 16 No. 4 by Sergey Rachmaninoff). Furthermore, after the workshop, Frenkel continued developing her idea, which finally became an art installation (Fig. 38).

Spahn and I introduced the possibility of connecting a number of devices in a chain in order to make a polyphonic sound.[92] The performance involved an audience, and they were invited to connect into a circle and share earphones with two neighbors (Fig. 39). Such design enabled the experience of the electric power generated by touching the built devices. At the same time, while hearing sounds generated by the next participant, the touched devices suggested a possibility to synchronize the polyphonic sound played by all participants. Having proposed to synchronize a piece played by a player whom other players (except

*92 http://triple-double-u.com/case-2-i-machine-and-energy-harvesting/ (Accessed 15 February 2021).

Fig. 38. Tanya Frenkel's installation including the artifacts built during the workshop. Photo: Tanya Frenkel

one) do not hear, this piece activated the experiencing of participants through electromagnetic waves passed through the earphones of all players.

Beside new ideas and proposals for their implementations that came up during the preparation of the workshop and the workshop itself, I should mention the dynamics of the

Fig. 39. Performance by participants of the workshop. Video still

emergence of the works in a collaborative setting, which does not necessarily lead to smooth work. For example, the idea to construct a synthesizer powered by a human body, the idea to connect people into a circle during the performance, and many tips for the implementation of the ideas were proposed by me during the collaborative work with Spahn. Nevertheless, Spahn insisted that both the synthesizer and the performance with participants were his artworks. Further discussions with colleagues and lawyers regarding authorship in a collaborative setting didn't lead anywhere, because the ideas are not considered as being copyrighted. I will address authorship in Maker culture in more detail in the later subsection "Conclusions and Discussion."

Workshop #3. Lactose-Intolerance DNA Portraits

This workshop[93] was constructed for manipulating and experiencing genome, which is the idea behind the toolkit "How I Prepare Myself to Be Cloned." For the practical part of the workshop, Auksė Gaižauskaitė and Miglė Kalvaitytė provided reagents for the analysis of the lactase gene's regulator, which, if mutated, would stop producing the enzyme that breaks lactose into glucose and galactose. If the lactase gene's regulator is mutated, the used restriction enzymes would cut the sequence into four different chunks of nucleotides, whereas in a genome that is not mutated, the sample sequence would be cut into five chunks. If the experiment is successful the comparison of the DNA samples would differ in mutated and non-mutated sequences. For the experiment, participants used both professional and DIY equipment. Proposed were three experiments: a polymerase chain reaction, an agarose gel electrophoresis, and DNA fingerprinting. An individually run gel electro-phoresis experiment had to produce slightly different results depending on the equipment used, the time electrophoresis was run, and the amounts of the reagents.

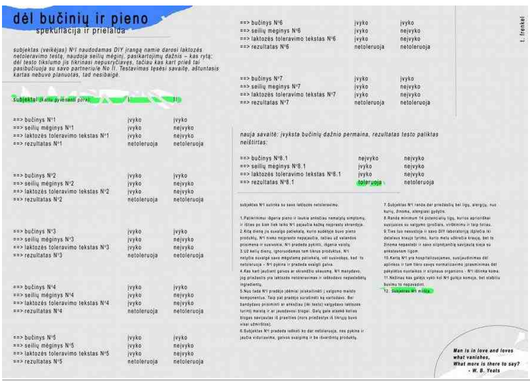


Fig. 40. Tanya Frenkel's speculative story on the tolerance of lactose. Poster: Tanya Frenkel

*93 The workshop was executed in collaboration with Auksė Gaižauskaitė, Miglė Kalvaitytė, and participants at MO Museum, between 15 and 17 June 2019.

In a broader context the workshop invited one to experience DIY manipulations of an individual genome and to discuss recent techniques for gene manipulation, including the CRISPR method. The references included the gene therapies of biohackers Josiah Zayner and Tristan Roberts who recently experimented with genome manipulations on themselves. These manipulations evoked recollections of experiments with one's own body by artists Marina Abramovic, Bas Jan Ader, or Stelarc. To lead people into a three-day-long experimentation around molecular biology, I inspired participants by asking: How can one diagnose one's own genetic mutations at home? Is it possible to clone oneself and, by cloning, fix the genome? And more specifically related to the theme of the workshop: What causes humans to tolerate dairy products differently? Are there ethical issues still to be resolved in relation to manipulations being done on oneself?

Experimentation showed that what it is possible to do over a duration of three days is very limited. This included the time needed for the preparation of experiments, the purchase of reagents, and the setting up of equipment. Nevertheless, participants of the workshop developed their ideas based on the tools provided: An art student, Tanya Frenkel, came up with a speculative script on the relationship between a couple who cannot tolerate lactose; Paulius Baranauskas conceptualized his slides based on the beauty of life; ten-year-old Sofia and her mom Danielė Zabotkienė conducted two electrophoresis experiments, the first while repeating negative words out loud and the second while repeating positive words; eleven-year-old Julius Judin experienced the failure of experimentation. Following, I will briefly introduce two outcomes: the script proposed by Frenkel, and the outcome proposed by Baranauskas.

Instead of focusing on scientific methods to extract and amplify DNA, analyze DNA while doing electrophoresis, and fingerprinting, Frenkel's attention was caught by DNA analysis using DIY tools. The possibility to do DNA tests at home inspired Frenkel to come up with a speculative story on the tolerance of lactose for a couple living together (Fig. 40). The script introduces a daily test for a duration of one week. As the result is positive, the testing subject agrees that he does not tolerate lactose and starts excluding suspicious foods from his diet.

Finally he dies because of the weakened organism. By writing a speculative script, Frenkel has critically approached the DIY methods, which suggested that any methods used in daily practices might not necessarily be truth. Having presented the script on a poster, Frenkel's outcome became an artifact ready to be exhibited.

Baranauskas, scientist, came up with a slideshow of four slides—all of them repeating the first word "IT" and the last word "sometimes." All the slides highlighted our daily lives: the lit up Earth from the sky, a demolished part of the city, a photo of a single atom, and a photo of an agarose gel

Fig. 41. Paulius Baranauskas's slide with a photo of an agarose gel displaying the tolerance of lactose in different samples of DNA

displaying the tolerance of lactose in different samples of DNA (Fig. 41). Assuming "IT" stands for all the universe, Baranauskas communicated the idea of how much science can tell about the universe and influence it. Besides a clearly communicated idea, it is important to note that within the workshop, Baranauskas was open to use the framework of the workshop, including the results of DNA analysis, his visualized idea, and comments of other participants, which led him toward the clean presentation of his idea.

Despite the limited resources around the analysis of DNA, both projects were interesting in terms of the emergence of new ideas through the communicated idea of the workshop. Interestingly, the workshop has also shown that scientists may be open for artistic input when it comes to visualizing individual ideas. The workshop brought me to yet another thought of the collaborative work, the educational moment.

Workshop #4. Radio Mycelium & How I Hack Plant Conversations

This setting at the MO Museum in Vilnius[94] proposed experimentation around interspecies communication and feedback loops between mycelium networks and their habitats. The theme of information transmitted between organic and inorganic matter is encompassed in the toolkit "Mycorrhizal Networks, or How I Hack Plant Conversations." An artist, Jan Glöckner, was invited to contribute his knowledge on fungi and to work together with participants of the workshop.

Four experiments were introduced: Glöckner invited participants to isolate the spores of button mushrooms and set them up to grow on an earlier prepared medium; I demonstrated how to build an interface to sense electric potentials in living organisms and use them for audiovisual expression, introduced how to solder the mycelial radio transmitter, and finally invited participants to use the built tools to make an audiovisual output.

Fig. 42. Alog's enclosed plant in a pot–an allusion to a Faraday cage. Video still

In order to trigger ideas from the participants, I introduced the concept of electrical signals that, if sensed on a living organism and passed to the computer and then back to the same organism, would produce an informational feedback loop between an organism and a computing machine. It was assumed that during

*94 The workshop was executed in collaboration with Jan Georg Glöckner, and participants at the MO Museum between 20 and 22 July 2019.

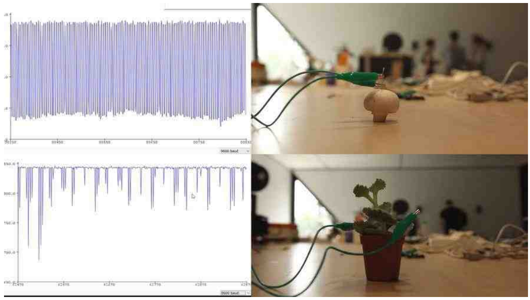
this time the living organism would be able to adapt to the passed electrical signal and be able to influence it while reacting to it. I asked the questions What if this signal is interrupted with some noise? How would it influence further growth of the organism?

The conceptual framework of the workshop invited participants to bring their knowledge and expertise for further contributions. The eleven-year-old Julius Judin took his radio transmitter outside into the museum's garden, attached it to various plants, and influenced the transmitted signal by touching either the plants or the antenna. Bon Alog experimented with the Faraday Cage idea and, while isolating her plant from the environment, let it "play" its polyphony. Paula Savaja used a scientific method for the analysis of two different organisms—fungi and plant—and visualized their differently perceived environments. The collaboration between Beatričė Bukantytė and Justina Kaminskaitė unfolded as a performance based on speed dating during which the mycelium noise sent through the radio transmitter was transcribed manually on paper.

I would like to point to two results of the workshop: the installation by Alog and the video by Savaja.

Alog had an idea to use two different ways to get a sound from the same plant and to, perhaps, combine them into a single piece combining two channels of audio and a visual output in Pd. While working on her piece, which would use the circuit of Martin Howse to pick up the signal from the plant, Alog questioned the signal being received from the plant. While trying to understand what they were, Glöckner brought forward the idea of a Faraday Cage, a shield used to block electromagnetic fields from the environment. Finally, Alog enclosed the plant within a pot, which became her Faraday Cage, isolating her plant from the environment (Fig. 42). Although the shield itself was symbolic in the final result,

Fig. 43. Paula Savaja's comparison of a mushroom and a plant. Video still



Alog questioned the "singing plant," which is often used in recent artistic expression.

The video from Savaja compared a mushroom and a plant, both connected to the circuit from Martin Howse (Fig. 43). The comparison was four channels—two displaying the varied signal picked up from the organisms, and the other two showing the organisms themselves. The video questioned the influence of environment to the organisms and the similarity of the organisms compared by the inner activity. This final result of Savaja is interesting because of different messages communicated to the audience. While usually artists would come up with a conversion of a plant's electric activity into a sound or a visual, Savaja has compared the inner activity between two different types of organisms.

Savaja's outcome demonstrated that any artistic outcome may be reused to express different ideas. On the other hand, Alog's installation very clearly showed, how, while working together, the ideas may travel in a collaborative setting until they achieve a substantial form.

Conclusions and Discussion

All the workshops in the *Self-Repair Lab* have shown the educational moment, where the artist took the role of a leader and the participants learned how to use artistic and scientific tools and methods. The educational moment could be defined as the following: The leaders of the workshop explained the framework of the workshop and helped the participants to implement experiments provided. The taken position was as introduced by Papadopoulos (2014) in his paper “Generation M,” with a strength on the added value of the made, and a pedagogical position through the mutual interaction. Let’s take a closer look into the position of a workshop leader.

For example, if participants worked around symbiosis and used the toolkit “My Collaboration with Bacteria for Paper Production,” I, as a workshop leader, would not explain the meaning of the use of the tools but rather introduce their function and possible outcomes. So the knowledge was transferred through the use of living bacteria, ingredients for growing bacteria, a pipette, a jar, a hot plate, a scale, and a microscope, and so on. By providing tools for direct interaction, the participants were encouraged to understand the tools and matter themselves, as well as to follow the change in perception, and the change of ideas during the change of the perception. That is rather facilitation and little of didactics, or, rather collaboration and little of curatorial work. And this is what makes me think critically of the idea of the workshop leader as curator, an idea presented by Yvonne Volkart in her article “Caring for Life—from Lab to Labbing” (Volkart 2021).

Yvonne Volkart’s argument for curatorial context was referred to the Latin word *cura*, meaning care. If “care” is viewed as a supportive activity with respect to the artistic outcome, rather than as part of the outcome itself, then what is the part of the artist in the workshop? In conducting the workshops, I saw myself primarily as a facilitator of different ideas, including artistic, scientific, and technical. That is, I actively participated in a collaborative setting such as a workshop. In addition, the outcomes of workshop participants reflected my contribution as an artist, so the workshop setting was experiential rather than illustrative. While Volkart referred to the "constitution and continuation of a collective elaborated context" (Volkart 2021, 204), for me the *Self-Repair Lab* is less about care and more about "Do It With Others," DIWO, a setting, where "[p]eers connect, communicate and collaborate, creating controversies, structures, and a shared grass roots culture." (Garrett 2014)

The strength of the *Self-Repair Lab* DIWO setting was the emerging creative process with an outcome of learning from the artist, other peers, and, if applicable, the computing machines. A reference here could be made with the emerging context rather than the curated context in the event titled *Art Hack Day Berlin: Afterglow* during the Transmediale 2014 festival in Berlin. Here the event united artists, audiences, workshops, performances, and presentations to share DIY knowledge and create new outcomes. Kristoffer Gansing, one of the curators of the exhibition, described the event in one of the follow-up emails to the Rohrpost mailing list[95] as "a living entity … rather than a predefined collection of the curators' best picks" (Gansing 2014). While referring to the curator as the one who "picks" the collection, the point rather lays in what emerges in the collaborative settings. Moreover, the term curating is usually used in the art scene to give visibility to the artists and their artwork instead of to work together with them on new ideas. To illustrate it, I propose to take a look into the notion of an artwork as defined by Dorothea von Hantelmann in her book *How to Do Things with Art*.

*95 Available at http://mikro-berlin.org/rohrpost/ (Accessed 24 March 2014).

This notion is described through the exhibition model, where a placed art object becomes a product containing the artist's subjective idea (Hantelmann 2010). If I were to think of an idea of art in the modern era as defined by Hantelmann, on one hand, I would have an observer who encounters the object and, on the other hand, the art piece itself. During the encounter, the subjective meaning of the produced object is transferred to the observer, generating another subjective meaning. Examples included an artwork separated from the exhibition context (James Coleman), an artwork merged with the exhibition context (Daniel Buren), refusal of materiality (Tino Sehgal), and refusal of meaning (Jeff Koons) (Hantelmann 2010). So, in the encounter introduced, both the object and the observer act as media, while the meaning is being generated by transporting information from one medium to another. In this case, I could already map a graph of two actors transporting meaning in one direction —from an art object toward the observer. Still, in this case an art product wouldn't build bidirectional interdependences between actors, the participatory setting introduced in the *Self-Repair Lab*. Therefore, the conventional "curating" or "taking care" in a collaborative setting makes little sense in an interactive setting and rather reminds one of the Hegelian understanding of aesthetics.

The collaborative DIWO setting within the *Self-Repair Lab* highlighted potential authorship issues that I did not anticipate at the time. While preparing for the workshop *I*, *Machine*, *and Energy Harvesting*, I myself experienced unexpected results that emerged from the collaborative work. Knowing Wolfgang Spahn and his abilities to build electronic devices, I invited him to help me to develop a synthesizer for a toolkit ("Ultra-Low-Voltage Survival Kit") I was developing at that time.[96] Further discussions and the development of the synthesizer ended up being a part of my toolkit and part of the workshop. While Spahn has refused to credit me in the project as an author, or at least a co-author, presenting me

*96 By that time the toolkit had two experiments introduced: the lit up LED by the human body, and sound generated by the difference of the electromagnetic field in the air and ground, a concept of crystal radio. Our collaboration started with bringing my first version of the toolkit to Spahn, sharing my research, and presenting my vision for the development of the synthesizer generating sound from the human body. While discussing the possibilities, Spahn came up with an idea to use the difference of temperature between the human body and the environment to generate the sound. I agreed that the idea fit my needs and had the potential to become a part of my toolkit.
*97 See, for more information, the website introducing the Symbiotic Synth. Available at http://paperpcb.dernulleffekt.de/doku.php?id=sound_boards:symbiotic_synth (Accessed 6 December 2020).

rather as a sponsor,[97] the idea of authorship in a collaborative artistic setting needs additional reflection.

I would like to bring in two examples here. While walking through the Venice Biennale I pondered a question: How many people would have worked on the Tomás Saraceno art piece *The Spider/Web Pavilion 7*? Although the work is attributed to one person, it seems that it must have been developed by a number of people. The Studio Tomás Saraceno alone counts over a hundred names.[98] So who is the author of the artwork? And is it ethically correct to not mention all of the team?

Another case within the same biennale: The winner of the Golden Lion for the best national participation was a Lithuanian project that was executed by a group of artists. While the website of the Venice Biennale mentioned three Lithuanian artists, a commissioner, and a curator,[99] the magazine *Notorious* mentioned only the name of the curator of the project.[100] So is the artist who works in collaboration with other artists or a curator of the exhibition the most important person in relation to the artwork? What about other people contributing or even making the artwork itself? What about the audience taking part in the performance or a participatory event, such as a workshop?

The very first thing to consider here are the contributions and the context that caused the artwork to develop its form. Back in 1967, Roland Barthes considered the issue of authorship in his essay “The Death of the Author.” While questioning the authorship of Balzac’s *Sarrasine*, Barthes asked if the author of the book is the person who has written the book, the protagonist, or the universal wisdom (Barthes 1967)? The answer provided by Barthes introduced the concept of authorship as being the product of a society, a “tissue” of quotations brought together in a written work. Barthes stressed the importance of the reader as the one who gives the writing certain meaning. One might draw a parallel to a work of visual art, where a work of art consists of a series of references, with interpretation left to the audience. Even if the audience is not necessarily a co-

*98 See Studio Tomás Saraceno. Available at https://studiotomassaraceno.org/ (Accessed 17 September 2019).
*99 See website of the Venice Biennale. Available at https://www.labiennale.org/en/news/biennale-arte-2019-official-awards (Accessed 17 September 2019).
*100 See Notorious magazine. Available at https://www.notorious-mag.com/article/winner-venice-art-biennale-2019 (Accessed 17 September 2019).

author of an artwork, the problem of authorship arises when the reader's or audience's interpretation becomes another contribution to the work and is presented as a new result.

In a scientific article or book, other contributions that have led to a new result are usually given in the references. A similar practice is used in open-source projects, where references to Creative Commons License, GNU General Public License, or similar licenses are given, explaining how authorship of the work should be attributed. In visual arts, the author would usually be the one who comes with an idea first. So in the case of collaboration between myself and Spahn, the authorship should be assigned to my name. Alternatively, one may question how much co-authorship is given to one case and how much to the other. In this case, the name of Spahn may be written after my name, indicating the relationship to how the artwork was developed—first the initiator of the idea (me) and then the contributor (Spahn).

As of contributions, they are often defined in a broader context, including what contributions were made. And if the work is not of equal contributions or authorship, at least credits should be assigned to contributors or collaborators. This should apply to Tomás Saraceno, who developed the piece *The Spider/Web Pavilion 7* but didn't mention his collaborators. The article published in *Notorious* magazine should also be viewed critically, as it didn't list artists' names. I would also expect to see my name at least as a co-author next to the synthesizer that was developed in collaboration with Spahn.

Altogether, the collaborative experimentation around the *Self-Repair Lab* has shown how quickly new ideas may emerge from the given artistic framework that includes mediation of scientific, artistic, and technical knowledge. The same should be said about how far from each other the ideas may be considering the given tools and conceptual framework for experimentation. As the participants were different from each other in their experience, motivation, and age, the results of the workshops were also different aesthetically and conceptually. For example, during the *Lactose-Intolerance DNA Portraits* workshop, art student Frenkel developed a speculative script on the intolerance of lactose, and scientist Baranauskas came up with a slide show questioning scientific knowledge. While in the workshop *Radio Mycelium & How I Hack Plant Conversations*, art student Savaja developed a video about the idea of the difference between seemingly similar organisms, and Bon questioned the “singing plant” enclosed within the imaginable Faraday cage. These results came after the three-day-long collaboration.

After presenting the results of the artistic workshops, I suggest that the active role of the audience has not disappeared in artworks of Maker culture and is as important as in the interactive artworks of the 90s. On closer inspection, the *Self-Repair Lab*, together with its participants, became a situation in which the artwork itself emerged from both historical references and social interaction: The workshops were reminiscent of the performative artworks of the 60s, including work by Georg Maciunas and Joseph Beuys; social events of the 90s, including the ones by Rirkrit Tiravanija and Christine Hill; and workshops of the last decade, including ones by Martin Howse and Marc Dusseiller. Being similar to earlier artistic formats, a question which is raised here is the difference between the earlier artistic “genre” and the participatory *Self-Repair Lab* workshops, if any. What is the dependence between the artist and the audience? Is there any difference between a workshop setting and a Fluxus performance or relational art?

To answer these questions, I decided to experience the participatory workshop from the perspective of a participant and then compare this experience with the workshops I executed myself. Therefore, I changed the perspective of myself, who offers a workshop setting, to the perspective of the participant, who experiences the workshop setting. Next I bring into the discussion a workshop *Hackteria’s Empathetic Taxidermia Lab*, executed by the scientist and artist Marc Dusseiller with myself in a participant’s role.

A Shift in the Role of an Artist

> We are entering an era in which everyone takes responsibility for the common culture, by participating in the decisions and actions which will inform it.
> —Roy Ascott (2015, 106)

One of my toolkits, called "My Collaboration with Bacteria for Paper Production,"[101] provides tools to work with the interaction of microorganisms. In a broader context, it introduces the symbiotic relationships between living organisms and non-living things. While using this toolkit as a basis for artistic experimentation within a collaborative setting, such as a workshop, this chapter develops the idea of a shift in the role of an artist from being central to being a mediating figure.

*101 For more information, see http://triple-double-u.com/my-collaboration-with-bacteria-for-paper-production/ (Accessed 21 March 2020).

Hackteria's Empathetic Taxidermia Lab

First, I would like to highlight one of the events I attended during the Pixelache Festival in Helsinki in 2016, called *Hackteria's Empathetic Taxidermia Lab*. The event was led by Marc Dusseiller, a co-founder of and the spirit behind the Hackteria community, which began their activities in 2009. The event was described as follows:

> Hackteria's Empathetic Taxidermia Lab is a durational, collaborative and explorative experimentation on taxidermy with Marc Dusseiller, aka dusjagr, a co-founder of the Hackteria network. The aim of the lab is to investigate artistic practices and traditional craft with living/non-living media to reconnect us with our ecosystem and ourselves.[102]

The description proposes that the event aims at an experimental laboratory, with collaborative experimentation around taxidermy. The description is packed with keywords that raise additional questions, including the (possible) killing of an animal, the purpose of preserving a dead body, and the borders of experimentation in artistic practices. In light of the Hackteria event having been aimed at the investigation of artistic practices and traditional crafts such as taxidermy, next, I will try to: (1) deconstruct the role of the artist and (2) define the experiential part of the event.

The two-week-long *Hackteria's Empathetic Taxidermia Lab* included the setup of a temporary lab, an introduction to the methods and tools of taxidermy, the preservation of rats and mice, and the collaborative production of a booklet, which included documentation of the event, a set of instructions for taxidermy, and reflections from participants. On one hand, the event reminded me of the DIWO workshop for learning and experimenting with taxidermy techniques, something that can be described as a traditional craft. On the other hand, the context aimed at engaging participants with contemporary artistic practices. I take Dusseiller's use of the term "ecosystem" to mean a community of living organisms and chemical compounds interacting with each other in their environment, and our "reconnection" with the ecosystem would be catalyzed by artistic practice.

*102 See "Proposal: Hackteria's Empathetic Taxidermia Lab." Available at https://temporary.fi/experiments/hackteria-s-empathetic-taxidermia-lab/hackteria-s-empathetic-taxidermia-lab (Accessed 6 March 2020).

In his essay “Back to Nature II: Art and Technology in the Twenty-First Century” (1995), Roy Ascott criticized both reductionist and holistic sciences for their approaches, thus expressing a need to redefine how we live in “natural” space. His sketched vision of nature involved working in an electronic space, with a call for arts to be mediators between nature and technology (Ascott 1995, 327). With no aim of contrasting nature and technology, Ascott suggested the role of art as mediating nature. In the case of the taxidermy workshop, I see the project leader Dusseiller as being in the position to help the participants to understand the tools, the making, and the ecosystem.

While thinking about artistic reconnection with the ecosystem, I suppose it is not literally about wiring dead mice and rats, but rather about sensing (and in such a way experiencing) them, and thus, understanding that the ecosystem is composed of living and dead matter. Dusseiller, who is, among other roles in the workshop, a mediator of tools, taxidermy, and the ecosystem, might intend for the participants of the workshop to feel disgust, or more specifically, to experience the ecosystem through the disembowelment of rats and mice. Through his workshop, he may also be instrumentalizing disgust, which, on one hand, could be simply explained as a biochemical reaction that happens through the release of hormones by the brain, thus modulating how our bodies deal with potentially unpleasant feelings. On the other hand, acknowledging the social dimension of disgust in order to break through the unpleasant thoughts and feelings associated with it, a participant in the workshop would have to transcend cultural influence to a degree, thereby potentially reconnecting themselves with the ecosystem while simultaneously communicating, sensing, thinking, and tinkering.

Here follows the “us” and “ourselves” mentioned in the project description above—a recursive aspect of our bodies that is framed as being less mental, affecting certain homeostatic senses, like the aforementioned disgust response. While sensing and dealing with living, semi-living, or dead bodies in the taxidermy workshop, the reconnection with ourselves and our ecosystem is more than imaginary—it is triggered by our homeostatic senses and, perhaps, thoughts induced by communication and tinkering.

What is new in a "traditional craft" setting such as taxidermy? First of all, we have a workshop leader in the role of a mediator—aiming at introducing tools, the process of taxidermy, and the idea of an ecosystem—through which workshop participants experience the ecosystem viscerally through embodied interaction. Second, the event itself—ending with concrete outputs, including the preserved rats and mice, the documented thoughts of the participants, and instructions for how to repeat the taxidermy process—may provide direct references from the participants and, in such a way, remain accessible to other people as a set of artifacts through which they can imagine the activities of the workshop, or even to repeat the experience.

Moreover, in the taxidermy workshop, while able to trigger a disengaged sense such as disgust, the artist mediates his knowledge of taxidermy and the ecosystem, and the participant in the taxidermy event can eventually critically evaluate their relationship to the ecosystem and perhaps reconnect with it through individual senses.

Additional thought needs to be given to the killing of mice and rats for the workshop. As this act might very well be deemed unethical, it should be positioned with specific purpose. If, say, the purpose is to kill for food, or in the name of population management, then killing an animal may be ethically supported. Killing for the sake of art, on the other hand, is perhaps not easily argued to be ethically acceptable, especially if the discourse of the workshop itself is the posthuman state as described by Rosi Braidotti (2013) or Donna Haraway (2008), which would suggest a horizontality that is not reflected by the human-nonhuman power dynamic of a taxidermy workshop dependent on non-human death. Nonetheless, the workshop positions the experience of the death of another as the bonding tie with the ecosystem.

The emotional experience provided by Dusseiller invites me to think of participative and performative art practices from the 1960s, particularly the Fluxus movement, which aimed at breaking the traditional understanding of art as an object and challenging entrenched taboos; it proposed experiential, experimental, and social activity that included the audience in a mutual action. Dusseiller's work also harkens back to art practices of 1990s, particularly relational art, which dematerialized the art object into human relations and social contexts. In this way, both Fluxus and relational art practices historically emphasized mediation between the audience and the arts, which had otherwise been largely focused on the—sometimes fetishized—object itself. Still, what makes *Hackteria's Empathetic Taxidermia Lab* a compelling contribution to artistic practice?

Experiment, Experience, and Mediation

Having proposed a collaborative workshop within a temporary lab, the leader of *Hackteria's Empathetic Taxidermia Lab* becomes a mediator, responsible for providing knowledge about the tools, the know-how about taxidermy, and references to scientific and artistic work related to an ecosystem. On the other hand, the participant of the event is invited to produce their version of taxidermy or contribute to the booklet, which then might develop into something more tangible, perhaps a new art project, which, in turn, would additionally be experienced within the framework of the workshop. So the contribution by the participant becomes possible only through input provided by the mediator and one's own experience, which, again, is fed back into the mental reconsiderations and practical tinkering by the participant. Moreover, able to learn new methods and to discuss ecology within the framework of the workshop, the participant is triggered by a new experience, which could include a thought exercise or additional auditory, visual, or tactile sensing.

How is that different from art of the 1960s and relational art? Quite a few experimental activities were happening in the 1960s: Joseph Beuys created his installations in real time; Georg Maciunas conceptualized the Fluxus movement, organizing and performing early happenings; Robert Rauschenberg collaborated with technicians on interactive pieces. Events to mention include *9 Evenings: Theatre and Engineering and E.a.t.*, which became a platform for showing the newest collaborations between the arts, technologies, and sciences. Contextualized by the concurrent performance art, happenings, and experiential art of the time, both *9 Evenings and E.a.t.* could be described as experimental, or laboratory, activities. Coming out of Fluxus parallel to the happenings were also "Fluxkits," collections of objects placed in various boxes. According to the Museum of Modern Art in New York, a Fluxkit encapsulates a collection of small objects to be held in the hand, read, and manipulated.[103] As Alison Knowles has described it, a "Fluxkit is an effort to namely contradict framed pieces on a wall, but to give people the idea of holding something in a hand, and also representing many different artists in one small container."[104] In so doing, Fluxkits enter a direct experiential moment, coordinated exceptionally by the viewer herself: the

*103 See the description at (Accessed 2 March 2020) https://www.moma.org/interactives/exhibitions/2011/fluxus_editions/category_works/fluxkit/index.html
*104 See https://www.youtube.com/watch?v=cPi0UyHB95U (Accessed 2 March 2020).

viewer decides how to navigate through the objects, how to read them, and how to place them back in the kits—even replacing the original objects with new ones. Yet another format introduced by Fluxus is a set of instructions for how to perform an artwork, or a "score," as per *The Fluxus Performance Workbook*, compiled by Friedman and colleagues (Friedman, Smith, Sawchyn 2002). The book is essentially an anthology of step-by-step Fluxus instructions by a variety of artists across many years, similar to short theater plays that could result in an artwork.[105]

Following the logic of Fluxus performance, the taxidermy lab starts with the invitation for the audience to bring their "own rat," alive or dead. While dealing with living, semi-living, and dead animals, the participants of the lab—that is, the audience of the event—have a chance to experience empathic feelings for the animal they have brought. The animal—alive or dead—becomes part of the artwork through empathic contact. With the aim of adding a technological framework to artistic performance, or inviting the viewer of the artwork to contribute to it, what happened in *Hackteria's Empathetic Taxidermia Lab* is very close to Fluxus experiments. On the other hand, having placed the focus on the conceptual part of the experiment itself, neither the performances nor the happenings nor the Fluxkits of Fluxus explicitly dealt with the meaning that evolves in reference to the mediator or the tools.[106]

How can relational art be positioned next to *Hackteria's Empathetic Taxidermia Lab*? Nicolas Bourriaud (2002) introduced a number of artworks from the 1990s as examples to help define the then newly coined term "relational aesthetics." Rirkrit Tiravanija organized a dinner in a collector's home, Christine Hill worked as a checkout assistant in a supermarket, Pierre Huyghe summoned people to a casting session, and so on, all in the frame of artistic practice. The short descriptions of the events can be seen as connecting back to the Fluxus happenings or installations of Joseph Beuys from the 1960s. Bourriaud described these events as "interactive," as lacking "imaginary and utopian realities," or simply as "ways of living" (Bourriaud 2002). In other terms, they merge within themselves an artistic setting and a social space, such as an exhibition's opening reception or a cooking session with an artist, to claim the idea of evolving

*105 The form of manuals, which are similar to Fluxus instructions, is also used by artists in DIY and DIWO settings.

*106 See Cascone (2000). Kim Cascone, while defining post-digital art, suggested that specific tools and not the technology communicate the meaning of an artwork.

meanings of an artwork through social process and engagement.[107] In such a setting, both the artist and the audience become an integral part of the artwork.

If relational aesthetics added to Fluxus happenings a sense of daily experience, such as a cooking session or an exhibition opening,[108] *Hackteria's Empathetic Taxidermia Lab* further contributes to this lineage with the role of the artist as mediator. While the artist within the relational artwork is a performer or part of the audience, the artist in a taxidermy lab is the one who mediates the artwork. In other words, the artist listens to the audience, reflects on the comments, and builds the artwork upon the reflections. At the same time, the audience is given a stage to participate in the emergence of new forms.

Emergence of New Forms

If I were to consider the emergence of the cells of living unicellular organisms, I would think of self-reference, of splitting DNA or RNA code into two identical sequences and forming a new identical cell or organism. On the other hand, if the cell is damaged, it could try to fix itself by repairing damaged strands of DNA and RNA. It is similar with multicellular organisms, which try to rebuild missing or damaged cells. In this way, on one hand, the organism reflects itself, and on the other hand, it adapts to its environment while reflecting it. However, this process is not necessarily perfect, and even though the organism refers to itself in this process, mistakes or changes are inevitable. These mistakes and changes might range from a change in one nucleotide in a DNA sequence to the development of a completely different organism. A parallel could be made with

*107 Claire Bishop is perhaps right that the artworks as defined by Nicolas Bourriaud (such as those by Liam Gillick or Rirkrit Tiravanija) were not that innovative in comparison to prior happenings or the social sculptures of Joseph Beuys. On the other hand, the social actions of Fluxus happenings were not, in their time, considered an integral part of the evolving meaning of the artwork.

*108 To elaborate on the idea of Merleau-Ponty about the unlimited range of possible readings, it is worth adding the practical experience an artwork provides. In 1945, Merleau-Ponty introduced the concept of temporal perception, which is not defined as a process of considerations but rather as a unity of considerations and practical experience. To illustrate it, he wrote about the table upon which he was writing. The idea of the table was evolving through a series of "sensations" that allowed him to perceive it (Merleau-Ponty, 2012). This is something similar to what Luhmann called a redescription: in order for an artwork to become established in the art system, it needs to be redescribed. It is the same in relational aesthetics—the meaning of an artwork emerges from the interaction between an audience and an artwork.

a Fluxkit, where the viewer, depending on their views and reflections, might replace the missing object or add something new, changing the idea or even the identity of the kit itself. The context of a workshop setting is also similar, where the mediator might give instructions on how to use tools in one context or another, but the result would still be different because it would be reflected from an individual perspective.

The emergence of new forms is worth mentioning because of the similarity between the above-mentioned cases: the naturally self-referencing organism and the participation of an audience in a creative process. This action could be described through the concept of "Umwelt," introduced by Jacob von Uexküll in his book *Theoretical Biology* back in 1926, wherein he described the adaptation of a living organism in its environment through the number of activities undertaken by the organism. In his concept, Uexküll distinguished between two sets of functions: the internal cycle and the external circle. In addition to the external function circle, which includes sensing (*Merkwelt*) and acting (*Wirkungswelt*), in the animal world, the animal has its inner function circle, which helps it to reflect its senses and act upon them, in turn, influencing its umwelt (Uexküll 1926). The umwelt obtains features of the animal and the animal obtains features of the umwelt, making the animal and the umwelt interconnected.

Referring back to *Hackteria's Empathetic Taxidermia Lab*, reconnection with our ecosystem and ourselves would mean sensing an umwelt and acting upon it. While Marc Dusseiller proposed a reconnection through participants' experience dealing with dead and semi-dead organisms, the next step would be to envision a situation where living, non-human organisms could participate within the interactive setting as well. In this way, we would be able to experience the impact of the organisms, and organisms would be able to experience us. Referring to scientific papers that deal with the impact of the microbiome on humans, I propose including microorganisms in the artistic framework. Such a framework may provide us with a mutual experience with our microbiomes, which, in turn, may result in the emergence of new feelings, visions, and forms.

Proposal for Microbial Therapy

The installation *Proposal for Microbial Therapy*—presented at the exhibition *Microorganisms & Their Hosts* at the Atletika gallery[109]—featured two aquariums with different sorts of yogurt: one colonized with *Lactobacillus reuteri* bacteria, and the other with *Streptococcus thermophilus* bacteria (Fig. 44). While questioning the ecology of humans, the impact of the microbiome on humans, and self-healing strategies, the installation proposed literally experiencing relationships with microorganisms. This artwork would not have been developed without collaborators in this project including Auksė Gaižauskaitė and Hege Tapio, who contributed to the project with their ideas.

Fig. 44. *Proposal for Microbial Therapy*. Aquariums with Lactobacillus reuteri (left) and Streptococcus thermophilus (right) bacterial strains. Installation view at Atletika, Vilnius, 2020. Photo: Andrej Vasilenko

While working with molecular biologist Auksė Gaižauskaitė, I started with the isolation of bacterial strains from yogurt. This step seemed to be important in order to understand how yogurt is composed and if diverse sorts of yogurt may have different effects on physical well-being. Then followed a two-day-long workshop with artist Hege Tapio, with whom we brainstormed our ideas to later be implemented aesthetically—for instance, the isolation of microorganisms from yogurt and the impact of the hormone oxytocin on humans. Then followed another two-day-long workshop, plus an additional three weeks allocated for the implementation of ideas, called *Lactose Intolerant? Let's Employ Bacteria!*[110] with Auksė Gaižauskaitė and workshop participants. And finally, we had a three-

*109 For details, see http://triple-double-u.com/proposal-for-microbial-therapy/ (Accessed 20 February 2020).
*110 More information at http://howto-things.com/Lactose_intolerant%3F_Let%27s_employ_bacteria! (Accessed 20 February 2020).

day-long workshop called *Biochemistry of Emotions* with Hege Tapio, Auksė Gaižauskaitė, and a bunch of participants.[111] The workshops welcomed contributions from anyone interested in the biological basis of empathy, art, and interdisciplinary projects.

Having started with the toolkit "My Collaboration with Bacteria for Paper Production," which provides tools for working around the interaction of microorganisms and, in a broader sense, the symbiotic relationships between living organisms and non-living things, my installation was built upon the idea of the impact of microorganisms on humans. Conducting the series of participative workshops, I was able to finally construct my new artwork, *Proposal for Microbial Therapy*.

While tinkering and discussing questions raised, we sourced a few scientific papers worth referring to. One is the paper "Lactose Digestion from Yogurt: Mechanism and Relevance," by Dennis Savaiano, which claims that fresh yogurt with *Lactobacillus bulgaricus* and *Streptococcus thermophilus* has active bacterial lactase, which helps break down lactose in the intestine and, therefore, can prevent symptoms in lactose-intolerant people (Savaiano 2014). Another paper, "Microbial Lysate Upregulates Host Oxytocin," by B. J. Varian and colleagues, concludes that yogurt with *Lactobacillus reuteri* may affect the release of oxytocin, a hormone that is responsible for social bonding (Varian, Poutahidis, DiBenedictis et al. 2017). Speculation on the idea that the consumption of fermented dairy products may improve lactose malabsorption or affect the sense of social bonding provoked further speculations on symbiotic relations between microorganisms and humans. While providing visitors with the opportunity to collaboratively experience the isolation of microorganisms, to consume yogurt of particular strains, and to use protocols for individual experimentation, I offered an artistic setting for the mutual experience of humans and microorganisms.

Having considered and reconsidered the outcome of the collaborative workshops,[112] I came up with an idea to consume yogurt with different bacteria for the sake of experiencing it. The concept for my artwork read as follows:

*111 More information at http://howto-things.com/Biochemistry_of_emotions (Accessed 20 February 2020).
*112 See "My Collaboration with Bacteria for Paper Production" toolkit, which is a part of the larger work Introduction to Posthuman Aesthetics. Available at http://triple-double-u.com/my-collaboration-with-bacteria-for-paper-production/ (Accessed 10 March 2020).

> How can one experience their own microbiome? Is there any interdependence between what we eat, how we behave, and what we think? Combining the isolation of a single microorganism, cooking medium for it, looking after it, and finally consuming it, the audience is invited to experience the relationship between the targeted microorganism and themselves.
>
> The installation consists of two aquariums with yogurt: the first one is inhabited by *Streptococcus thermophilus* and the second with *Lactobacillus reuteri* bacterial strains. The aquariums have appended electronics that help track the change in pH levels.
>
> In order for a human to experience a significant impact, it is recommended to consume 500 g of yogurt per day for several weeks. Keeping in mind that homemade yogurt may contain pathogens and unhealthy chemical compounds, the author suggests ingesting homemade consumables at their own risk.[113]

With this idea in mind, and having executed several workshops and worked on the implementation of individual ideas, I would like to point to two moments that may illustrate the artistic value of mediation between the humans, microorganisms, and chemical compounds.

The first moment is related to the emergence of new forms and meanings in a collaborative setting, achieved through the ideas of the participants, new considerations, and updated implementations of the project. Before starting the workshops, my plan was to work exclusively with the isolation of bacteria that thrives in yogurt to make a homemade yogurt for further consumption and possible well-being. The continuous discussions with Hege Tapio, Auksė Gaižauskaitė, and workshop participants led me to understand the impact of the microbiome on health at a molecular level. The scientific paper "Microbial Lysate Upregulates Host Oxytocin," provided by Gaižauskaitė, led me toward the idea of a self-controlled emotional state achieved by the consumption of *Lactobacillus reuteri*, which might help to release more oxytocin in the human brain.

*113 See http://triple-double-u.com/proposal-for-microbial-therapy/ (Accessed 21 February 2022).

The second moment is related to the fact that continuously consuming a certain group of microorganisms could have an impact on humans through the production of different chemical compounds: in the case of the consumption of *Lactobacillus reuteri*, the human brain produces oxytocin, and, in the case of *Lactobacillus reuteri* and *Streptococcus thermophilus*, the active lactase in the intestine breaks down lactose and prevents symptoms in otherwise lactose-intolerant people. In my project, I speculated that consuming yogurt with either *Streptococcus thermophilus* or *Lactobacillus reuteri* would have two distinct impacts on a person's well-being.

If we consider further Uexküll's idea of umwelt, that is, a mutual response between the world and ourselves, we see how input from others, including humans and microorganisms, may affect the experience of humans. Still, it is interesting to ponder how, in the above-mentioned cases, the microorganisms themselves are affected. While the study "Microbial Lysate Upregulates Host Oxytocin" suggests that the regular ingestion of yogurt may affect the release of oxytocin, it is not clear from that particular research how oxytocin itself may affect the targeted microorganisms and if the continuous growth of *Lactobacillus reuteri* bacterial colonies would result in the continuous release of oxytocin. Therefore, in one workshop, we developed an experiment on the impact of oxytocin on *Lactobacillus bulgaricus*, which is supposed to be similar to *Lactobacillus reuteri* and *Streptococcus thermophilus*, which is a different strain compared to the first one.

This idea led to the execution of two experiments: In the first experiment, we applied synthetic oxytocin to the isolated bacteria; and in the second experiment, participants attempted to apply synthetic oxytocin to themselves by directly spraying it into their noses. While the first experiment did not show any particular impact for the growth of bacteria, the second experiment ended up with different effects on the emotional states of participants. While, in some cases, the effect was emotionally positive, in my case, the spraying of oxytocin into my nose did not invoke any perceptible impact on my emotions.[114] Consulting Auksė Gaižauskaitė during the workshop, we arrived at the conclusion that, in the first

*114 Participants also filled out questionnaires on their emotional state, which provided further ideas on the different effects of oxytocin on the participants (see, for example, the work by Juozapas Švelnys, introduced in the next chapter). For more information, see http://howto-things.com/Biochemistry_of_emotions (Accessed 5 April 2020).

experiment, there was no particular perceptible impact because, from the perspective of the bacteria, oxytocin is a set of compounds to be consumed by bacteria based on need; they did not absorb it automatically, or at least, there was no visible impact on the bacteria. Whereas in the second experiment, the oxytocin molecules, perhaps because they were bigger in relation to other molecules,[115] did not seem to pass to my brain through the cell membranes, and therefore, I experienced no apparent emotional impact.

While collaborating with people from different disciplines and with different expertise in a workshop setting, we artists came up with ideas involving interaction between the world and organisms, and scientists contributed with knowledge regarding functions of organisms. While working together, we evoked alternative paths to experience the world. For example, if we wanted to help our organism break down lactose, we could produce and ingest homemade yogurt with specified bacterial strains. In addition, by working with other people, we came up with solutions to avoid using synthetic oxytocin to experience social bonding.

Within the project, the consumption of yogurt with *Lactobacillus reuteri* and *Streptococcus thermophilus* was not the goal but rather an option to be tried at home or in the gallery.[116] Moreover, the project may still be contemplated, reimplemented, or imagined while looking at its documentation and reading the step-by-step instruction sets for the experiments (see Annexes XII and XIII).

*115 For more information, see https://www.worldofmolecules.com/emotions/oxytocin.htm (Accessed 2 May 2020).
*116 Unfortunately, there is no record of whether participants practiced the isolation of bacterial strains individually outside the workshops.

Contributions by Others

Although I developed a new artwork, my artistic role in the workshop series was rather of a mediator between the participants of the workshop, the technologies, the microorganisms, and so on. My role was activated during the collaborative work, spread over the duration of three months. On one hand, I explained how to use tools for the isolation and culturing of bacteria, and, on the other hand, I explained how microorganisms may affect our ecology. Then came the collaborative experience of both isolating and cultivating microorganisms, the discussion of the issues raised, and the work on new ideas.

During the term of the collaborative work, the participants and I executed three workshops with fifteen participants who developed ideas, some of which turned into further artworks. For the sake of variety, I would like to briefly reflect on three works: *Narrative to Biochemistry of Emotions* by Hege Tapio, *N* by Bon Alog, and *Initial Thoughts on Musical/Sonic Potential Regarding Emotional States* by Juozapas Švelnys. All the works emerged from different circumstances, but at the same time, they were developed while reflecting on the input from other workshop participants.

As a concrete suggestion to feed into the workshop, Hege Tapio introduced the idea of collaborative work on an interface that could measure oxytocin in humans.[117] Additionally, the problem proposed was described by Tapio as follows: "In a contemporary society that favors artificial intelligence, algorithms, logic, and analytical processes, it seems important to reintroduce the concept of biology. Humans are built to function on a biological level—where our interaction with the world is run by a mutual response where biochemistry triggers emotional responses and vice versa."[118] As in the earlier quotation by Dusseiller, here I also see the need to reconsider the relationship to the ecosystem, or, to be more precise, the world—our umwelt. Differently from Dusseiller, Tapio proposes taking a look into biochemical reactions. Although the speculative design of the device to measure the amount of oxytocin was developed, further discussions pushed the project into a broader scope—the overarching topic dealing with senses, and by extension, empathy. Having developed parallel work

*117 For more information, see the documentation of the project at http://howto-things.com/Biochemistry_of_emotions#Hege_Tapio (Accessed 17 April 2020).
*118 Ibid.

around the human brain's response to the *Lactobacillus reuteri* bacterial species, Tapio ultimately dropped the idea of an interface that measures the amount of oxytocin in blood, and continued developing her idea about empathy, which could be controlled by the consumption of yogurt with specific bacterial species. So the collaborative work opened up new horizons to Tapio for the development of the project.

The installation *N* by Bon Alog (Fig. 45) reflects upon the effect of our microbiome on our well-being.[119] The DIY ingestible capsule was to include *Lactobacillus* spp., vitamin D, and the concentrated fiber, vitamins, and minerals available in dried fruits. The composition of different components in a capsule may boost the immune system (*Lactobacillus* spp.),[120] invoke a positive mood (vitamin D),[121] or improve blood pressure (dried fruits).[122] Further reflections on the input and discussions of those reflections led Alog to speculate on playful forms of the capsules, which could potentially trigger positive thoughts and be helpful to humans experiencing a bad mood or fatigue. The artwork suggests a critical re-evaluation of the benefits of our microbiome and critical reflection on the pharmaceutical industry's manufacturing of standardized supplements. Altogether, the collaborative process pushed the realization of the artwork a step further, from speculation to a prototype of a consumable product.

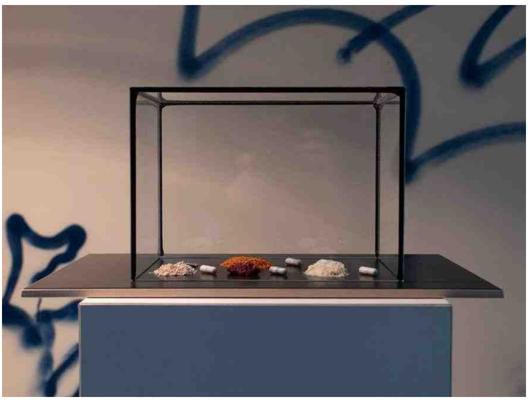


Fig. 45. Bon Alog, *N*. Installation at Alt lab, 2019. Photo: Vilius Vaitiekūnas

*119 For more information, see the documentation of the project at http://howto-things.com/Lactose_intolerant%3F_Let%27s_employ_bacteria!#Bon_Alog (Accessed 18 April 2020).
*120 See, for example, Maldonado Galdeano and Perdigón (2006).
*121 See, for example, Choukri, Conner, Haszard, et al. (2018).
*122 See, for example, Hernández-Alonso, Camacho-Barcia, Bulló, et al. (2017).

The participative installation *Initial Thoughts on Musical/Sonic Potential Regarding Emotional States* by Juozapas Švelnys (Fig. 46) is yet another idea that demonstrates how collaborative work may critically reflect upon conventional methodologies used by science.[123] The artwork features a laptop showing two sine waves being played in different frequencies. Next to the monitor, there is a bottle and glasses with a kombucha drink to be consumed by the visitors. On a conceptual level, the artwork speculates about the impact of sound on the release of oxytocin in the brain. In the artwork description, the author presents two cases: listening to the prerecorded music, and performing a sound piece with other people. While, in both cases, the release of oxytocin was assumed, the release in one case was triggered by listening and in the other case by performing with others. Being unable to perform collaborative singing, Švelnys chose to replace singing with the consumption of kombucha, which naturally fit with the public presentation of the workshop results. Although, at first glance, both types of objects (the laptop and the glasses of kombucha) are not of the same nature, the social experience triggered by the release of oxytocin in the brain (through listening to the music and consumption of the kombucha) is in effect. Aside from the input from other participants during the workshop, in this artwork, the collaborative experience unfolded through socializing, listening to music, and the release of chemical compounds in the brain.

Fig. 46. Juozapas Švelnys, *Initial Thoughts on Musical/Sonic Potential Regarding Emotional States*. Installation at Alt lab, 2019. Photo: Linas Tamošaitis

To conclude, all these works were developed while listening to, reflecting on, and discussing input from other workshop participants. I suppose that my input for Tapio's work was the idea that we may control our behavior (and, at the same time, the release of oxytocin in the brain) while controlling (and, at the same time, feeling) our

*123 For more information, see the documentation of the project. Available at http://howto-things.com/Biochemistry_of_emotions#Juozapas_.C5.A0velnys (Accessed 18 April 2020).

microbiome, and not necessarily by using technological tools to measure it. I also believe that Alog was influenced by my idea of the possibility of controlling our mood with homemade consumables. Finally, Švelnys was swayed by the idea of consuming homemade foods to trigger the release of oxytocin in his participative installation about social bonding.

Working in collaboration with other people within a shared framework, such as *Hackteria's Empathetic Taxidermia Lab* or in the collaborative workshops at Alt lab, may result in the realization of new ideas or even complex artworks such as those by Bon Alog or Juozapas Švelnys. The mediated ideas, the know-how about the isolation of microorganisms, and the consumption of symbiotic cultures could also lead to experiencing symbiosis with microorganisms through a change in physical well-being. Such frameworks suggest the shifted role of the artist, from being a centralized author to becoming a mediator between participants, technologies, and other organisms. In addition, as part of the artwork, participants, technologies, and other organisms can contribute to the artwork with their input.

Aesthetics through the Lens of the Posthuman

So what actually happens to the audience if the artist becomes a mediator between audiences, technologies, and non-human organisms? How may the impact of the others manifest in aesthetics perceived through experience? The considerations in the previous chapter led me to the full-range solo exhibition *Microorganisms & Their Hosts* and a participatory event comprised of three collections of wearables *You and I, You and Me.*

Exhibition Microorganisms & Their Hosts

The full-range solo exhibition *Microorganisms & Their Hosts*[124] (Fig. 47) was conducted in collaboration with scientist Auksė Gaižauskaitė (microbiology), artists Antanas Gerlikas (glass) and Laura Kaminskaitė (exhibition design and glass), curator Valentinas Klimašauskas, and many other contributors.

Fig. 47. Exhibition *Microorganisms & Their Hosts* at the Atletika gallery. Photo: Andrej Vasilenko

The main idea behind this exhibition was how our aesthetic perception is affected by the products we ingest. To see the context from a different perspective, I have also asked the question of how we—humans—affect microorganisms. Since the consumption of fermented products affects the populations of various microorganisms living in the gut and also contributes to the overall well-being of the human body, I speculated that as the well-being changes, the aesthetic perception of the exhibition will also change. To experience the change in perception, I suggested providing a workshop[125] next to the exhibition, inviting volunteers to join the workshop and asking them to work together to make different yogurts for the exhibition and consume them during the exhibition. Since the exhibition was scheduled for ten days, the effects on well-being should have also been noticeable.[126] Unfortunately, due to the pandemic, it was not possible for me to organize such a workshop in time, and the idea remained rather speculative. However, I presented the idea to the participants of the workshop later, as it was possible to hold it as part of the exhibition. I also presented the idea during the closing reception that became similar to a relational aesthetics event. Although not encouraged to do so, some participants tested the self-made yogurts (Fig. 48).

*124 Available at http://triple-double-u.com/microorganisms-and-their-hosts/ (Accessed 4 December 2020).
*125 See, http://triple-double-u.com/microorganisms-and-their-hosts/workshop-how-to-personalize-yogurt/ (Accessed 22 December 2021).
*126 See, for example, Lisko (2017).

Fig. 48. Audience tasting the self-made yogurt during the exhibition. Photo: Andrej Vasilenko

Altogether, the exhibition featured six different artworks and a workshop, all approaching the theme from different perspectives. While the video *Microorganisms & Their Hosts* presented the conceptual part of the exhibition from the perspectives of consumers, scientists, and artists, other works demonstrated how microorganisms are approached from cultural, scientific, and maker perspectives. For example, *Glass Containers* displayed the traditional way of making a fermented tea and *Glass Vessels* introduced the scientific method of fermenting yogurts. Two other installations provided an idea of how the pH levels change through the fermentation process. While *Proposal for Microbial Therapy* was designed to display the change of pH levels of fermented yogurts, the capsule *Rectal Candle* was to track the change of pH levels of our intestine. The installation *My Collaboration with Bacteria for Paper Production* featured a DIY lab, a toolkit, a video tutorial, and a manual, which were designed to allow the audience to try out the tools provided and to experience the setting while working with microorganisms directly in the exhibition space. At the same time, the installation was used for the workshop *How to Personalize Yogurt?* to let the audience actively participate in the exhibition architecture.

Microorganisms & Their Hosts

In the video *Microorganisms & Their Hosts*, Auksė Gaižauskaitė, Valentinas Klimašauskas, and I discuss the impact of the fermented products we consume (Fig. 49). The video proposes that we reconsider the ecology of a human while questioning the impact of the microbiome. The conversation encompasses self-healing strategies and how we experience an artwork in relation to changing environmental conditions. How can one experience their own microbiome? Is there any dependence between what we eat, how we behave, and what we think?

Fig. 49. *Microorganisms & Their Hosts*. Video still

Proposal for Microbial Therapy

The installation *Proposal for Microbial Therapy* (Fig. 44) emerged from the series of events within the proposed framework, which had included a series of workshops and presentations. The project featured two aquariums with different sorts of yogurt: one colonized with *Lactobacillus reuteri* bacteria, and the other with *Streptococcus thermophilus* bacteria. The yogurt in the containers was not provided to be tasted but rather provided to observe how the fermented yogurt changes within the time (Fig. 50). While questioning the ecology of humans, the impact of the microbiome on humans, and self-healing strategies, the installation proposed to imagine symbiotic relationships with microorganisms. How can one experience their own microbiome? Is there any interdependence between what we eat, how we behave, and what we think?

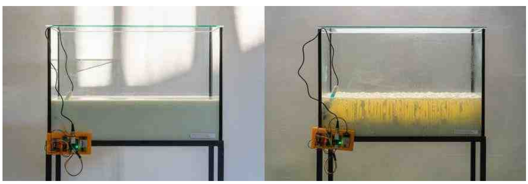


Fig. 50. Containers with Streptococcus thermophilus bacteria at the beginning of the exhibition (left) and at the end of the exhibition. Photos: Andrej Vasilenko

Glass Vessels

Glass Vessels is a collection of custom glass vases that feature diverse yogurts (Fig. 51). The objects are filled up with yogurt containing different bacteria, including *Lactobacillus reuteri*, *Streptococcus thermophilus*, *Bifidobacterium lactis*, *Leuconnostoc* spp., and a mix of each. Depending on the mood or the experience one anticipates, one may choose to consume one or the other yogurt. The installation offers the audience the chance to experience their well-being in relation to the consumed beverages, each with diverse microorganisms.

Fig. 51. Installation *Glass Vessels*. Photo: Andrej Vasilenko

Glass Containers

Glass Containers is an installation of custom-made glass bowls that features diverse sorts of kombucha (Fig. 52). The vessels are filled up with kombucha containing different ingredients, including different microorganisms. Depending on the experience one anticipates, one could choose to use one or the other sort of kombucha.

Fig. 52. Installation *Glass Containers*. Photo: Andrej Vasilenko

Rectal Candle

Rectal Candle is a capsule that measures and sends over Wi-Fi the pH of one's rectum (Fig. 53). If used along with different diets, one could track the condition of the microbiome or the change of one's well-being. The object questions the relationship between the well-being of humans and the changing microbiome. Moreover, being part of the intestine, the capsule may be considered as operating in concert with the organism, which, in turn, suggests the viewer (or the user) to reconsider posthumanism.

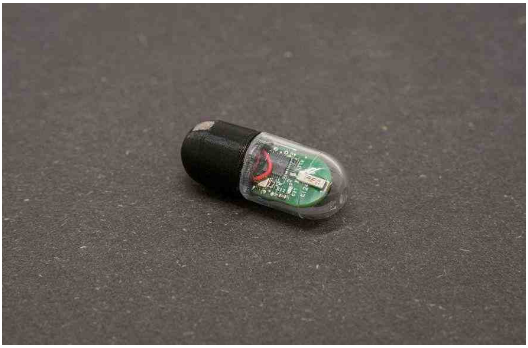


Fig. 53. *Rectal Candle*. Photo: Andrej Vasilenko

My Collaboration with Bacteria for Paper Production

My Collaboration with Bacteria for Paper Production, featured a DIY biolab, a toolkit, a video tutorial, and a manual (Fig. 54), which is a part of the *Introduction to Posthuman Aesthetics*. While offering visitors to use the lab for hands-on experimentation, the installation fulfilled the gap between the Maker culture and art. It invited the audience to experience the relationships between living organisms and non-living things in real time. Symbiotic relationships were outlined in the manual with references to related artistic projects and scientific research. The tools were provided for various uses: An introduction to the first experiment explained how to grow SCOBY; the second experiment showed how to isolate *Acetobacter* bacteria from grown SCOBY.

Fig. 54. Installation *My Collaboration with Bacteria for Paper Production.* Photo: Andrej Vasilenko

How to Personalize Yogurt?

The main theme of the creative workshops and the subsequent exhibition was the dependence of aesthetic experience on the products consumed, or how certain products (specific microorganisms in the case of this project) affect the biota-intestinal populations of various microorganisms, which contribute to the well-being of our organisms and possibly contribute to aesthetic experience.

The workshops were conceptualized to have the participants produce the individual yogurts. At the same time, the produced yogurts were supposed to be consumed by the same participants during the time of the exhibition, so the participants would have had individual experiences of the exhibition dependent on the consumed amounts of yogurts within the duration of the exhibition. Due to the pandemic restrictions, this idea was not realized, and audiences were invited to participate in the workshop without producing yogurts for the exhibition (or consuming them) (Fig. 55).

Fig. 55. Workshop *How to Personalize Yogurt*? Video Still

Aesthetic Experience in Microorganisms & Their Hosts

The artworks within the exhibition and the workshop invited the audience to experience the impact of microorganisms on well-being (and vice versa) from different perspectives. While *Proposal for Microbial Therapy* presented the relationship between fermenting yogurt and changing pH, *Glass Vessels* invited visitors to contemplate the fermentation processes of different types of bacteria in yogurt, and *Glass Containers* offered insight into the fermentation process of homemade green tea and black tea kombucha.

The capsule *Rectal Candle* inspired me to further speculation: If I would have the *Rectal Candle* in my intestine, it would sense the pH level of the intestine and send it to my smartphone or tablet. Depending on the values, I would consider eating fermented foods with specified microorganisms so they would affect the composition of my microbiome. The altered microbiome would change the pH value of the intestine, which, in turn, would suggest changing my diet, which, again, would change the microbiome and my perception of aesthetics.

To understand the change within the perception, a crucial role is being played by the acquired knowledge of the audience. So for example, a scientist with knowledge in molecular biology may experience the artworks in relation to chemical reactions of digested components, while an environmentalist may consider the ecology as a whole. My further interest here is rather philosophical, focusing on the impacts between actors within an umwelt. More concretely, in the exhibition *Microorganisms & Their Hosts*, the focus was on the impacts between humans and the microorganisms in the human microbiome. In the papers referred to within this research—”Lactose Digestion from Yogurt: Mechanism and Relevance” by Dennis Savaiano and “Microbial Lysate Upregulates Host Oxytocin” by B. J. Varian and colleagues—the impact was described as the breakdown of lactose in the gut and the release of oxytocin in the brain, a rather technical impact. If anything, this impact is reduced to a physical one. What would this mean for the aesthetic experience in systems, which bring interaction between different actors?

Here, I would like to propose the consideration of two positions within the interacting systems, the general systems theory of Ludwig von Bertalanffy and the social systems theory of Niklas Luhmann, to better understand the differences between the technical impact of the systems to each other and the aesthetic experience of the systems.

Bertalanffy's General System Theory was outlined as a holistic theory, wherein the whole is equal to more than the sum of its parts and wherein interaction between heterogeneous elements plays a significant role (Bertalanffy 1950).

> In the past centuries, science tried to explain phenomena by reducing them to an interplay of elementary units which could be investigated independently of each other. In contemporary modern science, we find in all fields conceptions of what is rather vaguely termed 'wholeness.' (Bertalanffy 1950)

With reference to Alfred North Whitehead, who defined every large organism as a unity of smaller organisms (Whitehead 1925, 18, 80, 105, 112), Bertalanffy's theory went a step further, introducing "wholeness" instead of "unity." Atoms, molecules, or crystals consisting of the union of other elements cannot be approached in a reductionist way—where any element can be viewed separately but has to be viewed as dynamic wholeness; where every single element fulfills the other element. While criticizing conventional physics, which considered every element in isolation from its environment, Bertalanffy proposed an interaction between elements, which is seen through the rather technical input-output lens (Bertalanffy 1950, 1968).

In contrast to the idea of Whitehead's unity and Bertalanffy's wholeness, a different understanding of interacting systems is proposed by sociologist Niklas Luhmann, who doesn't enclose the system into the final unit, or wholeness; instead, he puts systems into self-reference in relation to their umwelts (Luhmann 1991, 192). If Bertalanffy would consider differentiating systems through organization, such as being open or closed systems (Bertalanffy 1950, 1968), and, thus, would consider systems through rather technical input-output interactions, Luhmann emphases self-reference, thus putting strength on qualitative interaction of the system and the umwelt.[127] This notion is comparable to Uexküll's umwelt, the interaction between the inner world and an outside action,[128] and suggests a qualitative experience compared to technical reference through inputs and outputs. The exhibition *Microorganisms & Their Hosts* follows Luhmann's position between the system and the umwelt, and considers the impacts of humans on microorganisms and vice versa through self-reference in relation to the umwelt.

At this point, however, I can only think of the human dimension, and the microorganism dimension remains imaginary, although it is no less important than the human one. From Luhmann's perspective, taking into account the changing aesthetic experience while consuming yogurt with microorganisms, the interaction between different systems and the impact on human perception is extended to include the changing meaning of an artwork. This meaning is gathered from individual experience. For example, the meaning in Luhmann's theory is conceived through the established references in

*127 In Soziale Systeme: Grundriss einer allgemeinen Theorie (1991), Luhmann uses the term umwelt, whereas, in a translated version of the book, the Social Systems, the reader meets the term environment, which in Luhmann's systems is always specific to the system. Having introduced the use of the term umwelt in this thesis, I use here the original term as used by Luhmann in a German version of the book.
*128 See more on Uexküll's notion of "Umwelt" in the section "Transhumanist Tradition."

the art system (Luhmann 2008), and, in case of Roland Barthes, it would be a "'tissue' of quotations" (Barthes 1967). In *Microorganisms & Their Hosts*, then, the meaning will vary depending on the audience (and their temporal perception) who would experience the work. Here, the meaning is made through the consumption (or imagined consumption) of yogurt during the workshops and the established individual references. For example, from an audience perspective, my references were Maker culture, *Hackteria's Empathetic Taxidermia* Lab by Marc Dusseiller, and *Artist's Shit* by Piero Manzoni, among others. Whereas Aistė Kisarauskaitė came up with references of the struggle between good and evil, Nicolas Bourriaud's relational aesthetics, and Evaldas Jansas's performance inviting one to eat peas and beans.[129]

On the other hand, the meaning for microorganisms would be made by the microorganisms themselves, which I do not know but may try to imagine. This meaning is, then, microorganism-specific, depending on their sensory abilities and individual experiences, whatever that would mean for microorganisms themselves.

Having discussed the aesthetics for humans and microorganisms, I could think of aesthetic impacts for different organisms, including animals and plants. However, the aesthetic impacts would be different in a setting with machines. So the next question relates to an interactive setting of humans and non-human actors, including machines.

*129 See, for example, (Kisarauskaitė 2020).

Participatory Event *You and I, You and Me*

The participatory event *You and I, You and Me*[130] (Fig. 56) meets audiences with leaflets inviting them to imagine a future where humans, computing machines, and various types of hybrids share the space they live in. In the future setting, senses are altered, some are inextricably linked to computing devices. There, electricity is used to control the space and beings living in it. At the same time, humans take responsibility to reshape social ties to avoid being controlled by corporations and machines.

Fig. 56. Participatory event *You and I, You and Me*, Sapieha Palace, Vilnius. Photo: Arūnas Baltėnas

The installation of the project features wearables (Fig. 57) placed on the stands, which include collections of headwear (seven pieces), jewelry (eleven pieces), and shoes (five pairs). Next to them are three videos, giving an idea of how to use the wearables.

In the participatory event, the audience was invited to try out wearables that contain interfaces (computing machines) to connect humans to the umwelt. The invitation was carried out by the artists and the supporting team—altogether nine people—so that the audience did not realize that they themselves were part of the participatory setting.

The plan for the participatory setting was introduced to the supporting team as follows:

*130 The participatory event was presented at the Baltic Triennial 14 at the Sapieha Palace in Vilnius on the 30 July 2021. For more information, see http://triple-double-u.com/you-and-i-you-and-me/ (Accessed 28 December 2021).

Fig. 57. Installation *You and I*, *You and Me*, Sapieha Palace, Vilnius. Photo: Arūnas Baltėnas

18:15 – Start of the participatory event: the performers come one by one into the space where objects are installed, walk up to the objects, explore them, and put them on; ten minutes for everyone to come in.
18:25 – Performers begin to interact with colleagues, little by little, perhaps trying on colleagues' items; ten minutes for the activity.
18:35 – Performers can now approach the audience individually; others can interact with other performers; overall, try out the other performers' objects, explore the app, and find out how the objects work; as this is the main part, plan thirty minutes for it.
19:05 – If tired, go back to the stands and place the objects back onto the stands; slowly mix in with the audience; ten minutes for the activity.
19:15 – All objects are back to their original places; finish of the participatory event.

Altogether, the *You and I*, *You and Me* project explored the impact of the umwelt on humans through electricity that was passed in both directions through the interfaces containing computing modules. Here, I introduced the idea of humans being able to generate electricity, the idea which was explored in the toolkit "Ultra-Low-Voltage Survival Kit."[131] In parallel, I referred to the toolkit "Mycorrhizal Networks, or How I Hack Plant Conversations,"[132] which explored the transport of information between living organisms and non-living mater. Culturally, the project referenced traditional clothing and the importance of clothing to human identity.

*131 For further information, see section "Toolkit #3. 'Ultra-Low-Voltage Survival Kit.'"
*132 For further information, see section "Toolkit #2. 'Mycorrhizal Networks, or How I Hack Plant Conversations'"

Headwear

The collection of headwear (Fig. 58–59) has been designed to encourage the discussion on the impact of electricity on the human cortex and to experience other humans (and the umwelt) through an electrical signal. How far could electricity help in understanding the other? Is there a possibility to alter human senses by electric impulses? If our brains are affected by electric current, what happens then to the brain itself?

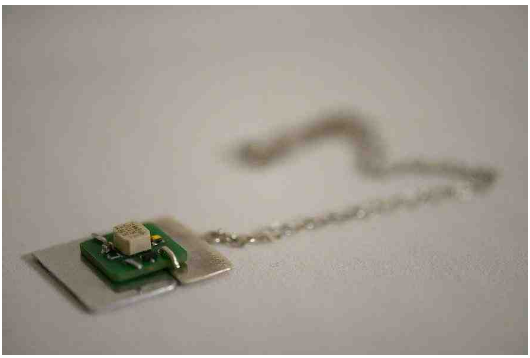
The project was inspired by research on brain-to-brain interfaces, including the study “A Brain-to-Brain Interface for Real-Time Sharing of Sensorimotor Information” by Miguel Pais-Vieira et al., which introduced the transfer of sensorimotor information between the brains of two rats (Pais-Vieira, Lebedev, Kunicki, et al. 2013). Another compelling paper, “Closed-Loop Deep Brain Stimulation Is Superior in Ameliorating Parkinsonism” by Boris Rosin et al., showed how the analog signal from six recording electrodes implanted in an African green monkey brain was amplified in an electronic chip, which, in turn, delivered electric impulses back into the brain through the two stimulating electrodes (Rosin, Slovik, Mitelman, et al. 2011). The inspirations suggested that—if used with non-invasive methods to work with the brain, such as electroencephalography (EEG) and transcranial direct current stimulation (tDCS)—we could combine the methods and implement them into a brain-to-brain interface for an artistic project.

Though the headwear was designed for humans, it is possible to imagine the interaction through the electric signals between humans and non-human animals (Annex XIV).

Fig. 58-59.
Headwear in use. Photo: Bon Alog

Jewelry

The collection of jewelry (Fig. 60–62) was designed to experience the umwelt through the electricity that is transformed into a blinking LED. The project questions the impact of differently charged ions on humans. By definition, an ion is an electrically charged particle produced by either removing or adding electrons from or to a neutral atom being in every solid, liquid, gas, and plasma. These differently charged subatomic particles, while interacting, generate electric current. Consequently, humans also generate electric current. What are the abilities of humans to generate electric current and, while using it, experience the umwelt?



The jewelry pieces hold within them a small LED powered by the human body. Being very sensitive, the flashing of the LED depends on humidity, temperature, contact to the body, and other parameters that affect the components used for the circuit (Annex XV).

Fig. 60. Jewelry in use. Photo: Bon Alog
Fig. 61. Jewelry. Photo: Martin E. Koch
Fig. 62. Jewelry. Photo: Martin E. Koch

Shoes

The collection of shoes (Fig. 63–65) were designed to experience the umwelt through sound. Here, the excess human heat serves as the energy source, which is converted into electricity to generate sound that varies depending on light and movement. Shoes also reflect daily clothing, something humans wear to protect themselves from unexpected environmental obstacles, including cold as well as other organisms that are not necessarily always friendly to humans. While being affected by the ambient temperature, light, and movement, the shoes suggest rethinking a human's relationship with nature. Furthermore, the collection critiques the hype surrounding renewable energy, which often pollutes the environment no less than the energy obtained from burning gas or coal (Annex XVI).

Fig. 63. Shoes. Photo: Bon Alog
Fig. 64. Shoes. Photo: Martin E. Koch
Fig. 65. Shoes. Photo: Martin E. Koch

Aesthetic Experience in *You and I, You and Me*

The participatory event was executed at the Sapieha Palace in Vilnius to involve the audience in interaction with the umwelt. Here, the artists, along with a supporting team, invited the audience to try out the objects for themselves, and guided the audience on how to use the objects. The choreographed event brought artists, audiences, and machines into bidirectional interaction. Interestingly, the audience effortlessly fit into the given setting, trying out wearables, discussing them and, without paying attention, turning the individual experiences into individual performances.[133] Here, the objects acted as interfaces between the audiences and the umwelt.

Technically, audiences and the umwelt were connected by electricity by converting electromagnetic waves to digital and back to electromagnetic waves in the headwear or using the human body itself as a source for the electrical signal, which in the case of shoes would be generated from the difference of temperature between the body and the environment, and in the case of jewelry would be generated from the chemical reaction between different electrodes and the body. By connecting computing machines directly to the body, I have addressed a functioning posthuman state as described by Katherine Hayles (1999).[134] Nevertheless, I was concerned with the changing perception of humans in relation to the changing umwelt. Therefore, the wearables were given to the audience to use for the aesthetic experience.

To try out different formats, this project was also conducted as an online workshop.[135] The workshop focused on communication asking the participants the following questions: What is your environment? With whom do you want to communicate? What do you want to communicate? How could the communication be done? Starting with electricity as a possible form of communication between humans and non-humans, the participants of the workshop pushed the idea fur-

*133 The participatory event is archived at https://www.youtube.com/watch?v=NmVE_78Y43o (Accessed 18 September 2021).

*134 For further notes on posthumanism, see section “Art and Posthuman.”

*135 The workshop was executed within the Molten Airs workshop series during Ars Electronica 21. The Molten Airs series builds its narratives on casual life processes, repetitive habits, and social practices. By speculating on the human relationship to plants, food, or energy, but also using methods borrowed from the sciences, the series delves into unknown interactions between small and large, real and fictional, alive and not alive, us and them.

ther into Karen Barad's intra-action, a philosophical concept describing forces that inextricably connect things.[136]

Having established direct links between humans and their umwelts through electricity, perhaps, I could further refer here to Ascott's "Nature II, "the idea I briefly mentioned in the chapter "A Shift in the Role of an Artist." In his "Back to Nature II" essay, Ascott referred to nature, which was always in opposition to city, technology, and culture. As it is not the case with the ubiquity of computer networks where the city is no longer the necessary site of commerce, and the country is no longer natural, Ascott proposed that there might be a solution which combines two different approaches. Instead of tearing up the nature into little pieces on one hand, and attempting to unify it into wholly new configurations on the other, Ascott suggested the return to nature calling it "Nature II" (Ascott 1995, 327–328). Referring to nature as Nature II, Ascott suggested the artistic use of technologies to perhaps help "unlearn" what humanity has learned thus far and see the technological arts as a way to better understand nature. While considering the role of technological arts in such a nature, Ascott referred to past cultures, where the aim of art was to mediate between mankind and the gods.

In the project *You and I, You and Me*, the role to connect different natures was given to the artistic objects themselves because, having embed in them computer networks, they would immediately reflect the umwelt independently from the physical location of the audience. And by referring to the past cultures aesthetically (for example, the headwear and the shoes mainly referred to examples from the Renaissance period paintings of Pieter Bruegel and Baroque period paintings of Johannes Vermeer) they would help in accessing cultural references. So with *You and I, You and Me* I can speculate that the proposed wearable objects mediated umwelts (or nature) to the audience through electricity, directly affecting brain activity in the headwear and indirectly affecting sight and hearing in the jewelry and shoes, respectively.

*136 The workshop is archived at https://www.youtube.com/watch?v=X1s2IEI8HgI (Accessed 18 September 2021).

The Role of Machines in *You and I, You and Me*

If within Ascott's nature art was given a role to mediate new challenges that combine in themselves physicality and virtuality, the participatory event *You and I, You and Me* was given the role to impact the aesthetic experience of the audience. This experience was gained by the implementation of the posthuman setting where communication happens with the help of electrical signals. If Ascott introduced the position of an artist as a producer of an artwork bridging both physical and virtual, the *You and I, You and Me* could be considered as being the illustration of such a setting. Here, the computing machines embedded in the objects acted as mediators between the audience and the umwelt.

I would now like to bring into the discussion a concept of a Turing machine and compare it with the *autopoiesis* concept of Maturana and Varela. On the other hand, I would like to compare the Konrad Zuse's Z3 computing machine (that is a practical implementation of a Turing machine) with the interacting cyclic tag systems presented by Stephen Wolfram. Alternatively, I would like to introduce the interactive Turing machine with Advice (ITM/A) of Jan van Leeuwen and Jiří Wiedermann, which is a conceptual framework of a conventional computer network such as the Internet. These examples will give an idea of how practically electricity may affect the human brain and with it the aesthetic experience of a human.

In the paper by Turing (1936), the computing machine was proposed as the simple idea of an apparatus which is able to compute discrete values—zeros and ones. In the same paper, Turing introduced the machine with an infinite length of tape and a tape head acting upon seven commands: (a) read the tape, (b) move the tape left, (c) move the tape right, (d) write "zero" on the tape, (e) write "one" on the tape, (f) jump to another command, and (g) halt. The idea of these commands was to show that output B could be generated from an initial state and input A. The position of the tape head on the proposed apparatus processing the information was dependent on the information stored on the tape: If the input information was defined, so was the output. The problem proposed in such a computational model is any numerically undefined variable which would cause the machine to stop processing information, or to "halt." The halting state or, according to Turing, the "decision problem" (*Entscheidungsproblem*) was the problem of digital computation being defined by numerical variables. Thus, the Turing machine was limited to computing all input information and to solving all given problems (Turing 1936). For the same reason, the transhumanist position introduced in the subsection of the first chapter "Transhumanist Tradition" was considered limited and not followed further within this research.

On the other hand, the term *autopoiesis* was used by the biologist and philosopher duo Humberto Maturana and Francisco Varela to bring living systems closer to an inorganic life context. The term extended Maturana's previously used term "self-reference," which was used in contrast to "self-organization" as proposed by Ross Ashby. The first and probably most important differences between previously evaluated conceptions and *autopoiesis* were the approaches to the object under consideration, for example the halting state introduced by Turing. While speaking of autopoietic systems, Maturana and Varela put an emphasis on the cyclic process of interaction and production, such as a feedback loop. The idea of a cyclic process was to take the machine one step further than the concept described by Turing. And although it did not contradict the Turing machine, the difference lay in the idea of computation. Whereas the focus of the Turing machine was on linear computation, the focus of autopoiesis was on re-evaluation of the computed information.

An autopoietic machine operated within a network of processes in order to regenerate parts and to therefore stay continuous:

> An autopoietic machine is a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which: (i)

> through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them and (ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network. (Maturana and Varela 1972, 78)

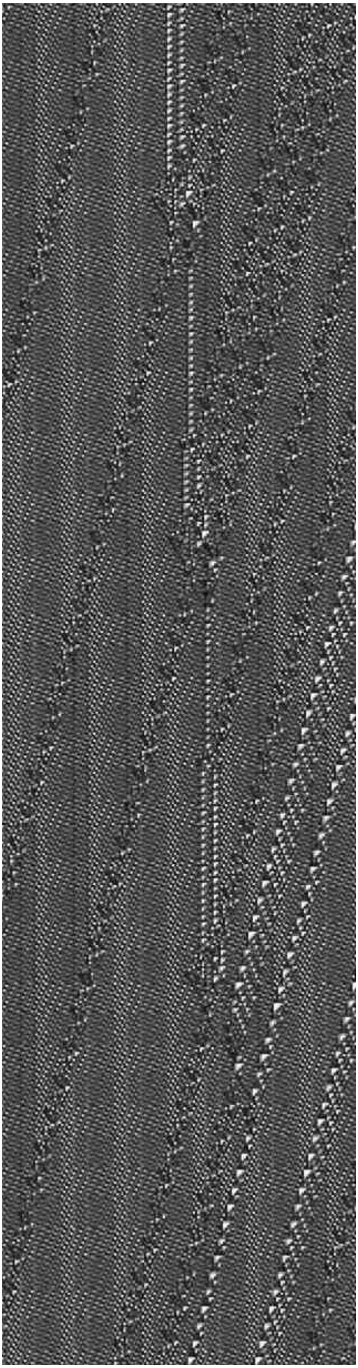
It is important to note that even if Maturana and Varela introduced an artificial system which had the potential to look like a living system, machines such as cars or non-material elements, such as the coding or transmission of information, were not in the domain of the autopoietic machine (Maturana and Varela 1972, 90).

So let's see how Maturana and Varela's autopoietic machine could look like in reality. The autopoietic machine could be presented as, for example, a programmable machine with variable input. The practical implementation of the Turing machine—Zuse's programmable computing machine Z3—was, theoretically, capable of calculating any number; it was programmable, used a binary number system, had an interface for inputting commands, and output the result on a display,[137] thus bridging the physical machine with digital computation. Although it was not built to re-evaluate the calculated number (as it was conceptualized in the concept of autopoiesis), it takes us further to a fused human-and-machine system that has the potential to partially solve Turing's halting state, or the "decision problem," by providing other types of input, such as a self-produced film strip punched with a simple hand punch (Zuse 2007, 54). Being able to imagine a film strip put into the loop—a technique used already in the experimental films of the 20s[138]—it is easy to imagine Z3 as an autopoietic machine.

Maturana and Varela's autopoietic machine could be also nicely illustrated with the interacting of two different automata systems, which was used by Stephen Wolfram (2002) to prove his idea of universal computation and also with ITM/A proposed by Leeuwen and Wiedermann (2001, 2008).

While using cyclic processes, Wolfram suggested that, after a number of generations, the evolved patterns in cellular automata start to demonstrate some complexity in their structures. To illustrate it, Wolfram used the interaction of

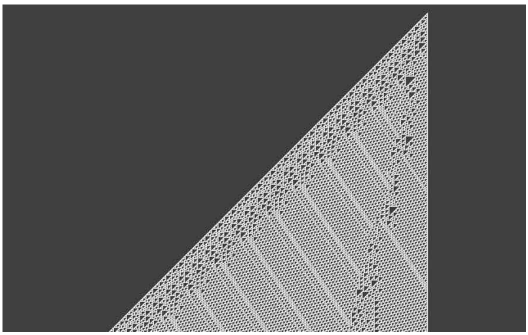
*137 For more information, see Zuse (2007).
*138 See, for example, Ballet Mécanique from 1924 by Fernand Léger.



two cellular-automaton-like elements, rule number 110, and a hypothetical Turing machine, which, through the process, was embedded into the structure of rule number 110. Combining this interaction with a cyclic tag system, which is defined by yet another kind of simple rule, he was able to demonstrate a pattern emerging from the interaction with a hypothetical Turing machine pattern. The interaction resulted in the emulation of other elements within the 110th rule of cellular automata, proving it to be capable of emulating a Turing-machine-type element (compare Fig. 66 and Fig. 67). A similar proof has been shown constructing a seven-state and four-color Turing machine based on the cellular automaton principle. The result Wolfram came up with was evidence that complex cellular automata bear a feature of universal computability (Wolfram 2002). Although the universal computability is not my focus in this thesis (but could be the focus of transhumanist tradition), the idea that two different systems, while interacting, may produce a unique outcome is obvious.

Fig. 66. Pattern of elementary cellular automata rule 110, generated with Golly for Mac OS X version 2.5

Fig. 67. Emulated example of a cyclic tag system in rule 110 in 3,200 evolution steps (Wolfram 2002, 685)



The possible merge of different systems—cellular automata and Turing machine—were also presented by Jan van Leeuwen and Jiří Wiedermann as interactive Turing machine with Advice (ITM/A) in their papers "The Turing Machine Paradigm in Contemporary Computing" (Leeuwen, Wiedermann 2001) and "How We Think of Computing Today" (Leeuwen, Wiedermann 2008). Within the latter paper, the authors argue that evolving automata and Turing machines are both defined using the same formal language. Therefore, they proposed two new models of computation: (a) every classical Turing machine, or even an interactive Turing machine (ITM), can be simulated by an evolving automaton, and (b) evolving automata can simulate interactive Turing machines with advice and vice versa. Thus, interaction of two automata could serve as a basis for the investigation of evolving interactive computing systems or as a model of a "living organism." Here, again, my focus in not a model of any living organism (which could be interesting for the transhumanist tradition), but an idea that two different systems, the evolving automata and the interactive Turing machine, could in theory be combined for bringing about a unique outcome.

Having no goal to either simulate a Turing machine or to illustrate an evolving interactive computer system, with *You and I, You and Me*, I propose that if computer systems and living organisms were put into interaction with each other, they would affect each other. In so doing, the audience's aesthetic experience would be affected by a machine, and the machine's computed numbers would be updated in relation to the changing physical world. My understanding suggests that, in such a way, the interacting system would solve (at least partially) the halting state, or the "decision problem," highlighted by Turing.

In *You and I, You and Me*, interactive systems were built between human and machine and between umwelt and machine, with the machine being the same interface for both. In this case, the umwelt functioned as an input to the machine and, further, to the human; or vice versa: the human functioned as input for the machine and, further, for the umwelt. Since both systems—human and their umwelt—were connected by a machine, there was a lot of room for speculation, analysis, interpretation, and experimentation. As an example, I could think of interacting human and machine as two different cyclic tag systems presented by Wolfram (2002). Or, I could also think of interacting human and machine as the interactive Turing machine model, presented by Leeuwen and Wiedermann (2001).

To illustrate how human perception would be affected, as an example I could bring the experience of Helmut Dubiel, a German sociologist suffering from Parkinson's Disease. Dubiel has written an entire book about his life and perception when carrying a brain pacemaker, which sends electronic signals into brain tissue depending on his activity and needs (Dubiel 2006). Other examples—a study by Miguel Pais-Vieira et al. introducing the transfer of sensorimotor information between the brains of two rats, and a paper by Boris Rosin et al. introducing how the analog signal in the African green monkey brain is amplified—were briefly presented in the subsection "*Headwear*."

How to connect a living organism to a microcontroller practically, I have explained in the toolkits "Mycorrhizal Networks, or How I Hack Plant Conversations" and "Ultra-Low-Voltage Survival Kit." The same setting was also applied on a human scalp in the headwear objects of the participatory event *You and I*, *You and Me*. Differently from the introduced cases by Dubiel or by Boris Rosin et al., I have only used the non-invasive electrodes to pass the electricity on a plant and on a scalp. In all of the above cases, the signal was digitally processed and converted to or derived from a chemical signal.

Aesthetics of Maker Culture

After presenting two projects, the solo exhibition *Microorganisms & Their Hosts* and the participatory event *You and I, You and Me*, and contextualizing the projects in terms of interaction, it is time to revisit the projects and see the audience's place in them.

The exhibition featured six different artworks and a workshop, all approaching the theme from different perspectives, and all being interactive and still conventional at the same time, where an observer encounters an art object and an object remains for itself. The lab setting—*My Collaboration with Bacteria for Paper Production*—was open to be used by the audience during the exhibition and to experience the interactions with tools and microorganisms on their own. This installation, like similar lab settings during the *Shared Habitats* exhibition, proved to have limited usability for the audiences and, at the same time, proved the need for assistance from the artist. On the other hand, this installation was intended to be used also for a workshop. The workshop *How to Personalize Yogurt?* was conceptualized for the audience to produce individual yogurts, which in turn, were supposed to be consumed daily for experiencing the exhibition. Although the workshop was executed, due to the pandemic it was not implemented to test the idea of changed perception through the consumption of yogurt. However, this setting still functioned from the perspective of the artist being a mediator, and was successful in terms of new outcomes and new speculations. Also, this workshop brought the audience together to experience the hands-on work, to collaborate with the artist, and to interact with microorganisms; in other words, to experience aesthetics of Maker culture.

Another artwork in the same exhibition, *Rectal Candle*, presented the object as a capsule to be inserted into an individual rectum for measuring changes of its pH levels. In conventional exhibition settings, most likely, this object would not have been allowed to be used as conceptualized. In other than an exhibition setting, the capsule was only tested for the proof of concept, but not tested in anyone's rectum. So it remained only functioning in speculations.

The works using microorganisms (*Glass Vessels*, *Proposal for Microbial Therapy*, and *Glass Containers*) were also presented as objects without a possibility for the audience to consume the products with microorganisms themselves.[139] So from an aesthetic point of view, these installations were not experienced fully, neither from the human perspective nor from the perspective of microorganisms. Also, the video (*Microorganisms & Their Hosts*) didn't have any interactive setting and functioned rather as an object of a conventional exhibition setting. Therefore, altogether, although the exhibition provided a setting to experience aesthetics of the Maker culture, it was not completely implemented to fully experience the aesthetics by participating in interaction with the content provided.

The participatory event *You and I*, *You and Me* included three collections of wearables: headwear, jewelry, and shoes. Since the wearables were made available for the audience to try out for aesthetic experience, the audience played as important a role in the event as the objects themselves. The audience was invited to experience the umwelt through different perceptions: visual and auditory as well as through direct electrical signals conducted through the scalp.

Interestingly, the audience participated enthusiastically in the participatory event and immediately reflected the objects through their own satisfaction or by sharing their enthusiasm with other audiences, turning their participation into an individual performance. Viewed from the side, the participatory event looked like a dance or theater performance, adding an additional cultural value on the art piece itself.

*136 Being responsible for other people and knowing that yogurt and kombucha may contain pathogens, I did not invite the audience to consume the products. This would have been possible under other circumstances, for example if I had an organization that operated such a production line, or if I could have found volunteers to make and test their individually produced yogurts. However, the idea remains open and may be realized in the future.

To be noted is also the role of the audience in both artworks, which was conceptualized as interaction with non-human organisms and machines. In the exhibition *Microorganisms & Their Hosts*, interaction between humans and non-human organisms was presented in equal terms; and in the participatory event *You and I, You and Me*, the role between humans, their umwelts, and machines was distributed equally. As within the latter case, the electrical signal played an essential role within the interaction between humans and non-humans, and provided a posthuman state described by Katherine Hayles (1999). In such a state, humans interacting with each other, with non-human organisms, and with machines shared the aesthetic experience.[140]

Thus, in Maker culture, in addition to the active participation of the audience in terms of reflecting historical references and dealing with social interaction, there is a new dimension that must be taken into account, namely the influence of the environment on the aesthetic experience. And because the perception of the audience is affected by others, including machines, I propose that the aesthetic experience of the posthuman state is different from that of the human state, which, in turn, suggests that the aesthetics of Maker culture is different from Fluxus performances, relational art, interactive works of the 90s, and the interactive installations described by Guljajeva as post-participative.

*140 In her lecture from 2021 Catherine Malabou refers to TrueNorth, a new type of microcontroller, developed by IBM which simulates neurons and synapses of a brain. Therefore the microcontroller develops “what we might call its own experience.” Lecture available at https://www.youtube.com/watch?v=8J235FFSO2A (Accessed 19 January 2022).

Discussion

The question of a posthuman state in which humans and computers merge was raised several times by the audience, leading to discussions about the vulnerability of such systems and the possible manipulations of the information in such systems.

Let's consider information being encoded in a form of an electrical signal. To transport the information in *You and I*, *You and Me*, I used electrical signals that were passed through the interface, or, in other words, the computing machine. Let's look again into the toolkit "Mycorrhizal Networks, or How I Hack Plant Conversations." Its setting involves feedback loops between a plant and a computing machine. Here, the chemical signal picked from a plant is converted into electrical impulses and sent to a computer; and vice versa: chemical signal of the plant is activated by electric impulses manipulated in a computer. When two different systems are connected through a machine by an electrical signal, a machine can affect the flow of information between the plant and its umwelt, changing the information being sent. Bringing in Claude Shannon's communication theory, I may speculate then that the transmitted signal could be manipulated by the different electrical potentials.[141]

In this context, I would like to bring in the Actor-Network Theory (ANT) of sociologist Bruno Latour and the concept of the rhizome of philosophers Gilles Deleuze and Félix Guattari. These examples might further help the understanding of information being shared between different actors.

The idea of ANT came from a sociological point of view, wherein Latour tried to rethink the meaning of social. While describing the traditional meaning of social

*141 For more details, see the subsection "Communication Systems and the Source Noise" of the section "al #2. 'Mycorrhizal Networks, or How I Hack Plant Conversations.'"

as a community defined by common attitudes, interests, and goals, Latour stated that such a definition of social needed to be redefined. Therefore, Latour extended the meaning of social into the world of other types of formats and activities, like law, science, technology, and so on (Latour 1987). From the perspective of Latour, the understanding of social has lost its physical representation and entered the realm of abstractions, which could be defined in the arts as, for example, concepts. The notion of social has shifted here from physical to abstract, and social in ANT has become a system of actors or abstractions interacting among themselves.

In Latour's sense, the ANT in *You and I, You and Me* would consist of humans, interfaces, and umwelt that would be equivalent in terms of actors in the network. Each node in the network would be an "actor" that transports information.

On the other hand, Deleuze and Guattari defined the rhizome[142] as a state in between things, situations, and concepts that is also a part of these things (Deleuze, Guattari 1980). As introduced in *A Thousand Plateaus*, a "rhizome has no beginning or end; it is always in the middle, between things, interbeing, intermezzo" (Deleuze, Guattari 1980, 25). It is like a bond, a mediator, between two homogeneous elements or two heterogeneous elements, such as a root and a stem. This bond, however, is not an endpoint of something, as it will always extend elsewhere within the territory (in terms of Deleuze and Guattari). One famous example of the heterogeneous in nature, but still carrying the idea of rhizome, is the interaction between a wasp and an orchid. Within this interaction, Deleuze and Guattari stated that, by being heterogeneous in nature through interaction, an orchid becomes similar to a wasp and vice versa. Being able to transport features, these elements together map a rhizome, or the rhizome becomes a medium for the transportation of information.

In both cases—the ANT and the rhizome—the elements are connected in the abstract environment, and they interact in transporting information. The difference here is the active part, where the information is being transported and translated or otherwise interfered with. If in *You and I, You and Me* the

*142 In the traditional use of the word, a rhizome is a botanical term defining a subterranean stem that is usually found underground connecting roots and sprouts; in other words, a rhizome is a part of a plant that is in between its root and its stem.

information would be interfered with by actors themselves—humans, interfaces, and the umwelt —in *Microorganisms & Their Hosts* the information would be interfered with by rhizomes. In both cases, I could think of Shannon and Weaver's (1964) communication theory, where information is being interfered with by noise. So there is not much difference in terms of vulnerability in a merged human and computing machine system. On the contrary, the possibility of transport of the information here can lead to new outcomes and meanings.[143]

*143 Niklas Luhmann, for example, puts an artwork into a larger social system which constructs the meaning (Luhmann 2000). While using the term Wiederbeschreibung (in English "redescription"), Luhmann gives some meaning to an object which, as an artwork, is established in the art system. Consequently, it is decrypted by finding connections to its references (Luhmann 2008).

Conclusions

The hypothesis established in this thesis pointed to the active participation of the audience in an artwork of a Maker culture, which indicated the need to actively experience the artwork itself. The context described was the posthuman one. At the same time the setting suggested the unlimited resources of knowledge and maker tools. Therefore, I raised the question: In what way does the hybridization of living organisms and non-living technologies affect art audiences in the culture that may be defined as Maker culture? To answer the question, I have chosen a practice-based research for engaging audiences in interactive artistic settings. The methods developed included interaction between humans and non-humans.

The interactive setting between humans and non-humans required me to think about my taken position toward aesthetics. I have wrapped up this position as posthuman aesthetics, which is different from the term used by the researchers at the Aarhus University. While the posthuman aesthetics introduced at Aarhus University follows the Hegelian type of understanding of aesthetics, e. g. the result of aesthetic experiences of an artwork, in this research, I have followed the aesthetics as presented by Dewey, e. g. as a process of experience itself. Furthermore, my proposed aesthetic experience uses the state of a posthuman that includes a merged living organism and a computing machine. Such a state was proposed by Katherine Hayles (1999). Still, with this term, I did not try to redefine aesthetics, but invited the reader to consider the impact of human and non-human actors by experiencing an artwork.

In the introduction, I referred to Varvara Guljajeva, who defined the role of the audience in the context of interactive installations as passive. According to Guljajeva, the data in interactive installations are used to create the performative character of an artwork, but not to trigger the audience in terms of their physical or otherwise experiential activity. Thus, within the referred interactive installations by Guljajeva, the audience had an inactive role, although the active role of the artwork itself remained. Such art has been defined a post-participative (Guljajeva 2018). I suggested that the post-participative arts would not contribute to the understanding of the work itself. More than that, such art would not stimulate the audience to understand the artwork, which in turn would have the potential to lead to a new outcome of cultural or economic value. Therefore, I proposed that in such a setting there would be no place for humanity—only for machines.

Being critical of Guljajeva's position and proposing different artistic methods, I came up with four new works—a set of four toolkits, *Introduction to Posthuman Aesthetics*; a set of four workshops as a *Self-Repair Lab*; a solo exhibition, *Micro-organisms & Their Hosts*, with six artworks and a workshop; and a participatory event, *You and I, You and Me*, with three new collections of wearables—all introduced in the main body of the research. The toolkits introduced new tools for individual artistic experimentation, while the workshops dealt with interactive settings involving humans, non-human organisms, and tools. The solo exhibition then questioned the impact of microorganisms on humans (and vice versa). And the participatory event reflected on the aesthetic experience of the audience through their interaction with umwelt, including machines.

A large chunk of the work concentrated on the production of artistic tools in the *Introduction to Posthuman Aesthetics*, which were assisting me within the duration of the research. For example, the toolkit "Mycorrhizal Networks, or How I Hack Plant Conversations" included a manual that introduced how to grow mycelia and set up a setting to capture electrochemical signals between different plants. The technical setting was elaborated with scientific and artistic contents, which was embedded in video tutorials. While the manual presented the scientific experiment by growing plants in two different containers, the artistic result was presented in the form of an audiovisual performance in the Brandenburg Forest. For further applications of the toolkit, I proposed the analysis of the effect of electric current on a plant, which could be evaluated by the captured electric signal from a plant with and without grown mycelia in the containers. For further artistic applications of the toolkit, I proposed sonification and visualization of data, implementing feedback loops between the plant and the computing machine.

To have the tools in the *Introduction to Posthuman Aesthetics* tested also by a broader audience, I have provided the Self-Repair Lab workshop series, reflecting themes developed within my artistic tools. So for example, the toolkit “My Collaboration with Bacteria for Paper Production” and the associated workshops *SCOBY*, *Shit and Humus* served as a base for the mutual interaction between different peers, including humans and different organisms. At the same time the toolkit “Ultra-Low-Voltage Survival Kit” and the workshop *I*, *Machine*, *and Energy Harvesting* served as a base for the mutual interaction between humans and machines. If toolkits in *Introduction to Posthuman Aesthetics* acted as the potential to produce new outcomes in solitude, the *Self-Repair Lab* provided the space and time for a collaborative experience.

The *Self-Repair Lab* brought me to what may be summarized as a cultural added value of the collaborative setting and the need for an active engagement of the audience in an artwork of Maker culture. As soon as the tools provided came into use, the participants asked questions about their meanings and possible uses, which ultimately put me in the position of an educator, suggesting the possible uses of the tools and the meanings behind them. The provided manuals that functioned as individual papers for specific thematic research, and the video tutorials that acted as a possible aesthetic result, helped me to avoid the didactic position of an educator. Instead, I followed the position of Papadopoulos (2014), with a strength on the added value of the made, and a pedagogical position through the mutual interaction. Such a setting provoked the workshop participants to implement new ideas upon the presented ones—a result which, unexpectedly, surprised me with the variety and quality of the developed ideas and the produced work in collaboration. The surprised outcome provoked me to try the collaborative setting from a participant position.

To have different perspectives on a collaborative setting, I chose to join an artistic workshop executed by Marc Dusseiller in collaboration with workshop participants. The deconstruction of the Hack*teria's Empathetic Taxidermia Lab* workshop brought me to new considerations. First of all, the development of ideas by other people were central in both, the *Self-Repair Lab* and the *Hackteria's Empathetic Taxidermia Lab*. Here, the leaders of the workshops provided instructions and tools to use, and the users, while interacting with scientific tools and methods, were engaged in artistic work themselves. Second, the leaders of the workshops, instead of thinking of their persons, needed to think additionally of the participants, who, besides learning about new tools and contexts, brought new outcomes in the form of a written idea, a built object, or a performed situation. These new outcomes needed to be discussed and put into the contexts again, so the role of the workshops' leaders extended into moderation and an active mediation of the ideas. While actively moderating and mediating ideas, the leaders of the workshops contributed to the work produced. By questioning the authorship of an artwork, considering the emergence of new ideas or forms, and pointing out the need for a mediating position, I have reached the point that the role of an artist has changed from being a central figure in an artwork to being a mediating figure of an artwork. This mediation included facilitation of knowledge between humans, non-humans, and machines.

The scenarios that led to the implementation of new ideas in a collaborative setting further provoked the materialization of my new ideas. They unfolded in two projects, the solo exhibition *Microorganisms & Their Hosts* and the participatory event *You and I*, *You and Me*. Following the *Self-Repair Lab* setting, I further used my tools developed within the *Introduction to Posthuman Aesthetics*. If the toolkit "My Collaboration with Bacteria for Paper Production" became a base for the solo exhibition, the "Ultra-Low-Voltage Survival Kit" became a base for the participatory event. The exhibition *Microorganisms & Their Hosts* explored the impact of microorganisms on humans (and vice versa).

Whereas, the participatory event added into the context computing machine. Both new projects wrapped up my idea of equally important actors in the artistic setting, including the non-human organisms and machines.

Conceptualized as a participatory exhibition of humans and non-human organisms, *Microorganisms & Their Hosts* explored the impact of microorganisms to the changing aesthetic experience of the audience. To elaborate on the changing aesthetic experience within the time, I used therapeutic methodologies to help people with lactose intolerance and lack of social bonds. And even if the exhibition was not implemented as fully as it was conceptualized, the access to scientific papers was able to trigger the imagination of the audience in terms of the changing aesthetic experience within time.

Similarly to the *Self-Repair Lab* workshop setting, the exhibition *Microorganisms & Their Hosts* offered an experience with the audience and, additionally, with microorganisms; whereas the participatory event *You and I*, *You and Me* incubated an atmosphere where participants got to interact with each other and, additionally, with computing machines. In this way, all three works were able to develop culturally loaded ideas in collaboration while making things, rather than in a conventional exhibition setting, where artifacts and artists are taken care of by the curator.

All three cases presented, *Self-Repair Lab*, *Microorganisms & Their Hosts*, and *You and I*, *You and Me*, faced the collaborative atmosphere with transferred knowledge, ideas, and meanings between the involved actors, either as direct references by the transferred knowledge between humans, sensory perceptions between humans and non-human organisms, or in peer-to-peer interaction with machines. By including DIY and DIWO strategies, the workshops of the *Self-Repair Lab*, the artworks of the exhibition *Microorganisms & Their Hosts*, and the participatory event *You and I*, *You and Me* proposed novel methodologies and novel formats of experiencing aesthetics that were given as part of the artworks. First, in contrary to Dorothea von Hantelmann's proposed unidirectional transfer of the meaning in contemporary artwork, all the artworks used a multi-directional interaction. Second, and in contrary to Yvonne Volkart's proposed context of artistic care, all the artworks stressed the avoiding of hierarchies between actors, including audiences and myself as an artist.

To wrap up, the position of an artist and the audience in Maker culture has changed. In Maker culture, the artist, while being a mediator, conjures connections between heterogeneous elements, such as audience and artist, plant and animal, digital and analogue, human and machine. The focus is laid on understanding diverse tools and the use of them to experience umwelt—both a virtual and a physical one. So the role of an artist in Maker culture is to mediate different knowledge and different positions, whereas the role of the audience is to actively engage in the artwork itself. Both audiences and artists may use artistic ideas to generate new hypothesis and incorporate them into new collaborative settings. In interactive settings, such as DIWO and participatory events that may be described as being of a posthuman state, the cultural added value is then built by extending artistic processes to areas other than art and by incorporating scientific and technical tools into art.

As suggested through the artworks, interaction between humans, non-humans, and machines defies borders between digital and analogue, living and non-living, processed and static. Thus, aesthetics of Maker culture defies borders between audiences and artists, engineering and creativity, theory and practice. Aesthetics of Maker culture also utilizes a variety of methods in the convergence of philosophy, science, and technology, and tends to unfold in non-traditional aesthetic forms and concepts, including those developed to be experienced with computing machines or while experimenting with biological forms. Finally, the aesthetics of Maker culture takes into account the impact of the umwelt on the aesthetic experience.

While bringing Maker culture into artistic discourse, my intention was to merge artistic, scientific, and technological perspectives. This, first of all, should have paved my understanding of all perspectives as equally important, both including and transcending any one field. To support my insights, I integrated my artistic practices into Maker culture and analyzed a number of activities implementing living organisms and computing machines. Also, I tried to question situations that are currently being discussed among futurologists, technicians, artists, and media theoreticians, thus making a contribution to the role of artist and audience in Maker culture. Although my combined artistic and written work does not provide an explicit need to be integrated into future societies, it is intended that the developed methodologies could at least be further adapted in artistic practices, philosophy, anthropology, and environmental studies.

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Annex I. Experiment #1: SCOBY and Kombucha Tea

This experiment introduces the growth of SCOBY, which, if dried out, could be used as bacterial paper (Fig. 6). The experiment could also be useful from the perspective of consumption because the growth of SCOBY produces a fermented tea, which could be imbibed as a beverage. If the fermentation process takes longer, the result could be used as a vinegar for different meals.

To prepare 50 ml of liquid to grow SCOBY and to also brew kombucha tea, we will use:

Equipment:
- An electric stove;
- A strainer;
- A sheet of baking paper;
- A piece of cloth;
- A jar;
- Scales.

Ingredients:
- A piece of the SCOBY within kombucha tea – 5 ml;
- Tap water – 50 ml;
- Green tea – one tea bag;
- Sugar – 2.5 g.

- Boil the water in order to kill unwanted microorganisms.
- Add a tea bag. Leave it in for at least 10 minutes to steep and throw it away afterwards.
- Add sugar and mix the solution thoroughly until the sugar dissolves.
- Allow the tea solution to cool to room temperature and add to it the sample of the SCOBY with kombucha tea. Place the jar in a safe place. It will take 2 to 3 days to see the start of the formation of the new SCOBY. After around 10 days, your SCOBY floating on top of the tea should reach 3 to 5 mm in thickness.
- Use a strainer to strain it from the unwanted bacterial pellicle. The brewed kombucha tea should be ready to drink.
- Put the grown SCOBY on the baking paper and let it dry for a couple of days until the pellicle is ready to be used as bacterial paper.

For further experimentation, use black tea, redbeet juice, or other natural ingredients. You may also want to experiment with growing the pellicle for different lengths of time, or in differently shaped containers (Gapševičius, 2019).

Fig. 68 Bacterial paper.
Photo: Mindaugas Gapševičius

Annex II. Experiment #2: Preparation of Media for the Growth of Acetobacter

This experiment introduces the isolation of Acetobacter from the SCOBY culture. The experiment shows how to inoculate microbial species from one single colony, which could be interesting for further research and analysis of living organisms. The grown Acetobacter could be further used for the production of cellulose. To prepare 50 ml of Acetobacter medium, we will use:

Equipment:	Ingredients:
- an electric stove	- a sample of the SCOBY within kombucha tea
- a knife	- glucose – 1 g
- a marker	- peptone – 0.25 g
- a jar	- yeast extract – 0.25 g
- agar plates	- disodium phosphate – 0.14 g
- a pipette	- agar – 0.8 g
- scales	- citric acid – 0.08 g
	- distilled water – 50 ml

- Mix the ingredients as outlined.
- Boil the mixture in order to sterilize it.
- Sterilize the agar plates provided.
- Pour the medium into each of them, and leave it all to stiffen.
- Cut a couple of square millimeters of SCOBY out of the culture provided.
- Put the pieces of SCOBY into the empty jar. You may add some kombucha tea as well.
- Add some distilled water to the jar.
- Shake the mixture for a couple of minutes so the microorganisms dissolve into the water.
- Pour a drop of the solution onto the first plate.
- Spread the solution with the paper clip.
- Prepare a 1:10 solution of dissolved microorganisms (Fig. 69); use a pipette and the empty jar.
- Pour one drop of the solution onto the second agar plate.
- Spread it with the sterile paper clip.
- Repeat the 1:10 dilution with the diluted solution and pour the third agar plate. Repeat this process with the forth and the fifth agar plates. This will insure that

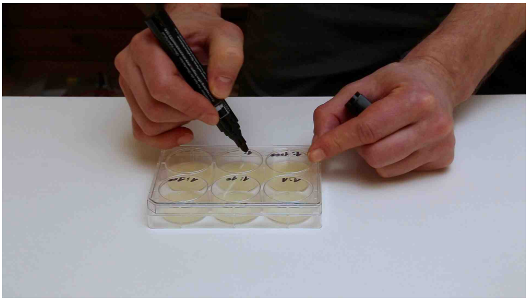
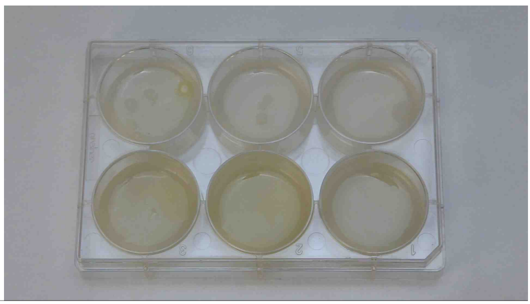


Fig. 69. Different solutions of dissolved microorganisms. Video still

you identify the Acetobacter colony grown from one single bacterium. Leave the sixth plate unchanged.
- Label your agar plates with a permanent marker for your records.
- Flip the agar plates upside down and leave them at room temperature for the next two to three days.
- After those two to three days, inspect your agar plates (Fig. 70).
- In our case, the first agar plate shows diverse colonies of bacteria that spread all around, and one colony of yeast that developed on the right side of the plate. The second plate has three colonies of *Acetobacter* in the middle of the plate. The third plate has only one colony on the right side. The fourth and fifth plates have no bacteria and no yeast, which means that the sample with kombucha had been diluted too much. So, the most successfully isolated bacteria are on the second and third agar plates. We will use the colony on the third plate for the new inoculation.
- Use the sterile paper clip to take the visible sample of the *Acetobacter* bacteria from one colony.
- Inoculate it into the sixth agar plate by carefully placing it onto the gel. If the experiment was successful, it should be clean.

For further experimentation, try isolating the *Lactobacillus* bacteria or *Candida* fungi found, for example, in saliva. Use medium appropriate for the microorganisms you want to isolate.

Fig. 70. Acetobacter growth after two to three days. Video still



Annex III. Experiment #3. Growing Mycelium on Coffee Grounds

In this experiment we will begin to grow mycelium (Fig. 71). The grown mycelium will be used for connecting electronic components to sense electric potentials among different organisms in the habitat. For the experiment, we will use coffee grounds and dowels with mycelium. In case different amounts of ingredients are needed, purchase mycelium dowels online from a commercial mushroom supplier. Coffee grounds can be collected at home. For the experiment we will need:

Tools:
- a petri dish
- a strainer
- a small pot
- an electric hot plate

Components:
- coffee grounds
- oyster mushroom dowels
- water

Fig. 71. Dowels with mycelium on coffee grounds. Video still

- Put coffee grounds into a pot and pour water on top so it covers them.
- Sterilize the coffee grounds by cooking them for ten minutes on a hot plate.
- Strain the coffee grounds. Leave them for a couple of minutes to cool down.
- Put the coffee grounds into the petri dish and wait until they reach room temperature.
- Add the dowels with oyster mycelium inside to the coffee grounds and cover the petri dish.
- Place the petri dish in a dark place.
- Inspect your coffee grounds after a couple of days. In two to three weeks, you should have your coffee grounds colonized by mycelium.

For further experimentation, grow larger amounts of mycelium, plant the seeds provided, and connect the grown plants to electronics. Also experiment with different substrates for growing mycelium, for example, wood chips, cardboard, and so on.

Annex IV. Experiment #4. Sensing Electric Potentials in Living Organisms

Once the mycelium has reached a level you are happy with, we will build an electronic interface in order to bridge the mycelium with a computer and measure small electrical impulses in the mycelium (Fig. 72). For the experiment we will need:

Tools:

- an AD620 amplifier
- a breadboard
- a 100 µF capacitor
- 1 kΩ resistors – 3 units
- an Arduino microcontroller with software
- jumper wires
- an A-B USB cable
- electrode patches – 2 units
- computer

Components:

- a mushroom and mycelium
- plants

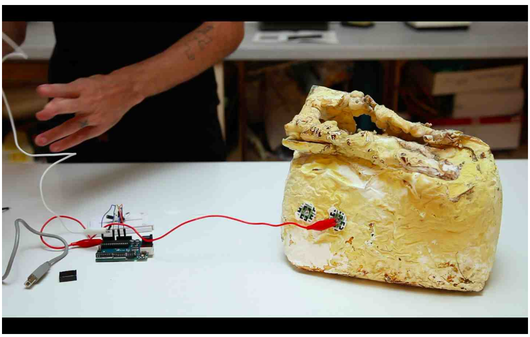


Fig. 72. Building an electronic interface to capture impulses in the mycelium. Video still

- Place the operational amplifier provided on the breadboard with its legs bridging the middle gap in the breadboard.
- Connect the 100 micro-farad capacitor between pin 4 and pin 7. The capacitor smooths the power supply from the Arduino.
- Place the 1 kilo-Ohm resistor between pin 1 and pin 8. This resistor sets the amplification of the organism's signal to a factor of 50.
- Connect pin 5 (reference) to the grown plants. The pin sets the ground reference for the amp.
- Add the two other resistors at pin 5 with one ending at pin 7, which is the power, and the other at pin 4, which is the ground.
- Connect pin 7 to the power source and pin 4 to the ground of the Arduino microcontroller.
- Connect pin 6 to the analogue input A0 of the Arduino.
- Pins 2 and 3 of the operational amplifier are then connected to the electrode patches, which are then attached to the grown mycelium.
- Connect pin 5, the reference, to the grown mycelium. The pin sets the ground reference for the amp.
- Connect the Arduino microcontroller to the computer using the USB cable provided.
- Open the Arduino application and set the port and the board in the preferences.
- Open the sketch by going to File, then Examples, then Basics, then click AnalogReadSerial. In the window, click the right-pointing arrow to upload it onto the microcontroller.
- Go to Tools, open the Arduino Serial Plotter, set the signal rate to 9600, and see the variation of electric potential in mycelium in action.

For further experimentation, use different mycelium, different sorts of plants, and/or other organisms, including yourself.

Annex V. Experiment #5. Assembling and Testing the Mycelial Radio Transmitter

In this experiment, we will build a very simple FM (frequency modulation) radio transmitter, which will use a mushroom and mycelium as part of its transmission circuit (Fig. 73). The transmitter will respond subtly to changes in the mushroom body, signals in the room, and the proximity of human and other bodies. The circuit we are assembling re-purposes a logic chip and a few components, and the signal can be received on the simplest FM/AM radio receiver, which you can find easily. We will need the following electronic parts and components:

Electronic parts:

- a diagram of the circuit
- the operational amplifier provided
- 2 10 pico-farad capacitors
- a 33 pico-farad capacitor
- a 100 nano-farad capacitor
- a 1 kilo Ohm resistor
- a printed circuit board
- a battery pack and three AAA batteries
- stiff copper wire for antennas and the mushroom connection

Components:

- a mushroom and mycelium
- a diagram of the circuit
- a soldering iron and solder
- a wire cutter
- an FM radio receiver

- Orient the printed circuit board according to the diagram (the view is from the top down). You will place parts from the top and solder them from the bottom.

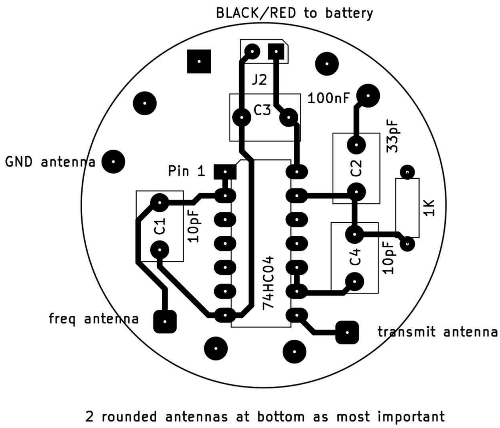


Fig. 73. Circuit diagram of the mycelial radio transmitter. Sketch: Martin Howse

- Place the operational amp chip provided (the fourteen-legged item) from the top onto the board. Pin 1, which is just underneath the notch, should be as in the diagram (Fig. 73). Turn it over and solder each leg in turn.
- Place and solder the four capacitors (of differing values) and the one resistor as indicated.
- The long leads on the bottom can now be clipped after you have soldered everything.
- Solder the battery holder with the red lead to the right, black lead to the left.
- Solder one thick 10 cm-long bare wire to the "frequency antenna" spot and one to the "transmit antenna" spot.
- Insert the "frequency antenna" wire into the mushroom body.
- Put batteries in (and switch on if the battery holder has a switch option).
- Switch on the radio, place it about one meter from the mushroom, and make sure it is set to FM with the switch. Tune the dial until you hear the sound change.

For further experimentation, try inserting wires into different parts of the mushroom, connect more transmitters to other mushrooms in the same space.

Annex VI. Experiment #6. Using Built Tools for Feedback Loops Between Plants and Computing Machines

In this experiment, we will use the built tools to set feedback loops between the electric potentials sensed in the grown plants and rewired with electric potentials in the Pd patch provided (Fig. 74). The idea is to influence the growth of plants and mycelium with the electric potentials generated in response to the sensed electric potentials. Finally, we will use the generated signal for the audiovisual expression. We will need:

Tools:
- an Arduino microcontroller with software
- Pd software with the provided pduino libraries
- previously assembled sensor for sensing electric potentials
- an A-B USB cable
- additional electrode patches – 2 units
- jumper wires and alligator clips

Components:
- previously grown mycelium
- previously grown plants

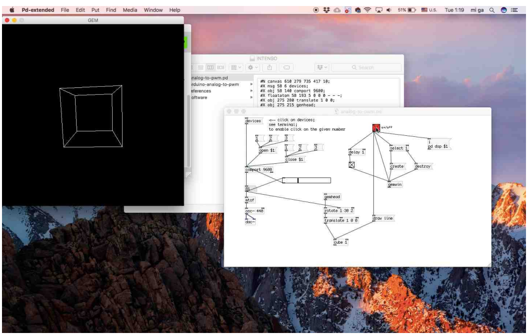


Fig. 74. Pd patch. Screenshot

- Attach pin #9 of the Arduino microcontroller to an electrode and place it next to one of the electrode patches of the sensor connected to the plants.
- Attach the "ground" of the Arduino microcontroller to another electrode patch and place it next to the second electrode patch connected to the plant in such a way that both electrode patches appear in between the electrode patches of the Arduino microcontroller.
- Open the sketch by going to Finder, then to the USB memory stick provided, then the Arduino-analog-to-PWM folder, then open the Arduino-analog-to-PWM file.
- In the window, click the right-pointing arrow to upload it onto the microcontroller.
- From the Finder window, open the analog-to-PWM patch with the "extended" version of Pure Data.
- Open the active port of the Arduino microcontroller by clicking on the object [devices] followed by clicking on one of the numbers below corresponding to the active port. Activate the [on/off] object of the PD patch so that the patch updates the values captured on the object, turns on the speakers, and activates the window for visuals. If everything is done correctly, the scale of the slider in the patch should start moving left and right, and you should hear sound and see visuals.

For further experimentation, add new objects to the Pd patch and change the audiovisual performance.

Annex VII. Experiment #7. Human Battery

In this experiment, we will build a circuit for an LED to be lit up by a human body (Fig. 75). This circuit uses a self-oscillating voltage booster, also known as a joule thief. For the experiment, we will use:

Components:
- a breadboard
- a coupled inductor
- copper and zinc electrodes – one of each
- a 2N3904 transistor
- a 1 kΩ resistor (optional)
- a 10 μF capacitor
- a low current LED
- jumper wires – 6 (7) units
- alligator clips – 2 units

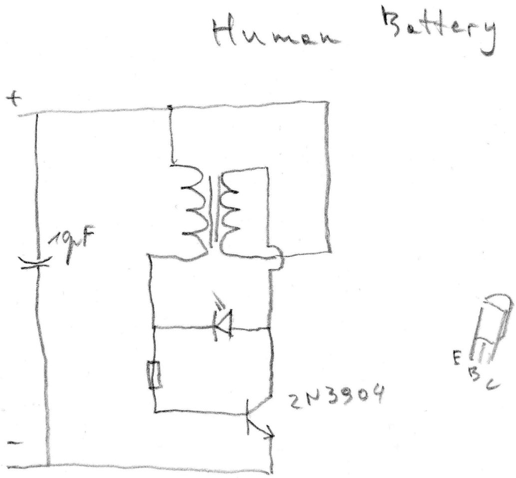


Fig. 75. The circuit for an LED lit up by a human body. Within the circuit, the electrode marked “+” is meant to be copper, and the electrode marked “-” is meant to be aluminum. The copper electrode could be replaced with, for example, graphite, and the aluminum with zinc. Other variations are also possible. Sketch: Mindaugas Gapševičius

- Push the transistor provided into the terminal strips with the collector leg on the left side and the emitter leg on the right side of the breadboard. Each of the three legs of the transistor should be allocated a different terminal strip (Fig. 76).

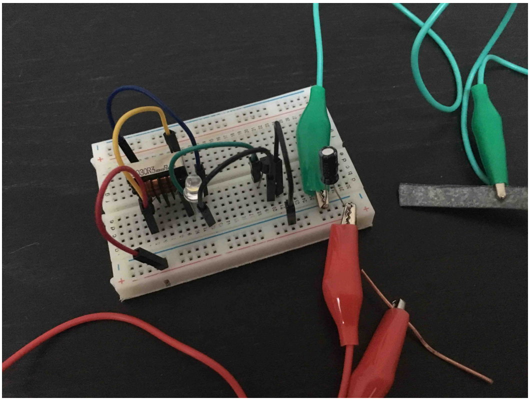


Fig. 76. An LED lit up by the human body.
Photo: Mindaugas Gapševičius

- Push a coil into the middle of the breadboard, left of the transistor, so each of the four legs of the coil is allocated a different terminal strip.
- Take a jumper wire and connect the bottom-left leg of the coil with the top-right leg of the coil.
- Connect the bottom-left leg of the coil with a power rail on the breadboard.
- Take an LED and push the long leg into the terminal strip with the bottom-right leg of the coil, then push the short leg into the empty strip on the breadboard.
- Connect the short leg of the LED with the top-left leg of the coil.
- Connect the collector leg of the transistor with the long leg of the LED.
- Connect the base leg of the transistor with the short leg of the LED.
- Connect the emitter leg of the transistor with the ground rail on the breadboard.
- Take a 10 μF capacitor and push its long leg into the power rail and its short leg into the ground rail.
- Take a copper electrode and connect it to the power rail, then connect a zinc electrode with the ground rail on the breadboard. Use the alligator clips provided.
- Take both electrodes in your hands. If the circuit has been connected correctly, the LED should start blinking.

For further experimentation, try to replace the copper electrode with, for example, graphite, and the zinc electrode with aluminum. Other variations are also possible, including the use of a potentiometer instead of a resistor, a Peltier element with an additional "joule thief" provided, different coils, and different capacitors.

Annex VIII. Experiment #8. Assembling a Symbiotic Synth

The experiment introduces and shows how a symbiotic synth works. It is a small synthesizer that is powered by body heat or, to be precise, the heat difference between the body and environment (Fig. 77). For the experiment, we will use:

Components:
- a breadboard
- 22 kΩ resistors – 3 units
- a 100 kΩ potentiometer
- a 330 pF capacitor
- a 1 nF capacitor
- 22 nF capacitors – 2 units
- a 1 µF capacitor
- 220 µF capacitor – 2 units
- BC547 transistors – 2 units
- a LTC3108 chip with 16-pin SSOP adapter
- a coupled inductor
- a low current LED
- a mini switch
- mono minijack sockets – 2 units
- airplane headphones
- a Peltier element
- a cooler
- jumper wires – 10 units

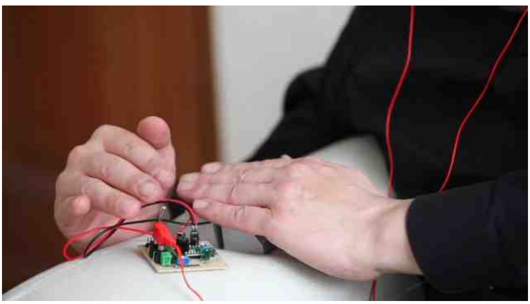


Fig. 77. A Symbiotic Synth. Video still

For building the circuit, besides the circuit board, we will need some resistors and capacitors in order to produce and store the energy. We also need some capacitors and two transistors for oscillating the circuit. The most important part is a small chip, LTC3108, which is a DC/DC converter. In combination with a coupled inductor 1:100 it will boost the voltage up to around two volts and with that it will power the oscillating circuit. The potentiometer will be needed for adjusting the frequency.

You also have to be careful with the polarity of the LED, the transistor, and the electrolyte capacitors. The headphones from airplanes, which have two mini-jacks, will be used instead of additional resistors.

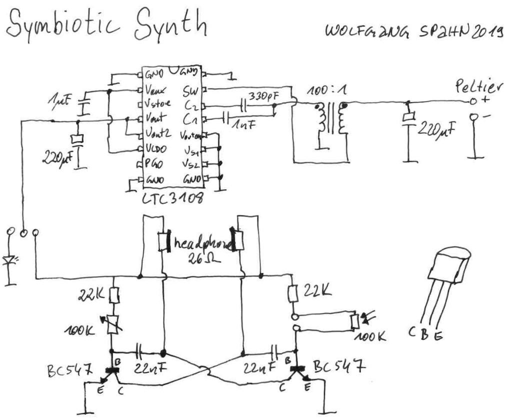


Fig. 78. The circuit of the Symbiotic Synth. Sketch: Wolfgang Spahn

Build a circuit as depicted in the sketch (Fig. 78). For further details, please refer to the website[144] or print the PCB sketch for a stripboard provided.

In order to see if the circuit works, lay your hand down on the Peltier element. The LED should light up if the body generates enough heat or the heat generates enough electricity. Switch the circuit to audio mode—you should be able to listen now to

*144 Available at http://paperpcb.dernulleffekt.de/doku.php?id=sound_boards:symbiotic_synth (Accessed 21 April 2019).

the synthesizer sound. That sound could be changed by readjusting a potentiometer or by adding additional sensors, like a light or a temperature sensor.

While the sound runs on headphones, the oscillations can be inspected with an oscilloscope (Fig. 79). The oscilloscope will show the peeks and oscillations of the circuit. Listen to the sounds while taking your hand away from the Peltier element. The oscilloscope will show the frequency decrease, which means the circuit is not generating electricity. The moment you heat it up again with your hand, it will resume oscillating.

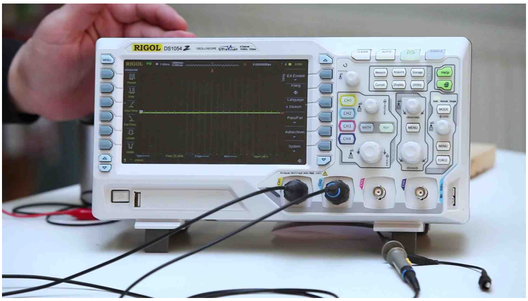


Fig. 79. Inspect oscillations with an oscilloscope. Video still

For further experimentation, readjust a potentiometer, replace a jumper wire with a light sensor, replace coupled inductors, or use more Peltier elements connected in series with no or differently shaped cooling elements. Also try experiencing audiovisual performances together with other people (Fig. 20).

Annex IX. Experiment #9: Polymerase Chain Reaction

In this experiment, we will amplify the LCT gene's regulator. For the amplification we will use a polymerase chain reaction technique. In order to amplify 50 µl of the sample, we will need:

Samples and chemicals:

- a sample of saliva – 1.25 µl
- Phusion DNA polymerase from Thermofisher[145] – 1 µl
- 2 x Phusion buffer from the Specimen Direct PCR Kit – 25 µl
- forward and reverse primers[146] – each 2.5 µl of 10 µmol working solution
- distilled water – 17.75 µl
- paraffin or other mineral oil – 10 µl

Equipment:

- a thermocycler with a power supply and an Arduino microcontroller
- Eppendorf 1.5 ml tubes – 3 units
- Eppendorf 0.5 ml tube
- a DremelFuge
- a 1 to 10 µl pipette
- pipette tips – 8 units
- a computer with the Arduino and Python 3 software preinstalled
- a Python script to control a thermocycler

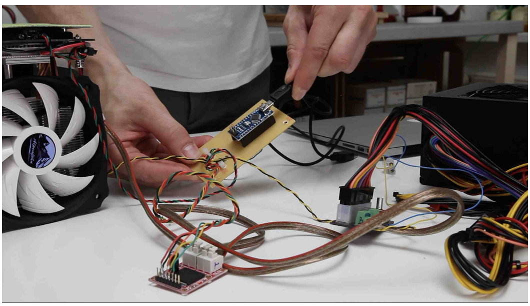


Fig. 80. Thermocycler connected with the Arduino and computer. Video still

*145 Order the kit at https://www.thermofisher.com/order/catalog/product/F150BID (Accessed 2 September 2018).

*146 Forward (5'-GTTGAATGCTCATACGACCATG-3') and reverse (5'-TGCTTTGGTTGAAGCGAAGATG-3') primers. Order the primers, for example, at https://webstore.biomers.net/OligoOrder/OligoOrder.aspx (Accessed 2 September 2018). The XS amount included will be sufficient.

- To begin with the experiment, connect the thermocycler with the Arduino in order to control it. Also connect the power supply to provide voltage to it (Fig. 80).
- Connect your computer with a USB cable to the Arduino microcontroller.
- Open the Arduino software and check what port it is connected to.
- Open the provided Python code and insert the correct port in the document.
- In the same Python code, set the activation temperature of Phusion polymerase to 98°C and let it run for sixty seconds. Set the cycles: 98°C for DNA denaturation (set the time to one second), 63°C to let the primers bind (five seconds), and 72°C for polymerase to complete the DNA sequence (twenty seconds). Repeat this cycle forty times; keep the final temperature of 72°C for one minute and leave your samples at a refrigerator temperature of 4°C until you are ready to store the samples in the freezer.
- Run the provided Python code on the terminal and see if there are no errors. Terminate the running program by pressing the cntrl+c keys.
- Mount the DremelFuge provided onto the drill.
- Collect some saliva in one of the 1.5 ml Eppendorf reaction tubes provided.
- Add 1.25 µl saliva, 25 µl of Phusion buffer, 2.5 µl each of the forward and reverse primers, and 17.75 µl distilled water. Finally add 1 µl of Phusion polymerase.
- Mix the tube gently and insert into the DremelFuge.
- Add 50 µl of saliva into the remaining empty 1.5 ml tube, and insert the tube into the DremelFuge diagonally to the other tube.
- Let the drill spin the DremelFuge for about two seconds.
- Take 20 µl of the mix into the 0.5 ml Eppendorf reaction tube.
- Add 10 µl of mineral oil on top.
- Place your Eppendorf reaction tube into a thermocycler and start it by executing the Python code provided. The thermocycler will run for about an hour.

For further experimentation, extract DNA from a small piece of skin, the roots of hair, or any meat of a mammal.[147] Instead of Phusion buffer you might want to try a Taq 2x polymerase master mix.[148] Also try using a proper thermocycler[149] and a centrifuge. Be sure that you have the right frequency of revolutions per minute (RPM), which will be mentioned in the documentation provided.

*147 Use, for example, a “DNeasy Blood & Tissue Kit” from Qiagen. Order the kit at https://www.qiagen.com/de/shop/sample-technologies/dna/genomic-dna/dneasy-blood-and-tissue-kit/#orderinginformation (Accessed 4 November 2017).
*148 Order, for example, at https://www.neb.com/products/m0270-taq-2x-master-mix#Product%20Information (Accessed 2 September 2018).
*149 Get it at eBay or at OpenPCR. Available at https://openpcr.org/ (Accessed 2 September 2018).

Annex X. Experiment #10: Electrophoresis

In this experiment, we will use a gel electrophoresis in order to see if the polymerase chain reaction was successful. The experiment will tell if the LCT gene's regulator was amplified to the sufficient amount in order to proceed with the analysis. For the experiment, we will need:

Samples and chemicals:

- an amplified DNA sample
- paraffin or other mineral oil – 10 µl
- agarose – 1 g
- 50 x TAE buffer – 4 ml
- distilled water – 200 ml
- SERVA DNA Stain G – 1.5 µl
- 100 base pairs DNA ladder – 5 µl
- 6 x coloring dye – 2 µl

Equipment:

- an empty Eppendorf 0.5 ml tube
- a power supply
- a gel electrophoresis chamber
- a 1 to 10 µl pipette
- pipette tips – 5 units
- an Electric stove or a microwave
- a knife
- a 200 ml glass flask
- a UV light
- a filter for the UV light
- precision scales

- For the beginning, prepare a 1% agarose concentration gel. Pour 100 ml of distilled water, 1 g of agarose, and 2 ml of TAE buffer into a glass flask.
- Heat it up until it boils. The agarose should be completely dissolved.
- Pour the agarose solution into the plastic container provided. Wait until it cools down to approximately 60°C. Use the time to wash the glass flask—we will need it again later.
- Add 1.5 µl of SERVA DNA Stain G and mix thoroughly to dissolve it. The SERVA DNA Stain G is needed in order to exhibit the molecules under the UV light.

- Place a plastic comb on the top of the container—it will make wells within the gel. If the comb doesn't hold well, use a paper clip or alternative to attach it to the side of the container. Wait until the gel thickens. In order to accelerate the process, we will place our container into a fridge.
- Take the container out of the fridge and cut approximately 2 cm of the gel next to the shorter sides of the plastic container provided. Throw out the cutouts.

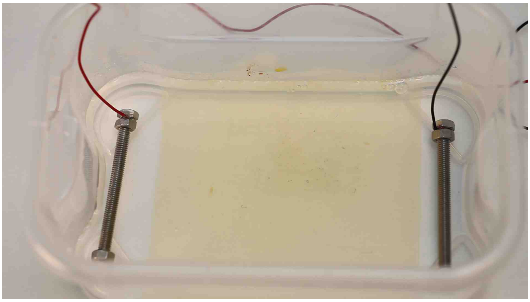


Fig. 81. Placed electrodes in the cutouts of the gel. Video still

- Place the electrodes into the cutouts (Fig. 81) and attach the wires to the power supply. Attach the red wire of the electrode to the yellow wire of the power supply provided and the black wire to the blue wire of the power supply. This combination will output 24 V of electric potential. Do not turn on the power supply yet!
- Pour 100 ml of distilled water into a glass flask and add 2 ml of the TAE buffer. Pour the buffer on top of the gel. Be sure that the buffer floods the electrodes and the gel.
- Pipette 5 µl of the DNA ladder into one of the gel pockets.
- Take an Eppendorf tube with a DNA sample and carefully take 5 µl of the sample. Pipette it into a new Eppendorf tube. Add 2 µl of the coloring dye. Mix the solution gently.
- Pour the solution into a well of the gel next to the DNA ladder.
- Turn on the power supply and let the electric potential flow through the chamber for about forty to fifty minutes.
- Inspect the results with the UV light. You might need a filter in order to see the fluorescent molecules. The fluorescent molecules of your result should be concentrated next to the measurement with 370 base pairs of the 1 kb DNA ladder (Fig. 28).

For further experimentation, use ethidium bromide for DNA detection in a gel, a 40% glycerol instead of coloring dye, and a different percentage of agarose. Run electrophorese with a different power supply and at different time lengths. For precise results, try also using a proper electrophoresis chamber.

Annex XI. Experiment #11: DNA Fingerprinting

DNA fingerprinting is a similar method to the previous one, except for the additionally added restriction enzymes, which cut DNA at specific sequences. This experiment will look at a single nucleotide mutation in a LCT gene's regulator. There are additional steps at the beginning and at the end of the experiment. In order to run the experiment we will need:

Samples and chemicals:

- an amplified DNA sample with the paraffin oil on top
- paraffin or other mineral oil – 10 µl
- agarose – 2 g
- 50 x TAE buffer – 4 ml
- distilled water – 200 ml
- SERVA DNA Stain G – 1.5 µl
- 20 base pairs DNA ladder – 5 µl
- 6 x coloring dye – 2 µl
- a restriction enzyme – 1 µl
- 10 x NEB buffer – 2 µl
- distilled water – 7 µl

Equipment:

- an empty Eppendorf 0.5 ml tube
- a thermocycler with a power supply and an Arduino microcontroller
- a computer with the Arduino and Python 3 software preinstalled
- a Python script to control a thermocycler
- a gel electrophoresis chamber
- a 1-to-10 µl pipette
- pipette tips – 5 units
- an electric stove or a microwave
- a knife
- a 200 ml glass flask or an alternative
- UV light
- a filter for the UV light
- precision scales

- To begin with the experiment, connect the thermocycler with the Arduino in order to control it, and connect the power supply to provide voltage to it.
- Connect your computer with a USB cable to the Arduino microcontroller.
- Set the temperature cycles in the Python code so it incubates the sample. In order to do so, we will set the start temperature at 37°C and let it run for more than an hour. Leave the rest of the code untouched.
- Take an Eppendorf tube with a DNA sample and carefully take 10 µl of the sample. Pipette it into a new Eppendorf tube.
- Take a new tip and add to the sample 2 µl of NEB buffer.
- Add 1 µl of the restriction enzyme to the solution.
- Add 7 µl of the distilled water to the solution. Mix gently.
- Add 10 µl of the paraffin oil to the solution.
- Place the Eppendorf tube into the thermocycler and run the Python code provided in the terminal. After one hour, terminate the running program by pressing the cntrl+c keys.
- Proceed with the steps described in experiment number two.
- Inspect the results with the UV light. You might need a filter in order to see the fluorescent molecules. The fluorescent molecules of your result should be concentrated next to the different measurements with up to fifty base pairs of the 1 kb DNA ladder (Fig. 28).

Annex XII. Experiment #12. Isolating the *Lactobacillus* spp. Bacterial Strain

This experiment introduces the isolation of the *Lactobacillus* spp. bacterial strain from yogurt purchased from the supermarket. Some *Lactobacillus* bacterial strains that live in the human gut—for example, *Lactobacillus reuteri*—may upregulate oxytocin (Varian et al. 2017), a hormone that plays a role in social bonding and sexual reproduction. To prepare 150 ml of the medium, we will need:

Equipment:

- pot
- electric stove
- 2 flasks
- 5 petri dishes
- pressure cooker
- incubator
- refrigerator
- pipette (ml or μl)
- paper clip
- 70% alcohol for sterilization of your desk and tools

Ingredients:

- yogurt with *Lactobacillus* spp. Bacteria (commonly found in Greek yogurt)
- 7.8 g MRS broth[150]
- 2 g agar
- 200 ml distilled water

- Suspend MRS powder in 150 ml of distilled water. Divide the solution into two flasks, one with 100 ml for use with the agar medium and another with 50 ml for the liquid medium.
- Add 2 g of agar to the flask with 100 ml of distilled water. To ensure homogeneity, shake the flask well before use.
- Mix well and heat with frequent agitation until the medium comes to a boil.
- Sterilize by cooking in the pressure cooker for fifteen minutes. At the same time, sterilize the liquid MRS broth.

*150 You can get the broth, for example, at Merck KGaA, https://www.sigmaaldrich.com/DE/de/product/sial/69966. (Accessed 24 February 2022)

- Cool down the agar medium enough that you can handle the flask with your hands, then pour it into five petri dishes, each up to approximately 5 mm, and leave until the medium stiffens.
- Add about 1 ml of yogurt into 10 ml of sterile water. Be sure that the water is no warmer than body temperature. Shake well.
- Take a drop of diluted yogurt with a pipette and release it onto the first stiffened petri dish. Distribute evenly. Dilute the diluted yogurt with 10 ml of sterile water and release onto the second petri dish. Repeat this action two more times. Leave one petri dish with no yogurt.
- Leave the petri dishes in the incubator at 37°C for two to three days until you see the formed bacterial colonies.
- Inspect your bacterial colonies. Take a sample of *Lactobacillus* and transfer it to a fresh petri dish with stiffened medium. Use a sterile paper clip to distribute the sample around the petri dish. Leave for two to three days in the incubator until the colonies have formed.
- Take some biomass from the grown bacterial colonies and mix it into the liquid MRS broth. Leave the bacteria in the incubator at 37°C for a couple of days to colonize the medium.
- Store the liquid MRS broth with the bacterial strains in the refrigerator at 2 to 8°C.

Annex XIII. Experiment #13. Preparation of Yogurt with *Lactobacillus* Bacterial Strain

In this experiment, we will prepare the required amount of yogurt and use it for therapeutic purposes, and, in so doing, we will set up bidirectional communication between the brain and the gastrointestinal tract—the so-called "brain-gut axis." The brain-gut axis is a complex system that includes the vagus nerve, which connects the emotional and cognitive areas of the brain with gut functions. To prepare 3.5 liters of yogurt, we will need:

Equipment:
- pot
- 3-liter jar
- electric stove
- incubator

Ingredients:
- 3.5 liters cow milk, any fat percentage
- bacterial colonies in a liquid medium (see Experiment #1 in Annex 1)

- Pasteurize the milk by cooking it in a pot for fifteen minutes.
- Cool it down to room temperature.
- Transfer the milk to the 3-liter jar.
- Add the liquid culture with *Lactobacillus* spp. bacterial strain to the milk. Mix evenly.
- Leave the milk in the incubator at 37°C for two to three days, after which point it will be yogurt that is ready to eat.
- Consume the yogurt daily for one week, 0.5 liter per day.

Annex XIV. Headwear

The headwear uses medical strategies based on brain cell communication: the electrical impulses are detected on the scalp while using electroencephalography, and brain stimulation is triggered by passing DC current through electrodes, a noninvasive method to treat depressive disorder, increase empathic abilities, or decrease antisocial behavior in violent offenders.

The headwear pieces have Wi-Fi modules, which allow the audience to connect different headwear pieces to each other and control them through tablets or cellphones. While the data is transmitted over Wi-Fi, the location is defined through the GPS data. If the GPS signal is too weak (which is often the case in exhibition spaces) or if only one piece of headwear is set up, the audience can experience their own brain activity while connecting their own headwear through a tablet or a cellphone. In this case the EEG signal is picked up on an individual cortex and transmitted through the same cortex, making a feedback loop between the EEG (Fig. 82) and tDCS (Fig. 83) modules and the cortex.

The collection of headwear that questions the boundaries of empathy and the intertwining of brain and umwelt is part of a larger project, *You and I*, *You and Me*, which explores the possibilities of communication through electricity.[151]

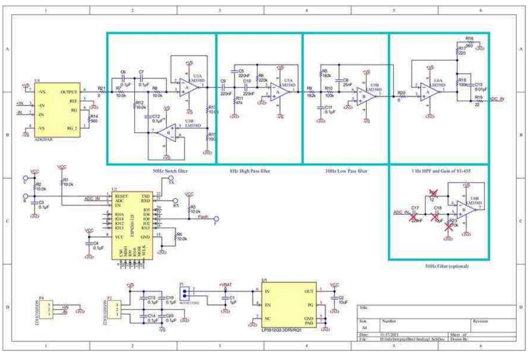


Fig. 82. Circuits of the EEG module. For a better quality image, see http:// triple-double-u.com/you-and-i-you-and-me-media/WiFiEEGsch.pdf (Accessed 2 January 2022). For the Arduino script, see http://triple-double-u.com/you-and-i-you-and-me-media/ ESP8266_EEG_Transmitter_210802.ino (Accessed 2 January 2022)

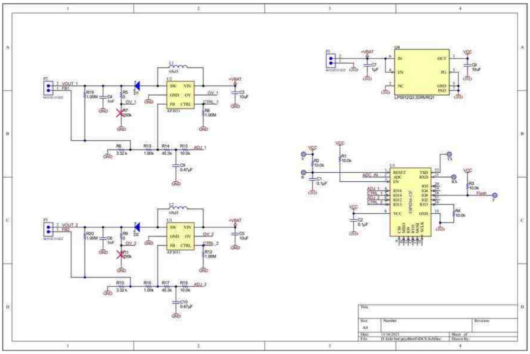


Fig. 83. Circuits of the tDCS module. For a better quality image, see http:// triple-double-u.com/you-and-i-you-and-me-media/tDCSsch.pdf (Accessed 2 January 2022). For the Arduino script, see http:// triple-double-u.com/you-and-i-you-and-me-media/ESP8266_tDCS_210802.ino (Accessed 2 January 2022)

Usage instructions

- Attach batteries and the circuit boards to the snap buttons on the headwear.
- Launch the app “You and I, You and Me” on a tablet or smartphone.
- Pair your app with the headwear.
- Look for peers with other headwear.
- Connect to peers by tapping an IP in the augmented reality interface.
- Use the slider at the bottom of the screen to control the intensity of electricity passed: left side—no electric current; right side—100 uA.

App

The software uses an augmented reality setting to control headwear and connect with other headwear on the local network over the Wi-Fi protocol (Fig. 84). To function properly, the app must be connected to the custom-built electronic devices embedded in the headwear.

Fig. 84. Augmented reality setting to control headwear. Video still

*151 For more information, see http://triple-double-u.com/you-and-i-you-and-me/ (Accessed 2 February 2022).

The Unity AR Foundation-based app to be installed on an iPhone or an iPad is accessible through the Apple Store, https://apps.apple.com/cz/app/you-and-i-you-and-me/id1581665872 (Accessed 28 December 2021).

Network setup

Wi-Fi is configured to be used within the local network named "You and I" (password "You and Me") in the range 192.168.0.1–255. This network is then divided into a static IP range between 1 and 99 and a DHCP range between 100 and 254. The static IP range is reserved for the devices using EEG (1–49) and tDCS (50–59). The DHCP network is reserved for cell phones used during participation in the event and/or for testing purposes.

The app uses the camera, the GPS system, and the OSC protocol. The camera is used to locate other people in the area, the GPS system helps locate audience members wearing headwear, and the OSC protocol is used to send data over the network between audience members wearing headwear. The app helps the audience to connect to their own headwear (locate "Pair …"), to other audience members with headwear (tap visible IP addresses), and to control the electric current flowing through the scalp (touch and move slider on the bottom of the screen).

Technical implementation of the headwear

The bridge between the EEG and tDCS is established while connecting additional modules to the techniques used. These include a module for signal transduction, an ATmega328P/Arduino microcontroller, a Wi-Fi signal transmission module ESP8266, and a Unity AR Foundation-based user interface. While there are quite a few commercial initiatives in the market, and local initiatives to use EEG technologies, my choice was a DIY EEG circuit and a DIY tDCS circuit we located on the Instructables.com website.[152] These circuits gave us maximum flexibility in integrating ESP8266 microcontrollers for the Wi-Fi access between both circuits within the local network.

For the communication between the two circuits, we have chosen to work with OSC protocol. Technically the communication works as follows: Dry electrodes on the headwear that are connected to the EEG module pick up an electromagnetic signal from the cortex and send it to the ESP8266 microcontroller, which converts it to OSC protocol and broadcasts the digital data to the local network. Then the ESP8266 microcontroller on the DIY tDCS module

*152 For DIY EEG circuit, see, Cah6, DIY EEG (and ECG) Circuit, https://www.instructables.com/DIY-EEG-and-ECG-Circuit/ (Accessed 28 December 2021) and for DIY tDCS, see quicksilv3rflash, Build a Human Enhancement Device (Basic TDCS Supply), https://www.instructables.com/Build-a-Human-Enhancement-Device-Basic-tDCS-Suppl/ (Accessed 28 December 2021).

picks up the OSC data from the local network, analyses it, and converts it to the electric current using PWM modulation. It is then passed onto the brain cortex through the integrated dry electrodes located in the headwear. The dry electrodes pass 0.1 mA, much less then is passed for the medical treatments, which suggest 1 to 2 mA. On the other hand, medical treatments use electrode patches instead of dry electrodes. Therefore, the current being passed on the scalp is also much more distributed as in the collection of headwear.

In the project, we have used a tDCS montage guide from an independent source for tDCS related news. For more information, see https://www.tdcs.com/montage-guide (Accessed 25 March 2021). Two montage uses are to be taken into account: depression treatment[153] and the increase of awareness[154] (Fig. 85 and Fig. 86). The current passed depends on two states of brain activity: aroused and calm. The reference is being calculated in real time depending on the individual brain activity.

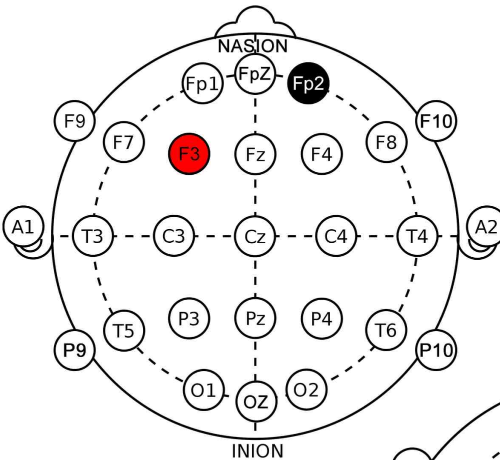


Fig. 85. Montage of electrode patches for the treatment of depression. Source: https://www.tdcs.com/depression-treatment (Accessed 31 January 2022)

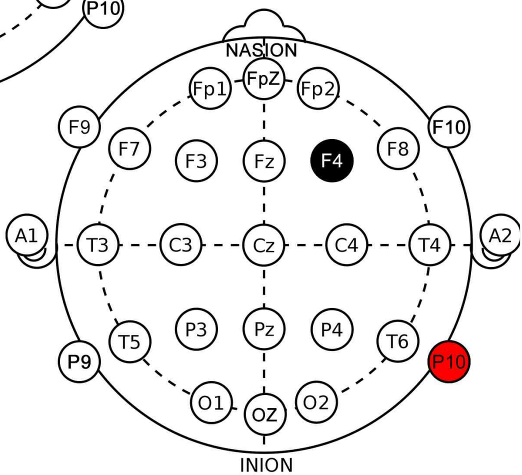


Fig. 86. Montage of electrode patches for the increase of awareness. Source: https://www.tdcs.com/increased-awareness (Accessed 31 January 2022)

*153 For details, see https://www.tdcs.com/depression-treatment (Accessed 31 January 2022).
*154 For details, see https://www.tdcs.com/increased-awareness (Accessed 31 January 2022).

Participant's consent form

Participants who wish to experience headwear created by artists Mindaugas Gapševičius and Maria Safronova Wahlström are required to sign this consent form.

The headwear uses medical strategies based on brain cell communication: the electrical impulses are detected while using electroencephalography (EEG), and brain stimulation is triggered by passing DC current through electrodes (tDCS), a noninvasive method to treat depressive disorder, increase empathic abilities, or decrease antisocial behavior in violent offenders.

The participant assumes all responsibility and risk for using the headwear. Artists and everyone involved in the organization of the event *You and I, You and Me* do not accept liability or responsibility to any person as a consequence of technological error that could affect a participant's health.

Your participation in the event *You and I, You and Me* is voluntary. You may refuse to participate or discontinue participation at any time.

The information you provide is confidential and will not be disclosed.

Annex XV. Jewelry

Jewelry pieces have a circuit board with two different electrodes, silver and zinc (or alternative) and are attached to the human body to generate electrical current, which in turn lights up an LED embedded in the piece of jewelry (Fig. 87).

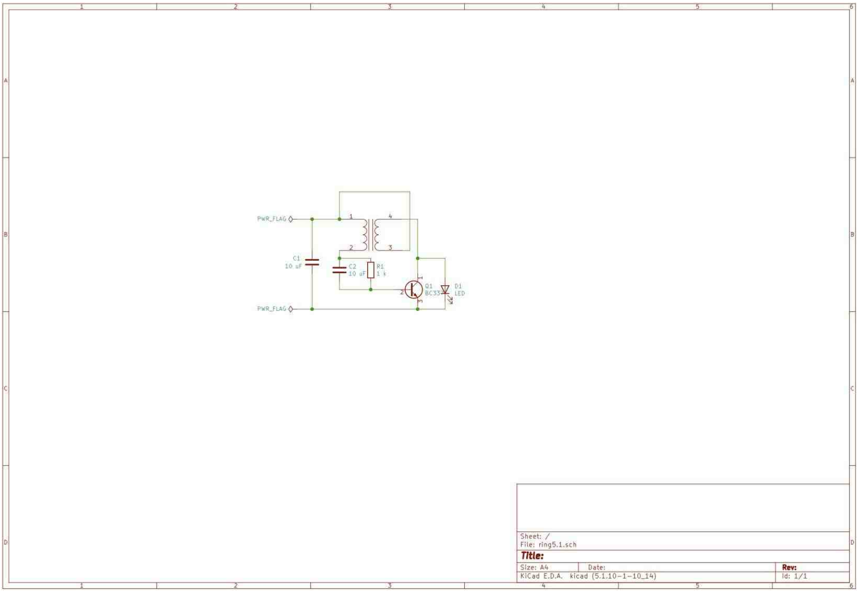


Fig. 87. Circuit of the Jewelry module. For a better quality image, see http:// triple-double-u.com/you-and-i-you-and-me-media/jewelry.pdf (Accessed 2 January 2022)

The collection of jewelry that questions the impact of differently charged ions on humans and the with the umwelt is a part of a larger project, *You and I*, *You and Me*, which explores the possibilities of communication through electricity.[155]

The project has been developed upon previously conducted research on humans as a possible source of electric energy, outlined around the toolkit "Ultra-Low-Voltage Survival Kit."[156]

Usage instructions

- Put a piece of jewelry on a finger, wrist, or your neck.
- Inspect flashing of the LED in a shaded or darkened environment.

*155 For more information, see http://triple-double-u.com/you-and-i-you-and-me/ (Accessed 2 February 2022).

*156 For more information, see http://triple-double-u.com/ultra-low-voltage-survival-kit/ (Accessed 2 February 2022).

Annex XVI. Shoes

Shoes were designed to be charged from the temperature difference between the human body and the environment. For doing so, it uses a Peltier element (Fig. 88).

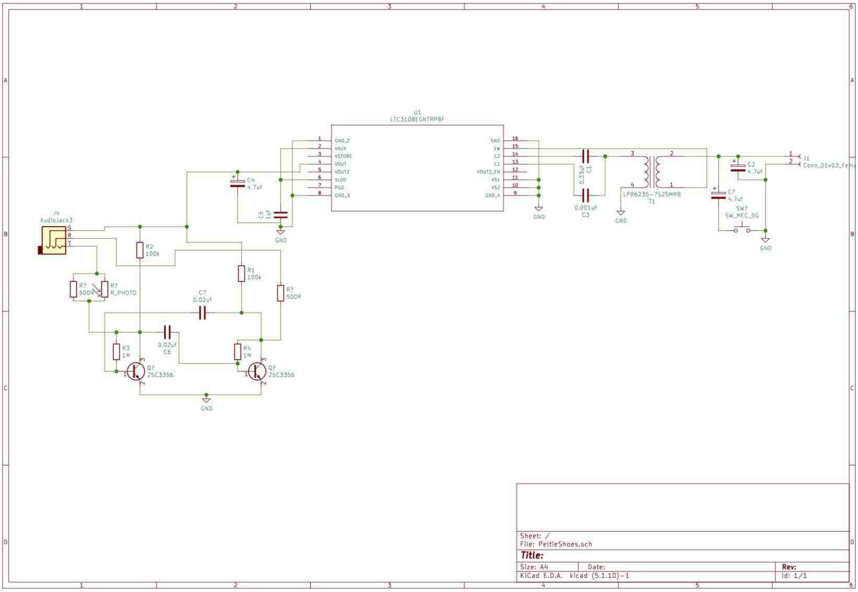


Fig. 88. Circuit of the Shoes module. For a better quality image, see http://triple-double-u.com/you-and-i-you-and-me-media/PeltieShoes.pdf (Accessed 2 January 2022)

The collection of shoes that questions if excess human heat can be used to experience the umwelt is part of a larger project, *You and I, You and Me*, which explores the possibilities of communication through electricity.[157]

The project has been developed upon previously conducted research on humans as a possible source of electric energy, outlined around the toolkit “Ultra-Low-Voltage Survival Kit.”[158]

Usage instructions

- Attach the headphones to the circuit boards.
- Put the circuit boards into the pockets of the shoes.
- Put on the shoes.
- Put the headphones onto your head.

Caution

The temperature in the environment should be 15 to 20°C so that the shoes can generate sound.

*157 For more information, see http://triple-double-u.com/you-and-i-you-and-me/ (Accessed 2 February 2022).

*158 For more information, see http://triple-double-u.com/ultra-low-voltage-survival-kit/ (Accessed 2 February 2022).