GRAZIELE LAUTENSCHLAEGER

SENSING AND MAKING SENSE

PHOTOSENSITIVITY AND LIGHT-TO-SOUND TRANSLATIONS IN MEDIA ART

[transcript] Media Studies

Graziele Lautenschlaeger
Sensing and Making Sense

Media Studies | Volume 81

To my parents
and to all those who believe and bet on the affective dimensions of learning.

Graziele Lautenschlaeger, born in 1983, is a Brazilian media artist and researcher, who conducted her PhD at the *Humboldt University zu Berlin*. As a multi-skilled agent in the field, she acts upon the challenges of grasping the symbolic, poetic and critical dimensions of technological devices. Her artistic and academic practice has been exhibited and acknowledged in Europe, South and North America.

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[transcript]

This book was submitted as a doctoral thesis at the Humboldt University Berlin, Department of Cultural History and Theory, in 2018.
The author was a scholarship holder from the German Academic Exchange Service (DAAD) between 2013 and 2018.

The EOSC Future project is co-funded by the European Union Horizon Programme call INFRAEOSC-03-2020, Grant Agreement number 101017536

The free availability of the e-book edition of this publication was financed by the project EOSC Future.

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at https://dnb.dnb.de

Published 2021 at transcript Verlag, Bielefeld

transcript Verlag | Hermannstraße 26 | D-33602 Bielefeld | live@transcript-verlag.de

Cover layout: Maria Arndt, Bielefeld
Cover photography: Author performing Self-portrait of an absence at the Gleisdreieck Park, Berlin.
Proofread by Joshua Vidich, Julia Jarrett and Sina Pankoke
Printed by: Majuskel Medienproduktion GmbH, Germany
Print-ISBN 978-3-8376-5331-1
PDF-ISBN 978-3-8394-5331-5
https://doi.org/10.14361/9783839453315

Printed on permanent acid-free text paper.

Contents

Abstract

Critical analysis requires the ability to think beyond simplistic dichotomies. This project investigates dichotomies that usually impoverish debates and proposals in media art –including material-immaterial, organic and machinic, theory and practice. Through the analysis of the appropriation of photosensitive elements in media devices and artworks, a critical discussion about media art aesthetics through its very materiality is developed. The methodology combines a historical and analytical approach, through new materialism, media archaeology, cultural techniques and second-order cybernetics. The examination also generates a brief genealogy of photosensitivity in relation to media art.

Each of the aforementioned dichotomies is respectively addressed in three chapters. In the first chapter, *Photosensitivity: materialities and operations*, photosensitivity is unfolded through the investigation of light-matter interaction from the atomic level to selected technical ensembles and operations. The project explores the notion of active matter, a relational perspective of materiality, which is also the fundament of the very notion of 'media' and, by extension, media art and its informational aesthetics. Chapter two, *Photosensitivity shaping hybrid systems*, focuses on the dichotomy organic-machinic. Since organic and machinic photosensitive elements have been used indistinctively in media artworks as creative sources, the analysis elucidates a circular, continuous and mutual influence between organic and machinic elements. The third chapter, *Light-to-sound translations*, focuses on the analysis of media devices and artworks based on light-to-sound translations, including a performance, *Self-portrait of an absence,* developed by the author. Articulating Flusser's perspective on the zero-dimensionality of electronic and digital media, the chapter unfolds the notion of translation of materialities, indicating the multiple roles of absence as a potent element in the creation of media artworks.

Several known media stories are reframed from an alternative perspective – that of photosensitivity. The reframing elucidates specific elements and implications of photosensitive qualities of media artworks as a metonymy to provide general and crucial guiding criteria for the media art production, criticism, education and

diffusion. Addressed to art students, artists, curators and theoreticians, this investigation contributes to a critical perspective of scientific and technological knowledge in aesthetic experimentations.

Kurzfassung

Kritische Analyse benötigt die Herausforderung, über einfaches dichotomisches Denken hinaus zu kommen. Um Dichotomien, z.B. materiell-immateriell, biologisch-maschinell und Theorie-Praxis, die häufig Kunstwerke und Diskussionen im Fach Medienkunst verkümmern lassen, zu vermeiden, wurde ein strategisches Forschungsobjekt gewählt: Lichtempfindlichkeit. Durch eine Analyse der Verwendung von lichtempfindlichen Elementen in Mediengeräten und -Kunstwerken wurde eine Diskussion der Medienkunstästhetik über ihre Materialität entwickelt. Die Methodologie umfasst einen historisch-analytischen Ansatz, Neuen Materialismus, Medienarchäologie, Kulturtechnik und Kybernetik zweiter Ordnung. Die Analyse legt eine kurze Genealogie der Lichtempfindlichkeit in Bezug auf Medienkunst an.

Die Dissertation ist in drei Kapitel strukturiert und jedes Kapitel spricht eine der vorgenannten Dichotomien an. Im ersten Kapitel, *Photosensitivity: materialities and operations*, wird Lichtempfindlichkeit durch Licht-Materie-Interaktion vom atomaren Niveau bis zu den für die Analyse ausgewählten Technik-Ensembles und deren Operationen betrachtet. Die Argumentation beinhaltet die Auffassung von *active matter*, einer relationalen Perspektive auf Materialität und Grundlage für das Konzept 'Medien' und somit der Medienkunst und ihrer Informationsästhetik. Kapitel zwei, *Photosensitivity shaping hybrid systems*, konzentriert sich auf die biologisch-maschinelle Dichotomie. Da lichtempfindliche Elemente als kreative Quelle in Medienkunstwerken unterschiedslos angewendet wurden, deckte die Analyse eine zirkuläre, kontinuierliche und gegenseitige Beinflussung zwischen biologischen und maschinellen Elementen auf. Das dritte Kapitel, *Light-to-sound translations*, umfasst die Analyse von Mediengeräten und -Kunstwerken, die auf Licht-zu-Ton Übersetzungen basieren, das auch die von der Autorin konzipierte und präsentierte Performance *Self-portrait of an absence* beinhaltet. Durch Vilém Flussers Perspektive auf die Nulldimension der elektronischen und digitalen Medien argumentiert das Kapitel in Richtung einer Materialitäts-Übersetzung und hebt die Rolle von Abwesenheit als ein potenzielles und wirksames Element bei der Schaffung von Medienkunstwerken hervor.

Bekannte Mediengeschichten wurden aus einer alternativen Warte neu erzählt, jener der Lichtempfindlichkeit. Die Analyse zeigt, wo die Dichotomien sich befinden und wie unfruchtbar es ist, sich weiter ihrer zu bedienen. Spezifische Aspekte und Implikationen von Lichtempfindlichkeit in Medienkunstwerken wurden als Metonymie erklärt, um generelle und entscheidende Kriterien für die Medienkunst-Produktion, -Kritik, -Ausbildung und -Vermittlung anzubieten. Die Dissertation ist an Kunststudierende, Künstler_innen, Kurator_innen und Kritiker_innen adressiert und zielt auf eine kritische Perspektive in Bezug auf technologische und wissenschaftliche Erkenntnisse bei ästhetischen Experimenten.

Acknowledgements

Primarily I thank the Deutscher Akademischer Austauschdienst (DAAD), in cooperation with the Brazilian National Council for Scientific and Technologic Development (CNPq), for supporting my five years of research in Germany. Since institutions are made of people I kindly thank my DAAD correspondent in Bonn, Maria José Salgado Martinez, and the DAAD correspondent at Humboldt-Universität zu Berlin, Christine Schneider.

Many thanks to my supervisor, Prof. Dr. Wolfgang Schäffner, my co-supervisor Prof. Dr. Giselle Beiguelman and Prof. Dr. Alberto De Campo for opening doors, accepting my proposal and enhancing my research project with ever fruitful references.

My research process has been substantially enriched by conversations with professors Christina Vagt, José Cabral dos Santos, Wolfgang Ernst, Michael Hohl, Patricia Ribault, Christian Kassung, Geoff Cox, Christian Ulrik Andersen, Tobias Cheuen and Anja Pratschke. I thank each of them for their provocative questions and comments.

I owe huge debt of gratitude to all the collaborators in executing Self-portrait of an absence, especially to my friends Edgar Zanella Alvarenga, Radamés Ajna da Silva, Caterina Hering Renaux and Lina Gomez, the researchers from the 3DMIN project Till Bovermann, Dominik Hildebrand Marques Lopes and Amélie Hinrichsen, so as Stefan Schwabe, in charge of the mechatronics workshop at Universität der Künste Berlin, and many others who posteriorly participated in the video documentation and further scheduled performances.

Many thanks also to colleagues and friends I met at the Humboldt-Universität zu Berlin for their ever cooperative attitudes and constructive comments: Ricardo Cedeño Montaña, Martin Müller, Jose Muñoz, Maria Keil, Li-Chun Lee, Marina Cavalcanti and Kristine Wolf, so as to my PhD-Tandempartnerin Lígia Milagres.

Hereby I also acknowledge the importance and generosity of those who provided me with significant information, permission for the publication of specific images, among them inspiring artists and researchers I met in conferences, exhibitions, through recommendations or fortuitous encounters: Ranulph Glanville (in memorian), Albert Müller (in memorian), Clare Charnley, Patricia Azevedo,

Guto Nóbrega, Marcus Bastos, Caroline Menezes, Aernoudt Jacobs, Leslie Garcia, Simone Wicca, Klaus Filip, Lindsay Mann, André Mintz, Ralf Burmeister (Berlinische Galerie), Ianina Canalis, Alessandro Volpato, Špela Petrič, Paul Weston, Paul Pangaro, Robert Martin, Christa Sommerer and Laurent Mignonneau, Gebhardt Sengmüller, Kathrin Stumreich, Jasia Reichhardt, Hermione Pask, Amanda Heitler, Cildo Meireles, Ernesto Klar, Mário Ladeira, Joachim Sauter, Antje Ehmann (Harun Farocki GbR), Peter Keene, Jonathan Klassen, Arcángel Constantini, so as the attentive staff of the Media Archaeological Fundus (HU Berlin), the Vilém Flusser Archive (UdK Berlin), Heinz von Foerster Archive (University of Vienna), Inhotim, Galeria Strina, Kunsthalle Bremen, and others.

In addition, I am grateful for the contributions of the copyeditors Joshua Vidich, Julia Jarrett and Sina Pankoke, transcript's project manager Katharina Kotschurin, and other helpers one might not think of at first while writing a PhD thesis: my physiotherapists Angela Höhr and the team from Orthotrain Berlin.

Despite the solitude, while writing this doctoral thesis I was lucky to have the support of good friends who assisted me in overcoming the many intellectual and psychological challenges. Special thanks to the new *Berliner Freundeskreis*, to the old and welcoming *Linzer Freundeskreis* based in Berlin, and for the same reason, I thank the presence of those friends who, even while located overseas, participated and supported me.

The most sincere and eternal gratitude I owe to my partner Jörg Klenk for the exciting conversations, for his extraordinary interest, participation and patience accompanying me on this enterprise, in joyous times and in difficult periods. He has been my emotional pillar and his engagement has been absolutely superb.

Last, but definitely not least, from the deepest of my heart, I thank my beloved parents Nelda Aparecida Izeppe Lautenschlaeger and Vagner Lautenschlaeger, my siblings, cousins and other relatives for all kinds of support and especially for their ever calming and encouraging words, giving me the confidence to keep following my ambitions.

Berlin, September 25, 2018.
Updated Rio de Janeiro, July 28, 2020.

Introduction
On sensing...

Theories of media art have often concentrated on the intersection between science, technology and aesthetics. There are also those that have lauded the ephemeral nature of media itself and media art as a niche in contemporary art.[1] Regardless of whether one's perspective on media art is the most up-to-date or old-fashioned,[2] one cannot neglect the knowledge produced under the umbrella of both media and media art studies programs, nor the specificities of their cross-disciplinary scope.

In a basic and simplified form, media art is considered here as the poetic, aesthetic and symbolic uses of materials and media devices in such ways that the artworks themselves generate other media and communication processes. In order to establish a common understanding of media, Sean Cubitt's (1953-) definition is here appropriate. We understand media as *"the physical processes – matter, energy dimension, and form – in which all human communication takes place, (…). Before we can communicate, we mediate"*[3]. Equally relevant is Cubitt's comments on Merleau-Ponty's (1968) proposition concerning the reciprocal nature of mediation, the condition that everything that mediates is mediated in turn. As Cubitt remarks:

> Mediation is the ground of relationship, the relationship that precedes and constructs subjects and objects. Media matter, both in the sense of giving material specificity to our descriptions of such abstract concepts as society and environment, and in the sense of the active verb: mediation comes into being as matter,

1 Daniels, Dieter. Whatever happened to Media Art? originally "Was war die Medienkunst? In: Pias, Claus (Ed.) *Was waren Medien?* Zürich/Berlin: Diaphanes, 2011. pp. 57– 80.

2 I had long taken it for granted that in the European context the segregation of media art from contemporary art no longer existed. However, after visiting *Documenta 14* in Kassel I was surprised to realize that it is still strongly present, depending on the background of the curators and organizing teams. The experience of various exhibitions in Berlin visited between 2013 and 2018 at *Haus der Kulturen der Welt* and *Akademie der Künste*, or even the *Skulptur Projekt Münster* in 2017, for instance, had given me a completely opposite impression.

3 Cubitt, Sean. *The practice of light: a genealogy of visual technologies from Prints to Pixels.* Cambridge, Massachussetts/London, England: MIT Press, 2014. p. 2.

> its mattering constitutes the knowable, experienceable world, making possible all sensing and being sensed, knowing and being known.[4]

The adoption of the term 'media' in the scope of this research also relates to how it encompasses the characteristics of a cultural production whose origin coincides with the beginning of the automation of image and sound production by means of machinic apparatuses. This cultural paradigmatic change coincides with the emergence of the notion of media within artistic and communication contexts[5] and, therefore, with the beginning of its historiography. They are part of the broader context of industrialization, which gave birth to the philosophy of technology, marked by works such as August Koelle's *System der Technik* (1822) and Ernst Kapp's *Grundlinien einer Philosophie der Technik* (1877)[6].

In the interest of including a more ecological and contemporary perspective on media, the exchanges and physical processes occurring among non-human living organisms and matter activity per se, as addressed by cybernetics and more recently post-humanist and new materialist theories, are also considered here.[7] While searching for an object of analysis able to unfold crucial issues of the intermediate agencies in media artworks, the gap between sensing and making sense particularly attracted my attention, leading me to center the investigation around a genealogy of photosensitive materials and devices in relation to media history and art.

As one of the basic and essential conditions to establish communication processes among living organisms and machinic and hybrid systems, sensorial structures are crucial for enabling inside-outside exchanges. Moreover, since media art is regarded as a dynamic and essentially process-based artistic expression, analyzing sensitive materialities in media artworks is a direct way to address their relational characteristic.

Sensitive materials and devices also proved to be a promising object of analysis for addressing concerns stemming from preliminary research and observations made during my praxis in the field as media artist, curator and lecturer. One of these concerns was the frequent neglect of the materiality of electronic and digital

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4 Ibid.

5 According to the Online Etymology Dictionary, the term as a noun 'medium', plural 'media', has its origin in the late 16th century, denoting intermediate agency, channel of communication. Its Latin root means literally "middle, midst, center; interval". The specific meaning related to communication media was first observed in the mid-19th Century. <https://www.etymonline.com/word/medium> Accessed May 21st 2018.

6 Fohler, Susanne. *Techniktheorien: Der Platz der Dinge in der Welt des Menschen*. München: Wilhelm Fink Verlag, 2003.

7 Latour 1996; Barad 2003; Bennett 2010; Schäffner 2015.

media[8] and its specificities. The implicit material-immaterial correlation between the processes of sensing and making sense involved in media artworks could be examined through any kind of physicochemical phenomenon. Nevertheless, while observing the historical importance of photosensitive materials in the origin of audio-visual media as well as the increasing variety of uses attributed to photosensors in artistic installations and performances, the prospect of unboxing photosensitivity presented itself as an intriguing way to deepen the discussion on the (im)materiality of media art.

Another concern that emerged from my previous experience was the insistently prevalent *"gap between 'two cultures' of natural sciences and the humanities"*[9], which has been deconstructed in various contexts in the thesis. To reveal the complexity of photosensitive materialities and operations in media artworks, both the cross-disciplinary practice itself and the analysis here conducted face the challenge of bridging opposing traditions, which reflect the dichotomous relationship between theory and practice. The diversity of references – ranging from highly technical to philosophical – was intentionally chosen to trigger dialogues among the various types of media art agents: artists, scientists, critics, curators, and students.

To query the dichotomous issues often present in media artworks – material-immaterial, organic-machinic, theory-practice – a genealogy of photosensitivity was constructed to stress relevant concepts and historic and contemporary examples in support of a relational material approach concerning media art. Retelling some well-known media histories from an alternative perspective related specifically to photosensitivity,[10] the examination shows where the dichotomies are located and how counterproductive it is to feed them. The purpose was to elucidate specific elements of the photosensitive qualities found in media artworks and their implications, as a metonymy to provide general and crucial guiding criteria for the production, criticism, education and diffusion of media art.

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8 When renowned authors in the field, such as Edmond Couchot, state that *"the image-making processes are no longer physical (material or energy related)"* (Couchot, 2007: 182-3), all the existent materialities that the human senses cannot perceive are ignored. Pierre Lévy in *O que é o virtual?* (1996) has precisely critiqued the problem of the misconception of the virtual and its immaterialization.

9 Daniels 2011: 5.

10 It is more frequent in the literature of media and art history the focus on the role of light and visuality, while photosensitivity is relegated to being a secondary and less discussed topic. Some examples are the aforementioned Cubitt's *The practice of light:* and Peter Weibel and Gregor Jansen (Eds.) *Lichtkunst aus Kunstlicht/Light Art from Artificial Light. Licht als Medium der Kunst im 20. und 21. Jahrhundert/Light as a Medium in 20th and 21th Century Art.* Ostfildern: Hatje Cantz, 2006.

Material-immaterial

Intertwined with abstractions and materialities, every media presents specific characteristics that express a worldview and suggest how one relates with it. Abstractions are here understood as concepts, languages, codes, symbols, software, mathematical models and operations, etc.; whereas materiality refers to the set of materials, devices, physical objects, technical ensembles, hardware, and so forth. In this sense, analysing media artworks is very close to detecting and studying the various ways of combining and implementing their materialities and techniques, their physical characteristics and their operations, respectively, in a given context.

The lack of knowledge about media art materialities and operations often produces an imprecise terminology for media art within the art world. The problem increases if one considers the complexity of each element forming media devices as technical ensembles. Ignoring the technical knowledge produced by scientists can lead to a series of misunderstandings and false premises. Light, for instance, given its dual electromagnetic nature as particle and wave, can mediate physicochemical processes as both energy and signal sources, requiring different structures for specific operations. Philosopher Peter Sloterdijk's (1947-) perspective on the concept of matter in relation to its response to light is especially pertinent here. He wrote: "*Matter is present wherever light cannot penetrate. Matter is called matter when a resistance or an opaque size, that is, a dense or impermeable size, obstructs the propagation of light*".[11] This quote can lead to a false generalisation, which is easily deconstructed if one looks deeper into the differing material reactions to light actuations, especially by observing the variations provoked in a given material's resistance. Some materials, for instance, have special characteristics that entail that light changes their resistance. As light passes through matter, there is an interaction, and light may be absorbed, reflected, scattered, dispersed, or otherwise altered. Here lies an important part of the present work, dedicated to reveal, or at least acknowledge, mankind's ability to manipulate and attribute aesthetic significance to matter that is beyond the capacity of the limited human sensorial apparatuses to perceive. In other words, the interplay between material and immaterial cannot be considered solely from the human perspective of what is visible and/or tangible.

Walter Benjamin's *The work of art in the age of mechanical reproduction* (1936), as a response to Paul Valéry's inquiry into the emerging ubiquity of representations in the *beaux arts*,[12] is a seminal study in media theory and history concerning the new

11 From the original in German: "*Materie überall dort vorliegt, wo Licht nicht durchdringen kann. Von Materie spricht man dann, wenn ein Widerstand oder eine opake Größe, das heißt, eine dichte oder undurchlässige Größe sich der Ausbreitung des Lichtes in den Weg stellt*" Sloterdijk, Peter. Licht und Widerstand. Über Materie. In: Heibach, Christiane. Rohde, Carsten. (Hg.) *Ästhetik der Materilität.* HFG Forschung Band 6. Paderborn: Wilhelm Fink, 2015. p. 43.

12 Valéry, Paul. La conquête de l'ubiquité. In : Tremblay, Jean-Marie (Ed.) *Les classiques des sciences sociales.* Chicoutimi, Québec, 2003. Electronic edition from Valéry's text originally published

challenges brought by new materials and methodologies. Curiously, while technological development frequently forces standardization, it also provides a potential increase of variability, fostered essentially by the invention, combination and recombination of new information and materials. In this sense, media art production is a propulsive force toward the generation of disruptive forms of media, in other words, of new means to communicate. Photography is an accessible example of what is meant here. The photo camera is a complex machine based on different fields of knowledge. Principles from physical optics, chemistry, geometry and perspective were joined in an ensemble that is able to capture and store images, which later, with the assistance of another machine and devices, can be reproduced. The camera itself is a media (mean) to make an image possible and concrete: the negative, the print, a data file, all of which are media (means) themselves. One cannot conceive photography without the set of apparatuses that are used to produce it, which are still now being constantly reinvented.

The development or enhancement of a technology provokes paradigm changes in its aesthetic appropriations in similar proportion. What photography inaugurated has been considered as the liberation of the hands of the artist and, ironically, as the beginning of a dependence on machines. Nevertheless, instead of judging how free from or attached to the tool the artist is, it is relevant to recognize the increasing distance between mind and hand, a space that has become filled with numerous inter*media*te elements. Since the advent of photography, the supposed talent required from an artist to produce an image became coupled with the potential and limitations of a series of industrial products: photosensitive emulsions applied to celluloid, the cameras, the developing chemicals and print machinery. Thenceforth, artistic expression was also able to be executed by digits[13]: a shot[14],

in 1928, in Œuvres, tome II, Pièces sur l'art, Nrf, Gallimard, Bibl. de la Pléiade, 1960. pp. 1283-1287. Available at <http://classiques.uqac.ca/classiques/Valery_paul/conquete_ubiguite/conquete_ubiquite.html> Accessed: May 30th 2016.

13 The term 'digit' refers simultaneously to a finger and a numeral. This is a special example to draw attention to the role of metaphors in media development, which also embodies the material and immaterial aspects at the same time.

14 Numerous theoreticians have discussed the historical connections between cameras and guns in ways that go beyond the language domain (with the verb 'to shoot') to encompass their technical developments. For more information concerning this topic, I suggest reading Paul S. Landau's *Empires of the Visual: Photography and Colonial Administration in Africa*, published in Landau, Paul S.; Kaspin, Deborah D. *Images and Empires: Visuality in Colonial and Postcolonial Africa*. Berkeley: University of California Press, 2002. pp. 146-49. A classic media artwork on the topic is *World Skin: a Photo Safari in the Land of War,* by the French artist Maurice Benayoun. More details at his official webpage: <http://www.benayoun.com/projet.php?id=16> Accessed March 15th 2016.

a bang, a trigger, a number. This represents an escalation of abstraction[15], as has been suggested by media philosopher Vilém Flusser (1920-1991), who in his *Filosofia da caixa preta: Ensaios para uma futura filosofia da fotografia* (1983)[16] suggested one to deplete the apparatus' possibilities. Nevertheless, the higher the degree of abstraction the more combinations between the immaterial and the material world tend towards infinity through the continuous invention of apparatuses. As known from traditional media history, what was learned from photography was later incorporated in techniques to develop machines for producing, storing and distributing moving images, which gave birth to another seminal media: cinema. However, it also took time to assimilate the dimension of time to film itself and to subsequently explore cinema's own expressive language. There is no way to ignore that film development and editing used to be a very material praxis. Material issues also emerged when sound and colour were added to film technology.[17] Therefore, to understand and explore media-specificity in both terminological and practical instances, it is crucial to think about media's materiality.

In the aesthetic domain, the liaison between an idea to be communicated and the materiality to be used is mediated by the sensing phenomena. Outlining a genealogy of light-sensitive elements in relation to media art is also a strategy to highlight the expanded creative possibilities of today, beyond the disciplinary boxes that institutions normally impose, so that thinking about the possibilities of dealing with images (and per extension the imaginary) can move far beyond verisimilitude.[18]

Substantial changes in relation to the material-immaterial relationship were triggered by Modernism[19] during late 19th and early 20th centuries during the in-

15 Flusser, Vilém. *Universo das imagens técnicas: Elogio da superficialidade.* São Paulo: Annablume, 2008.

16 Flusser 2011.

17 Kittler, Friedrich. *Optical media: Berlin Lectures 1999.* Translated by Anthony Enns. Cambridge, UK/Malden, USA: Polity Press, 2010 (first published as *Optische Medien/Berliner Vorlesung 1999*. Berlin: Merve Verlag, 2002).

18 In the history of art, the sense of sight has been paramount in the production and perception of an artwork, and this tradition continues today in art museums due to preservation and security issues through the imperative, "do not touch". Furthermore, the mixture of modern artistic experiences with media development pushes both the history of art and the philosophy of images to transcend the limits of art, as shown by *Theorie des Bildakts.* The theorists of this movement base their work largely on Ernst Cassirer's philosophy of symbolic forms, stretching the idea of materialized symbols and their embodied forms, as well as a form of animism. An excellent introduction to this perspective can be found in: Bredekamp, Horst. The Picture Act: Tradition, Horizon, Philosophy. In: *Actus et Imago – Bildakt at Warburg Institut*. Berlin/Boston: De Gruyter, 2014, pp. 3-32.

19 Argan, Giulio Carlo. *Arte Moderna: do Iluminismo aos movimentos contemporâneos.* São Paulo: Companhia das Letras, 1992.

dustrial revolution. Along with the wide-scale transformations of Western society emerged artworks emphasizing the crisis of representation in the visual arts, whose further development lead to the neglect of the art object itself and a simultaneous emphasis on artistic processes and situations. Artists increasingly proposed artworks in which the role of the audience was necessary for the artwork to occur and, therefore, to be experienced.[20] These sort of initiatives also contributed to reviews of the exhibition spaces themselves.[21]

Simultaneously, art history recorded examples of technical and material primacy[22]. The tension between the abstraction of concepts and the concreteness of materials is unavoidable. In media artworks, whose materials and technical means are mostly dependent on industrial artefacts, this tension increases in complexity and influences the core of the creative experience. Remembering the Platonic definition of '*techné*', often translated as 'art', 'craft', 'skill', 'technical knowledge', 'expertise', and even 'science'[23], helps to explain why media art historians and critics structure their arguments around the fruitful intersections between art, science and their common technological apparatuses.

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20 Popper, Frank. *Le déclin de l'objet - art action participation 1*. Chêne, Paris, 1975. A more critical perspective can be found in Bishop, Claire. *Artificial Hells: Participatory Art and the Politics of Spectatorship.* London: Verso, 2012.

21 In 1942, for instance, in the exhibition *First papers of surrealism* Marcel Duchamp (1887-1968) proposed the *Twine* installation. As he was also contributing to the exhibition design, he filled the whole space with twines, in such a way that the visitors needed to pass through the materiality of the work to experience it as well as to reach the others artists' artworks. There are several possible interpretations of this artwork, however, the intention here is to show the beginning of the trend to physically include the audience in the artwork. Within this context, as states art critic Vick John, "*Duchamp himself, also tended to stress more his twine's functional value than its symbolic meaning*"[21]. John, Vick. 2008. *A New Look: Marcel Duchamp, his twine, and the 1942 First Papers of Surrealism Exhibition*. Available at <http://www.toutfait.com/online_journal_details.php?postid=47245> Accessed March 14th 2016. A later significant example in this trend is the *Relational Objects* series by the Brazilian artist Lygia Clark (1920-1988), who largely contributed to what in art history is called Participatory Art, mainly in the 1960s and 1970s. In this series of works she used objects to engage people in situations of exchange. The objects themselves had no meaning. The same phenomenon is observed in optical and kinetic artwork, developed in the same period by artists such as Yaacov Agam, Jesús Rafael Soto and others.

22 As contemporary examples there are the colour and paint patent cases, such as the International Klein Blue, a deep blue hue first mixed by artist Yves Klein (1928-1962) in the 1960s, and more recently the Vantablack, the blackest and therefore least light reflecting pigment ever produced, developed by the British Company NanoSystems and patented by Anish Kapoor (1954-) for artistic applications.

23 Roochnik, David. *Of art and wisdom: Plato's understanding of techne.* Pennsylvania State Univ. Press, 1996.

Furthermore, these cases do not merely exemplify the interplay between material-immaterial, visible-invisible, tangible-intangible, they also reflect the link between psychic and social systems, which are frequently divided in art theory and criticism. Entangled within the operationalities of art, psychic and social systems integrate what the cyberneticist sociologist Niklas Luhmann (1927-1998) named 'art system'.[24] From this perspective, analysing photosensitivity in artistic dynamics strategically addresses the continuity, mutual influence and communication among humans and other organisms and wo_man-made and artificial objects.

Organic-machinic

For the philosopher of technology Gilbert Simondon (1924-1989), organisms and technological artefacts emerge from distinct evolutionary processes of individuation.[25] Nevertheless, there are plenty of examples of how the understanding of the natural world and the human ability to create and construct media and machines mutually influence one another. Although clearly distinguishing the borders between biological and technological beings, Simondon believed that human-machine coupling can exist when a common code to the memories of both can be discovered, so that through the convertibility from one system to another one can achieve a possible synergy.[26] Flusser's notion of the zero-dimension of electronic and digital media will be used to support this thesis' argumentation on the possibilities and implications of the convertibility mentioned by Simondon. The current technological context is materially and technologically enhancing the possibilities of merging the evolutionary principles of organic and cultural objects, thereby leading towards the emergence of hybrid systems.

An implementation of this framework of thinking can be found, for instance, in the biological notes of the conceptual machines described in *Vehicles – Experiments in synthetic Psychology* (1984) by the cyberneticist Valentino Braitenberg (1926-2011), who blurred the traditional borders between nature and culture in relation to neuroscience and computer science.[27] Referring explicitly to the McCulloch-Pitts neuron model, Braitenberg modeled his vehicles on the electrical properties and function of neural cell membranes, following the fundamental operations of calculus and logic propositions: conjunction (AND), disjunction (OR) and negation (NOT). Those operations coincide with the elements of logic used by Greek philosophers

24 Luhmann, Niklas. *Art as social system*. Stanford, CA: Stanford University Press: 2000.

25 Simondon, Gilbert. *Du mode d'existence des objets techniques*. Domont/Roubaix, France : Éditions Aubier, 1958/2012. p. 82.

26 From the original in French : "*Le couplage de l'homme à la machine commence à exister à partir du moment où un codage commun aux deux mémoires peut être découvert, afin que l'on puisse réalizer une convertibilité partielle de l'une en l'autre, pour qu'une synergie soit possible*". (Simondon 1958: 173)

27 Braitenberg 1984: 109.

in antiquity and by programmers today. In the arts, such coincidences have allowed artists to use mathematical models of complex natural phenomena to create generative and self-organizing audio-visual artworks, such as autonomous light and robotics sculptures and video and sound art, which frequently use biological matter as well.[28]

Looking at these kinds of possibilities and focusing on the intersection between photobiology and sensor engineering, the thesis addresses how photosensitivity (light-matter interaction) plays an essential role in both life and media development through the relationship between sensorial/material limits and human endeavors to play with them, enhancing, altering and extending their characteristics.

Theory and practice

The insertion of machinic apparatuses in the production of art mirrored the pre-existent division based on the dichotomy between theory and practice, which separates those who think about and conceptualize from those who execute and master the material and technical aspects. This separation began far before modernity and industrialization with the history of culture, which coincides with the history of abstraction.[29] Contemporary media art likewise stems from this historically and culturally constructed gap between the world of thinkers and the world of makers. In association with the concept of process-based artworks and the immateriality this concept suggests, related terms and roles like 'participant', 'interactor' and, more recently, the 'maker'[30] have emerged and carried over to the idealism of Do-It-Yourself (DIY) and hacking cultures. However, while in art history discourses the art object has lost its significance, the commoditization of the artwork is (and always has been) a constant requirement of the art market. To fit these requirements, process-based artworks are either shrunken to take place in exhibition spaces, or artists find alternative spaces more adequate to their ideas. To a certain extent, banal views of interactive art are associated with this phenomenon. Often the word 'interactive' has been used to refer to any use of digital media in art exhibitions, undermining the aesthetic movement towards the potential openness of

28 A recent example is the cybernetic synthesizer CellF, created by Guy Ben-Ary. CellF is an autonomous instrument made from evolving networked biological matter. More information about the project at <http://guybenary.com/work/cellf/> Accessed May 9th 2017.

29 Flusser 2008:16-19.

30 The Critical Media Lab (Swiss Institute of Experimental Design and Media Cultures), at the Transmediale Festival 2016 – conversation pieces, critically addressed the maker culture by presenting the intervention Unmaking_Kits. The curatorial program of the festival was divided into four parts of the contemporary anxieties related to the digital media: Anxious to act/Anxious to make/Anxious to share/Anxious to secure. More information about the intervention available at <http://www.ixdm.ch/portfolio/unmaking-5-anxieties/> Accessed July 31st 2016.

artworks.[31] Instead of freeing objects from deterministic statements and forms, so-called interactive media artworks often constituted mere reactive systems, with little margin for uncertainty and indeterminacy.

One can hardly say that there is a difference between thinking and acting in media art practice. Nevertheless, one notices that the levels of intimacy with media materialities diverge at the same pace as that of the antagonism between the developers and the users logics.[32] In the history of electronic and digital culture, the emergence of the graphic user interface (GUI) is a classic example of this dissociation and the increasing number of intermediate layers between artists' minds and hands. Other facilitators for media artists and designers in relation to software and hardware tools (e.g., the development of Processing, Arduino and Raspberry Pi boards as well as many other visual programming platforms such as Isadora, Max/msp and Pure Data) are also manifestations of these intermediate layers that have emerged in the creative industry of human-machine communication.

Human history, memory and culture are essentially developed through relationships with objects. Electronics and digital objects have the special feature of being programmable. The increasing miniaturization of devices and the encapsulation of calculation and algorithmic processes on a scale that human senses cannot perceive have brought with them a sort of media device fetishism. Seduced by their external appearance and ignoring the internal operational processes, one easily renounces learning and understanding when dealing with electronic and digital objects. This is one of the possible driving forces behind the dichotomous relation between theory and practice in media art as well. However, Vico's[33] axiom seems to be still valid: *"man is able to understand only that which he himself has produced"*,[34] and, from a complementary viewpoint, that which one has oneself experienced. Coming closer to the materiality of things and acknowledging the role of the observer when observing a system are essential conditions for participating in processes of knowledge production.[35] While refraining from the nostalgia for pre-industrial times, it is necessary to recognize the craftsmanship values behind media artworks, reducing the theory-practice dichotomy.

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31 Eco, Umberto. *A obra aberta: Forma e Indeterminação nas Poéticas Contemporâneas.* São Paulo: Perspectiva, 2003.

32 Krippendorff, Klaus. Discourse and the materiality of its artifacts. In: T. R. Khun (Ed.) *Matters of communication: Political, cultural, and technological challenges to communication theorizing*. New York, NY: Hampton Press, 2011. pp. 23-46.

33 Expressed by the Enlightenment polymath Giambattista Vico (1668-1744).

34 Bredekamp, Horst. The Picture act: Tradition, horizon, philosophy. In Marienberg, Sabine; Trabant, Jürgen. *Bildakt at the Warburg Institute. Band XII Actus et imago*. Berlin/Boston: De Gruyter, 2014. p. 9-10.

35 In a historical and comparative study of work skills Richard Sennett reviews and updates Vico's idea in terms of the current technological cultural environment. Sennett, Richard. The craftsman. New Haven, Connecticut: Yale University Press, 2008.

One can certainly find few examples of artists and groups that have been successful in bridging the gap between theory and praxis in the cross-disciplinary field of media art. However, artists do frequently rely on the knowledge of engineers to solve problems on the material level and, albeit rarely, let a media artwork evolve as a collaborative process by means of knowledge exchange. This reproduces the pre-established work division between conceptualization and handicraft. This problem results, on the one hand, from the lack of integration between scientific and aesthetic knowledge and, on the other, from how educational systems are organized. In this sense, the Simondonian perspective on the chasm between technical and intellectual knowledge is very actual.[36] According to Yuk Hui, *"for Simondon, the divergence of knowledge production between science and technology, theory and practice, leads to the opposition between culture and technics, and so we need a new philosophical thought to bring society together, hence the technics can be re-inscribed in culture"*[37]. This is one of the assumptions and endeavours of the present thesis as well in light of the technological advances being experienced by the current generation of artists and the difficulties of dissolving this dichotomy in highly specialized environments.

The above inquiries into media art were incited by a hands-on approach with photosensitive elements. By means of resisting and counter-acting upon the established and embodied ways of doing, the research process has been an attempt to use critique and self-reflection as a means to emancipate of artists from unrecognized dependencies.[38]

The conceptualization and execution of an aesthetic experiment re-informed the aforementioned material-immaterial, organic-machinic and theory-practice issues, leading to the formulation of a general research question: *How do photosensitive elements support a reflection on the (im)materiality of media art that provides a basis to discuss its aesthetics, specificities and adaptability to each media artwork context?*

To address each dichotomy directly, the thesis poses specific research questions in each of its three chapters.

Methodology

The research methodology combined historical and analytical approaches, including cultural techniques, media archaeology, new materialism and second-order cybernetics. The articulation of this conceptual toolbox indirectly mirrors the triadic structure often implemented in formal and informal levels of art education:

36 Simondon 1958.

37 Hui, Yuk. *On the existence of digital objects.* Minneapolis, London: University of Minnesota Press, 2016. p. 5

38 Habermas, Jürgen. *Theory and praxis.* Boston, USA: Beacon Press, 1973. pp. 1-40.

to read, to make and to contextualize, as systematized by art educator Ana Mae Barbosa (1936-)[39] based on Paulo Freire's (1921-1997) pedagogic theory.[40]

Cultural techniques

Frequently implemented in media studies, cultural techniques encompasses practices and methods of producing culture located at the interface between the humanities and the technological and natural sciences, and it constitutes a condition of the possibility of culture per se.[41] In practice, the approach of this thesis consisted in opening the black boxes of knowledge embedded within photosensitive biological models, technological artefacts and their operations. The procedures form a framework that allows comparisons among the analysed elements, enabling a historical and a critical genealogy to emerge.

Implicit in this process is the mutual influence between body and media technology, as also suggested by the cultural studies scholar Harun Maye.[42] This perspective structured the development of a genealogy of photosensitivity in relation to media art, starting with the analysis of basic elements and followed by various combinations among them and their surroundings, forming, in Simondon's terms, technical ensembles and their milieu.

Furthermore, cultural techniques are an effective theoretical framework to deal with cyclic translation chains between characters, persons and things. As a cultural practice closely related to the human sensorial-cognitive system and the invention of technical apparatuses, media artworks' complexity can hardly be grasped if not through such an approach. Understanding its translation dynamics is essential for media artists to enhance their own awareness and production concerning the relationship 'form-function-content'.

Media archaeology

Looking carefully at media theory and history, one can notice that, despite a movement toward innovation, inventors and artists are not driven by a linear progression of technology. They are rather driven by the friction between traditions and the discovery of new techniques. Media are constructed by complex relationships that constantly and dynamically overlap, adapt and reorganize elements.[43] In this

39 Barbosa, Ana Mae; Cunha, Fernanda Pereira (Orgs.) *A abordagem triangular no ensino das artes e culturas visuais.* São Paulo: Cortez, 2010.

40 Freire, Paulo; Illich, Iván. *La educación: Una Autocrítica.* Búsqueda: Buenos Aires, 2002.

41 Maye, Harun. Was ist eine Kulturtechnik? In: Engell, Lorenz; Siegert, Bernhard (Ed.) *ZMK Zeitschrift für Medien- und Kulturforschung.* Band 1. Hamburg: Felix Meiner Verlag für Philosophie. 2010. p. 121.

42 Ibid 123.

43 The German Media Theory school elucidated the architecture of knowledge by clarifying the existence of abstract operations of media technologies over time: processing, transmitting

sense, media-archaeological approaches relativize media obsolescence and present alternative and unexplored paths to explain why, for instance, film did not make books obsolete, television did not make cinema theatres disappear, or Youtube has not incited the disappearance of both. The history of stereoscopic image devices, which have experienced several waves of popularity since the end of the 19th century, is another didactic and interesting example to demystify the disruptive character marketed together with certain technological devices.[44]

Therefore, the compilation of ideas shared in the thesis was based on the combination of media archaeological excavations with sharp examinations of contemporary media art exhibitions and artworks, followed by a systematic selection of samples that present the potential to enhance the argumentation. This collection and systematization aims to clarify interrelations between photosensitive elements, media art histories and knowledge construction.

Jussi Parikka defines media archaeological approaches in general as *"digging into the background reasons why a certain object, statement, discourse or, for instance, in our case, media apparatus or use habit is able to be born and be picked up and sustain itself in a cultural situation"*[45]. However, as a relatively recently established field of study, each theoretician or artist dealing with past media has developed their own way of dealing with them. Hence, regarding the variety of media archaeological approaches, a hybrid one was adopted here, embracing on the one hand, the work of the media theorists Wolfgang Ernst, Jussi Parikka and Friedrich Kittler, who incorporate Foucault's genealogical method, not only going back in time in historical terms, but also inside machines' infrastructures[46]; and on the other hand, that of Siegfried Zielinski, who counts on *"fortuitous finds instead of searching in vain"*[47].

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and storing information, from electrons and ions to images and sounds. The works by Friedrich Kittler, Wolfgang Ernst and Wolfgang Schäffner mark the origins of this work. More specifically see: Schäffner, Wolfgang. Elemente architektonischer Medien. In *Zeitschrift für Medien und Kulturforschung*. Nr. 1. 2010, pp. 137-149. Ernst, Wolfgang. *Digital Memory and the archive*. Minneapolis: University of Minnesota Press, 2013; Kittler, Friedrich. *Aufschreibesysteme 1800/1900*, München: Fink, 1985; and from the same author *Grammophon, Film, Typewriter*. Berlin: Brinkmann & Bose, 1986.

44 Many authors are relevant in demonstrating through media-archaeological perspectives what I state here. Among them, those that most influence my thought are: Grau, Oliver. *Arte virtual: da ilusão à imersão.* São Paulo: Editora Unesp/Editora SENAC, 2007; Zielinski, Siegfried. *Deep time of media: Toward an archaeology of hearing and seeing by technical means.* Cambridge/London: MIT Press, 2006.; Crary, Jonathan. *Techniques of the observer: on vision and modernity in the nineteenth century.* Cambridge/London: MIT Press, 1990.

45 Parikka 2012: 6.

46 Parikka 2012: 81

47 Zielinski 2006: 15.

New Materialism

Another important issue is the definition of materiality, which is here understood as the constitutive nature of objects and lives, as manifestations of matter in the perceived and known (studied and modelled) physical world.

Complementarily to the media-archaeological perspective, new materialist approaches consider the agency of matter through its material-discursive practices.[48] They endorse a post-humanist worldview, in which matter (such as meaning) is dealt with as a doing, rather than as a static object. In this sense, matter is considered through its on-going historicity, as part of the continuous stabilising-destabilising activities happening in and shaping the world.

Since the creative process in media art happens in the flux between the conceptual and the concrete worlds, between purifications and translational processes[49], a new material approach is the most suitable contemporary theoretical framework to embrace the complexity of operations involving photosensitivity.

To consider a new materialist approach in relation to media art does not entail adopting deterministic viewpoints. On the contrary, it includes the problem of media-specificity and its relationship with the subject being communicated. This means that the coherence and cohesion among the elements implemented in media artworks are more relevant and insightful than merely appreciating the beauty of a final enclosed art object.

Second-order Cybernetics

Cybernetics evolved as a cross-disciplinary science in the 1940s to study control and communication in machines and living beings.[50] Highly criticized for of its use in military contexts, it has undergone substantial changes since 1974, when Heinz von Foerster distinguished first- from second-order cybernetics, *"respectively, the cybernetics of observed systems and the cybernetics of observing systems"*[51], highlighting the observer's role in the observation process. Nowadays, cybernetics remains a successful methodological tool to consider recursive movements from abstract to concrete, from beings to machines, and from nature to culture.

The inclusion of the role of the observer in the research process supported by the meta-theory of second-order cybernetics has enabled the integration of thinking and doing in media art. The second-order observer is the conceptual tool that has enabled the researcher to address as directly as possible the conflict between theory and practice. To maintain a minimum level of consistency given the critique of

48 Latour 1996; Barad 2003; Bennett 2010; Schäffner 2015.

49 Latour 1993: 11.

50 Wiener, Norbert. *Cybernetics or control and communication in the animal and the machine.* New Orleans, Lousiana: Quid Pro Books, 2016 (1958).

51 Scott 2011:30.

this specific dichotomy, the present research could not be based only on readings, technical visits and conversations with artist and specialists.

As a methodological tool for this practice-lead research[52], an aesthetic experiment in media art was developed, named *Self-portrait of an absence* (2016). The researcher's partial absence of vision was appropriated to conduct a second-order cybernetic approach. Using her own body as source of investigation and considering the eye as an epistemological object, her role as observer has been inevitably acknowledged throughout the research process. By confronting organic and machinic light-sensitive entities, namely eye and camera, a part of the research was motivated by the triad: eye-camera-black box. This constellation was assumed as a challenging epistemological and relational object, provoking reflections that structured the subjects articulated in this thesis.

Thesis structure

The thesis is divided into three chapters, which each unfold increasingly complex technical ensembles.

In chapter one, *Photosensitivity: Materialities and operations*, the protagonists are photosensitive elements from media history and media art. Developing the argumentation from individuals to technical ensembles, the chapter sketches the relationships between the discoveries of materials, the development of devices, models of understanding of biological elements, and their expressions in the aesthetic field.

The questions orienting the chapter are: *What is the technical and scientific knowledge embedded in light-sensitive matter? How does this knowledge relate to media development? What has been aesthetically integrated in media artworks?* These questions evolve into material, technical and operational explanations, showing how overlapping the material and immaterial layers of media art are. This leads to a discussion based on the notion of media art's informational aesthetics.

The second chapter, entitled *Photosensitivity shaping hybrid systems,* focuses on another dimension of photosensitivity, namely the organic-machinic dichotomy, and addresses its manifestations in media artworks. The question orienting the chapter is: *What photosensitive materialities and operations being used in media artworks can help to deconstruct the organic-machinic dichotomy?* Due to the immense variety of photosensitive elements, it was necessary to narrow the analysis down to a specific typology. Therefore, light-sensing as vision has been privileged, by means of a comparison between eye and camera. Nevertheless, guided by new materialist and

52 According to Henk Borgdorff *"embedded in artistic and academic contexts, artistic research seeks to convey and communicate content that is enclosed in aesthetic experiences, enacted in creative practices and embodied in artistic products".* (Borgdorff 2011: 45)

post-humanist approaches, the chapter also presents some examples that demonstrate the relevance of photosensitivity in relation to non-human living organisms within media art.

The first and second chapters prepare the reader by introducing the background information required for the core argumentation of the thesis, developed in chapter three *Light-to-sound translations*. Including the performance *Self-portrait of an absence* developed by the author, media devices and artworks technically based on light-to-sound translations are analyzed and compared in their specificities. The set of questions guiding the chapter are: *How do translations from light into sound occur? Can media artworks be seen as processes of the translation of materialities? How do media artists embrace their role as translators? What are the challenges for the artists underlying this endeavour?* The argumentation evolves from the definition of a sensor, which transforms a physicochemical stimulus into an electric signal[53] that together with its programmability, structures a sort of meta-language for communication between beings and things. The zero-dimensionality of electronic and digital media, as proposed by Flusser, allows media artists to translate any material into another.[54] The analysis leads into a discussion of the implications of creative processes based on the translation of materialities, drawing attention to the absent zone found in between the systems in translation.

The thesis is addressed to art students, artists, curators and theoreticians and aims to contribute to a critical perspective on the use of scientific and technological knowledge in aesthetic experimentation. It presents arguments for recognizing the bridging role of the artist, who creates empowering tools for reflecting, acting upon and triggering reflections about technocratic society and the potential freedom embedded in imaginative and poetic uses of technical objects.

53 Fraden 2004: 1.

54 In addition to Rainer Guldin's (2010) ideas about Flusser's work, the technical definition of a sensor by Jacob Fraden (2004) and insights obtained from researcher's own practice justify the use of the term 'translation'.

Chapter 1
Photosensitivity: materialities and operations

> "man's disregard for the material basis of his life still causes him to err in a serious way".
> George Bataille[1]

In the recent past, a common way to open a discussion of media art was to unfold the principles and aesthetics of technical images.[2] It has been challenging to detach the emergence of technical images[3] from the role of light and the supremacy of the sense of sight. In consonance with a general neglect of the world's materiality, light plays a predominant role in media theory and history, where one also finds an emphasis on the geometrical qualities of optics and its derivative apparatuses that reinforces the visual aspects of media.[4]

Since there has been a great deal of theoretical work casting light and image as the protagonists of media aesthetic discussions[5], the challenge here is to shift the perspective by means of excavating and analysing the other side of the light-matter

1 Bataille, George. *The Accursed Share. Volume 1: Consumption*. 1991. p. 21

2 Flusser 2008.

3 Vilém Flusser's use of the more general term 'technical image' implies overcoming the notion of image as a bi-dimensional space merely resulting from an incidence of light and visual perception. Other important expansions of the notion of image are found in the works of the philosopher Régis Debray and in *Bildakt Theorie*, headed by art historian Horst Bredekamp, who points to other theoretical frameworks to transgress the prevailing mimesis in the theory of pictures.

4 A few important publications from the last three decades that support our argument are, for instance, Jonathan Crary's *Techniques of the observer* (1990), Ulrike Hick's *Geschichte der optischen medien* (1999), Friedrich Kittler's Optical Media: Berlin Lectures 1999 (2000), Siegfried Zielinsky's *Deep time of media* (2006) and Sean Cubitt's *The practice of light* (2014).

5 For instance: Weibel, Peter; Jensen, Gregor (Eds). *Lichkunst aus Kunstlicht: Licht als Medium der Kunst im 20. und 21. Jahrhundert.* Catalog for an exhibition "Light Art from Artificial Light: Light as the Medium of Art in the 20th and 21st Centuries" at the Zentrum fur Kunst und Medientechnologie in Karlsruhe, Germany, 2006. and Cubitt, Sean. *The practice of light: a genealogy of visual technologies from Prints to Pixels.* Cambridge, Massachussetts/London, England: MIT Press, 2014.

interaction: the photosensitive elements. This object of analysis was strategically chosen as a means to consider media artworks in their expanded, heterogeneous, relational and dynamic expressions.

As active materials, photosensitive elements are inextricable from the processes and relationships in which they take part. This perspective draws on the physicist and new materialist Karen Barad's (1956-) agential realism[6], which deals with matter (such as meaning) not as a static entity but as a doing and sees its ongoing historicity as part of the constant stabilizing-destabilising process of the world's iterative intra-activity. As a new materialist approach, it envisions the inseparability between epistemology and ontology[7] by means of investigating similarities and differences in the materiality of photosensitive elements. Through this process, the accumulated knowledge they enclose is revealed, and the findings are complemented by aesthetic implications for media art.

In this sense, my approach has also been directly influenced by the notion of active matter expounded by science and media historian Wolfgang Schäffner (1961-). Schäffner analyses the paradigm shift in the role of materiality in the humanities by observing the developments in the multiple ways of understanding the materiality of knowledge, ranging from the passive materials of Kantian philosophy to the active materials of quantum physics and contemporary new materialist approaches. His analysis defines the form of an object as a diagram of forces, thereby making materiality and its related operations interdependent[8].

One of the premises to bear in mind is that every material is somehow sensitive and reactive to physical or chemical stimuli, with each reacting differently in time and according to specific contextual changes, such as temperature, pressure, moisture, and so forth. Photosensitive matter is just one among a multitude of possible case studies.

General contemporary explanations of sensors by biologists and engineers[9] show surprising consensus. Biologist and neurologist Friedrich G. Barth states that *"all sensors absorb some kind of energy (an exception being cold receptors responding to loss of thermal energy), typically in minute quantity, and generate electrical signals"*[10]. This func-

6 Barad, Karen. *Agentieller realismus: Über die Bedeutung materieler-discursiver Praktiken*. Berlin: Suhrkamp, 2012.

7 Barad 2012.

8 Lecture "*Materialität und operationen I: Active Matter*" by Wolfgang Schäffner, in the *Ringvorlesungen* at *Humboldt-Universität zu Berlin*. January 28th 2015. A parallel and historical perspective complementary to this approach is the work by Sir. D'Arcy Wentworth Thomson's (1860-1948) *On Grown and Form* (1917).

9 For an introduction to our basic understanding of sensors, see: Barth, Friedrich G; Humphrey, Joseph A.C.; Secomb, Timothy W. (Eds.) *Sensors and sensing in biology and engineering*. Wien/New York: Springer, 2003; and Fraden, Jacob. *Handbook of Modern Sensors: Physics, Designs and Applications*. New York, Berlin, Heidelberg: Springer-Verlag, 2004.

10 Barth 2002: 3-4.

tional aspect of sensors is crucial to the understanding of photosensitive elements and has important implications for cultural studies, which will here be discussed in relation to artistic practices.

Knowledge of the atomic world and its quantum mechanics has led to new methods for handling matter and constitutes the main foundation of current approaches to the diverse expressions of active matter. It is now known that the physicochemical properties of a certain chemical element are predominantly given by the configuration of its electrons; more precisely, by the structure of the outermost layers, where the so-called valence electrons are located. The mobility of these electrons enables the rearrangement of atoms and molecules, that creates every activity of matter by means of chemical reactions that change its physical properties. The mobility of valence electrons is also what generates electric current, which is the physical basis of phenomena related to electricity and magnetism.[11]

Curiously, although atomist theories emerge from the obstinate human drive to find the minimal and indivisible part of matter, the more scientists discover, the further they are from finding a minimal end point in the atom or a maximal one in the expansion of the universe. Recent studies on quantum physics have shown that sub-atomic particles also exhibit wave properties.[12] Such discoveries have led to dynamic conceptions of matter.

Furthermore, the dual quality of light (physically described as electromagnetic radiation with wave-particle properties) that enables the "magical" light-matter interactions, offers an interesting example to deconstruct the prevailing dichotomous relationship between material and immaterial. What has been thus far discussed is enough to realize that photosensitive matter is just as responsible for the development of media devices and techniques as light is, and an image in the traditional sense is only one of the manifold possible outcomes of photosensitivity.

This opening chapter intertwines the realms of materialities and operations related to photosensitive matter in order to build the foundation for a discussion of issues relevant to media art aesthetics. Due to the relational aspect of the sensing phenomena, the operations involved in the analysed materials are simultaneously addressed. They often address concepts, models and methods that have been systematised in order to be learned, reproduced and, if possible and/or necessary, improved.

Each part of the chapter articulates a thought based on the increasing complexity of the technical ensembles analysed, recalling Gilbert Simondon's perspec-

11 Kohen, Elli; Hirschberg, Joseph; Santus, René. *Photobiology*. San Diego, CA: Academic Press, 1995. p. 20.

12 Ibid: 16-19.

tive,[13] articulating both concrete and abstract instantiations of knowledge. These range from models for understanding molecular activity in photosensitive materials, through their concretizations in media devices to their implementation and operations in artistic contexts. Artificial classifications and chronological threads have been avoided, being the photosensitive elements recruited along the text according to their usefulness in clarifying the thesis argumentation.

The information above provides the conceptual and technical tools to deconstruct the historically embedded dichotomous material-immaterial relationship within media art. In what follows, this topic is unfolded through the notion of informational aesthetics and the analysis of the media artwork *Luzes relacionais* (2010), by Ernesto Klar.

1.1 Light and photosensitive matter

One of the very first premises of this study is that light *"only becomes evident when it interacts with matter"*[14]. Therefore, it is only possible to discuss the effects of light from a relational perspective. The interaction between light and matter has been observed, understood, depicted and controlled in a huge variety of ways in the history of culture. For instance, in the Middle Ages, *"scholastic metaphysics classified light as a substance, an embodied spirit, which distributes divinity to all God's creation"*[15]. The scholastic attribution of the divine to light can likewise be experienced in the architecture of gothic cathedral. Architect and theoretician Philip Tabor explains further: *"through the stained-glass windows, Divinity radiated more through light as essence than through the images depicted on the windows. Light's primary role was performative. The medium was the message"*[16].

Interestingly, the approach becomes much more distinctive if one compares it with the symbolic role of light related to reason and rationality that came to predominate in the Enlightenment. When the first sprouts of the scientific method as known today emerged, light was subjected to empirical tests in order to depict and

13 In *Du mode d'existence des objets techniques*, Simondon elaborates his theory of the concretization of technical objects based on their 'evolution' through processes of individuation and/or the organized collection of individuals. (Simondon 1958:75)

14 Le Grand, Ives. *Introduction to photobiology: The influence of light on life.* London: Faber and Faber, 1970, p. 15.

15 Tabor, Philip. Striking home: telematic assault on identity. In: *Doors of Perception 2*. 1994. Available at <http://museum.doorsofperception.com/doors2/transcripts/tabor.html> Accessed July 5th 2016.

16 Ibid.

explore its nature. The physicist Isaac Newton's (1643-1727) experiments in optics[17] in the seventeenth century are the most significant to mention here. Indeed, the history of the birth of chemistry as a discipline in the eighteenth-century is very much related to findings concerning photosensitivity, photochemical effects and studies on the materiality of light, which required distinguishing between fire and light, and between light and heat[18].

Since the focus here is on media history and aesthetics, these brief aforementioned examples are mentioned merely to briefly outline the phases of the exploration of light in its empiric, abstract and symbolic levels. More relevant is how light in association with photosensitive elements, not only gave birth to visual media but participates in its deconstruction as well. The transformation of light sensitive materials into sensors that translate luminous stimuli into electrical signals opens an enormous field of possibilities for expanding the concept of the image beyond that of the mimetic traditional, where it is viewed as something inscribed and seen only by light. Yet this entails an exponential expansion as it requires one to go beyond the human eyes' visible light spectrum, which, according to the calculations of the physicist Augustin Fresnel (1788-1827), ranges from wavelengths of about 400nm to about 750nm[19]. In addition to this spectrum there are non-visible forms of radiation, such as infrared and ultraviolet[20].

In communication theories influenced by the mathematical and engineering perspective of Warren Weaver (1894-1978) and Claude Elwood Shannon (1916-2001), the role of sensors in transforming light into electric voltage has been defined as part of a system's receiver, constituting an interface through which input data is enabled. The "captured" data (which is essentially electric voltage changing inside a microprocessor's circuits) can be sequentially processed and programmed to turn the initial electric energy (input) into any other physical manifestation (output). As a sort of membrane, sensitive matter demonstrates how permeable and modifiable things can be. Artworks that embed sensors, using their technical principles as aesthetical means, manage to drive artistic experiences to another epistemological layer encompassing the manipulation of matter subjected to implications of data processing and programming. In this sense, media artists may participate more deeply in the process of shaping the forces that govern the activity of matter. The following pages discuss how photosensitive elements both found in nature and

17 Among other studies, the English physicist explored the refraction phenomenon of light, demonstrating through a prism the existence of monochromatic light and the intimate relationship between light and colour. (Kittler 2010: 122-123)

18 In Western culture, before the birth of chemistry, since the Greek Antiquity, the elements that every being in the world were defined only through the elements of fire, air, water and earth. (Kittler 2010:122)

19 $1nm = 10^{-9}$ m.

20 Kohen et al 1995:12.

created by humans present and enable this permeability of dynamic systems. It is precisely this quality of sensitive matter as an interface that testifies to the dynamic materiality of media art.

Since it is impossible to include the immense variety of existing photosensitive materials and their correlated techniques, key examples have been chosen that indicate stronger relationships to media history and have had a broader impact on the aesthetics of media art. These examples include, for instance, light-sensitive proteins, silver salts, selenium, sensitization technique, photolithography with semiconductors, and others. In order to better understand how photosensitivity is possible, it is crucial to briefly address the basic structures and principles governing light-matter interactions on the molecular level.

1.1.1 Molecules act

Photochemistry is the established field in charge of modelling light-matter interactions. It describes the agents and mechanisms involved in chemical reactions caused by the absorption of light, from ultraviolet and visible light to infrared radiation. Due to quantum theory, elaborated in the beginning of the 20th century[21], the theoretical basis of photochemistry today has established a solid basis that enables scientists and artists to investigate and play with the rules of photo-biological processes and other photoelectric effects incorporated in sensor engineering.

The valence electrons present in the outermost orbits of an atom allow the molecules to be recombined, altering the qualities of matter and/or producing a variety of specific physicochemical effects. The photoelectric effect[22], which according to classical electromagnetic theory corresponds to the transfer of the energy of light to an electron of a specific material, is one of these and has been used extensively in the development of photosensitive artefacts. In photobiology such physicochemical effects are associated, for instance, with bioluminescence, photosynthesis, phototropism and other related phenomena[23].

Scientific observations of the photoelectric effect have, moreover, contributed to the current understanding of the wave-particle characteristics of light. It was ex-

21 In 1908, Johannes Stark (1874-1957) and Albert Einstein (1879-1955) published the "Law of photochemical equivalence". (Le Grand 1970:26) Moreover, quantum mechanics has been enhanced since the discovery that electrons also have wave properties, which enabled more complete calculations to be made by the physicists Erwin Schrödinger (1887-1961) and Paul Dirac (1902-1984).

22 The photoelectric effect was "*first noticed by Heinrich Hertz (1857-1894) when he was in the process of discovering radio waves ca. 1887*". (Kohen et al 1995:14)

23 In photobiology, when a specific beam of radiation is "*absorbed by biomolecules, the outermost electrons, e.g., those involved in atom binding, are affected. As a result, chemical changes can occur during light absorption*". (Kohen et al 1995: 22)

periments on the photoelectric effect and Max Plank's theory that energy exists in small and discrete pieces called *quanta* that served as the point of departure for Albert Einstein's 1905 proposal on the dual nature of light. As the photoelectric effect occurs *"when light strikes a solid in a vacuum and electrons are ejected from the surface"*[24], the quantity and energy of the emitted electrons from the surface form an electric current that can be measured[25].

Another discovery concerning the interaction between light and matter that is relevant to media history harks back to Newton's 1666 experiments showing that white sunlight is not a single entity but a spectrum of infinite colours. Today, this principle has been extended to the idea of colour's immateriality and its absolute dependence on physical properties of the light spectrum and material it is in contact with.[26] When isolated, the energy of a monochromatic beam of radiation is related to its wavelength and frequency – measuring parameters commonly used either in scientific or aesthetic investigations.

Nonetheless, the immaterial condition of colour is questionable if one regards photosensitivity through the molecular structure of pigments. Visual pigments of vertebrates, for instance, share structural features in their molecular level, being basically constituted by an opsin apoprotein plus a chromophore.[27] Opsin, a group of light-sensitive proteins found in the photoreceptor cells of animals' retinas, mediate the conversion of a photon of light into an electrochemical signal. Chromophore is the part of the pigment molecule responsible for the colour (light spectrum) to be absorbed by the cell[28]. Photon capture through the photoisomerization[29] of the chromophore is the first step in the visual transduction cascade and the only light-dependent phase.[30]

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24 Kohen et al 1995:14-5.

25 Also, according to Kohen et al. (1995), when electrons are bound to atoms and molecules they have well-defined quantities of energy. The rise to the condition of radiation (absorption of quantum or emission of photon) only happens when they 'jump' from one orbit to another.

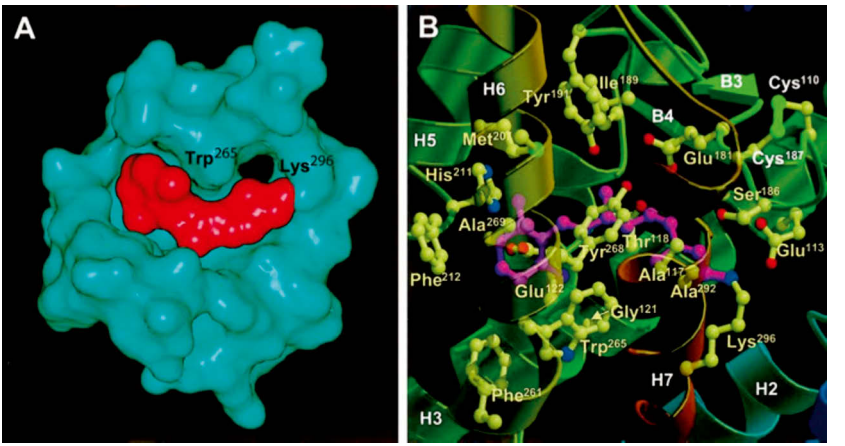
26 A complete publication bridging Science and Art in relation to the conceptual and phenomenological principles of colour, and its immaterial quality is Pedrosa, Israel. *Da cor à cor inexistente.* Rio de Janeiro : Léo Christiano, 1977.

27 Menon, Santosh T.; Han, May; Sakmar, Thomas P. Rhodopsin: Structural Basis of Molecular Physiology. In: *Physiological Reviews.* Vol. 81, n. 4, October 2001. p. 1660.

28 Parihar, Parul; Singh, Rachana; Singh, Samiksha; Tripathi, Durgesh Kumar; Chauhan, Devendra Kumar; Singh, Vijay Pratap; Prasad, Sheo Mohan. Photoreceptors mapping from past history till date. In: *Elsevier - Journal of Photochemistry and Photobiology, B: Biology* Vol. 162, September 2016, pp. 223–231.

29 An isomer corresponds to a molecule that presents more than one chemical structure for the same formula. Photoisomerization is the molecular behavior caused by photoexcitation that changes the molecule structures, although its formula remains the same.

30 Menon et al 2001:1661.



1.1: Detail of a chromatophore on a visual pigment in molecule model. A: Part in red; B: Part in magenta; Source: Menon et al 2001: 1663.

Concerning photosensitivity in the so-called inorganic side of photochemistry, a prominent role is ascribed to the chemical element silver and its derivate compounds, namely the silver halides (AgX)[31], such as oxide of silver, silver nitrate, silver chloride, silver bromide, silver iodide and iodate.

The pre-history of photography is attributed to the first experiments conducted by polymath Johann Heinrich Schulze (1687-1744) around 1725.[32] After observing that a leftover chalk and nitric acid into which some silver had been dissolved was darkened by sunlight, Schulze made experiments combining several materials with silver nitrates. One of them was to apply that same paste of silver nitrate and chalk in a glass bottle and wrap it in a piece of paper containing cut out letter shapes, which darkened after being exposed to light. Schulze's experiments, however, did not provide permanent images, which were mostly achieved by using objects (letters) as masks placed between the light source and light-sensitive surface.[33]

31 Many of the halides are salts, binary compounds with a halogen atom [fluorine (F), chlorine (Cl), bromine (Br), iodine (I), and astatine (At)] plus an element or radical that is less electronegative (or more electropositive) than the halogen. Fujita, Shinsaku. *Organic chemistry of photography.* Berlin/Heidelberg: Springer Verlag: 2004. pp. 39-44.

32 Hage, Wolfgang. Die Entropie der Fotografie. Skizzen zur einer Genealogie der digital-elektronischen Bildaufzeichnung. Referat Oberseminar Friedrich Kittler at Humboldt-Universität zu Berlin. July, 10th 2001. Available at <http://www.whagen.de/PDFS/11049_HagenDieEntropiederFot_2001.pdf> Accessed May 19th 2017.

33 Watt, Susan. Silver in photography. In: *The elements: Silver.* New York: Benchmark Books Marshall Cavendish, 2003. p. 21-24.

Although historians assert that Schulze's light-writing experiments anticipated photography[34], media archaeologist Friedrich Kittler (1943-2011) claims that this would be acceptable only for the literal meaning of the word 'photography', but not for the photographic process itself, which involves many more complex combined techniques. Kittler alleged that what was at stake in Schulze's experiments was encoding data rather than storing images by means of light: "*Schulze did not want to store the contingent nature of the real (in Lacan's sense of the word) in a technical medium, but rather he wanted to introduce the symbolic, namely a written code, into nature*".[35]

Predecessors of Schulze in the history of the photosensitivity of photographic technique – Joseph Nicéphore Nièpce (1765-1833), Louis Jacques Mandé Daguerre (1787-1851), William Henry Fox Talbot (1800-1877) and others[36] – were, in contrast, far more explicit in their intentions to fix and reproduce images due to its promising commercial and industrial purposes. Nevertheless, what is significant in Kittler's thinking is his media-archaeological ability to establish atemporal relationships among the operational qualities of media. This sort of analysis is possible so long as an accurate look at the materialities and operations is involved. If one compares the technical knowledge of materials and techniques with learning a language, the more one is acquainted with the grammar, the bigger the chances are that one uses one's own repertoire to create relevant information, or, in cases of artistic intent, poetry.

The chemical term 'emulsion' refers to the mixture of two or more liquid solutions; in photography, it refers to the photosensitive layer coated on the support being used, whether glass, cellulose acetate, celluloid, paper or other. Photographic emulsions are basically made by blending a neutral solution of silver nitrate[37] with any soluble halide and a medium to bind the emulsion to the surface.

At the molecular level of photochemical processes with silver halides, silver's photosensitive quality is explained by the breaking down process of silver nitrate into pure metal by the agency of light. For the same reason, many other silver-based compounds are photosensitive and are used not only for coating but also for developing films and, subsequently, in the transfer of the image to paper or another surface.[38]

The first experiments by the painter and physicist Louis Daguerre aimed at fixing an image using a camera obscura were done with silver iodide coated in a polished copper plate, which was later immersed in mercury vapour. The process

34 Eder 1978: 62 apud Kittler 2010:122.
35 Kittler 2010:122.
36 Hage 2001.
37 Silver nitrate ($AgNO_3$) is a compound formed from the mixture of silver metal (Ag) and nitric acid (HNO_3). Watt 2003: 15.
38 For more details see Fujita 2004.

resulted in expensive unique images, which later became commercially obsolete with the reproducibility enabled by the use of negatives and paper[39].

The photographic film still in use today is coated with silver bromide, the most common compound used in negative emulsions. Silver bromide is formed of positively charged silver ions (Ag^+) and negatively charged bromide ions (Br^-). When excited by a photon, a bromide ion starts a reaction that discards an electron, thereby becoming a bromine atom. The released electron joins the silver ion, forming a silver atom.[40] In this process, a latent image is formed, in which the clearest parts of the photographed image are the darkest parts marked in the emulsion, and vice-versa. The inverted colour nature of the latent image in the film is the reason why it is called a negative.

The quality and origin of the binding medium also influences the sensitiveness of the emulsion and was initially the albumin, or egg white[41], which was a pioneering and commercially successful method of producing photographic prints on paper from a negative. Another organic material that supplanted albumin was gelatine, a substance extracted from animal's bones, horns and paws. In 1871, photographer and physician Richard Leach Maddox (1816-1902) invented gelatine negative plates[42], which was more practical for commercial purposes than the former collodion wet-plates process. On paper, in turn, gelatine was applied in 1885, when photo-chemist Johann Baptist Obernetter (1840-1887) developed a gelatine-chloride emulsion printing-out paper.[43]

1.1.2 Toward more complex technical ensembles: immediate and colourful

The documentation of the technological environment of the industrial period shows that due to financial convenience or even military purposes[44] there was a constant search for more sensitive emulsions, that is, reactively faster materials, and the instantaneity of photographic processes. It is not by chance that technicians developing instantaneous cameras like the Polaroid managed to overlap film and paper functions. Such merging of functions in a single technical ensemble represents a

39 In 1841, chemist William Talbot introduced the negative-positive method in photography by using paper soaked in silver iodide to form an image. The technique was named calotype or talbotype. (Kittler 2010:132-136)

40 Watt 2013: 23.

41 The albumen silver print method was developed by the photography enthusiast Louis Désiré Blanquart-Evrard, who published his findings in 1847. Newhall, Beaumont. 60,000 Eggs a day. In: *IMAGE Journal of Photography of the George Eastman House*, Vol. IV, n. 4 April, 1955.

42 Viebig, Reinhard. *Tudo sobre o negativo – revelação, correção e sua aplicação.* São Paulo: Editora Iris, 1975, p. 13-15.

43 Newhall 1955.

44 Kittler 2010 and Viebig 1975.

trend toward convergence that has been accelerated by electronics and digital technology.

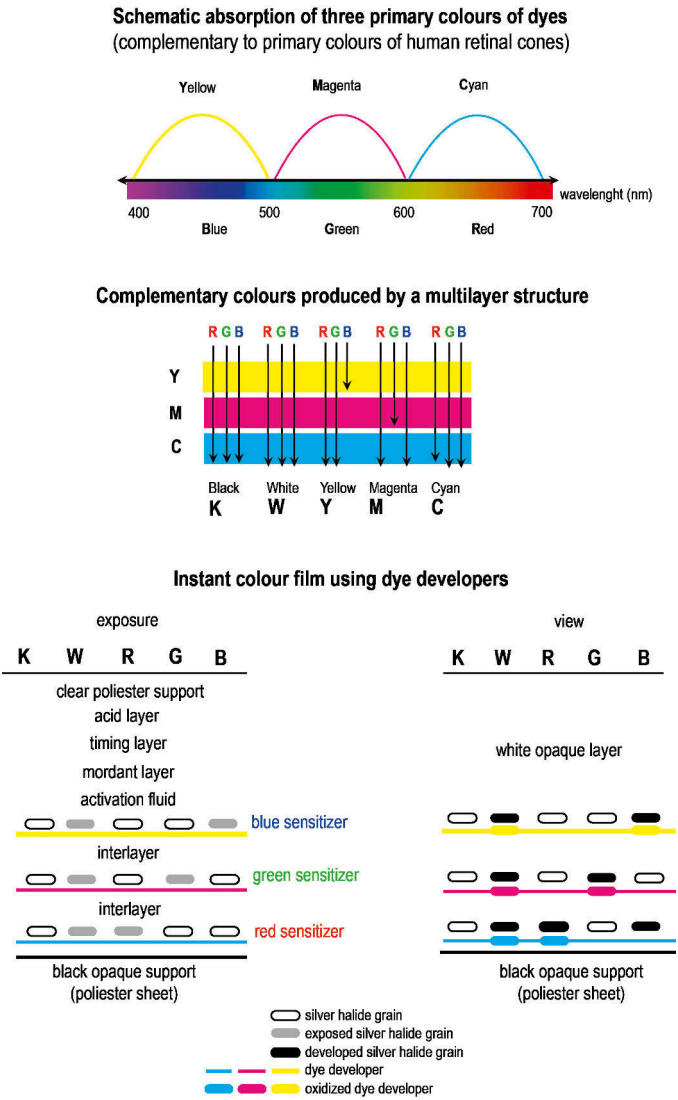
Another result of the supremacy of vision in western culture and the related drive to obtain images more attuned to the capacities of the human eye were demands for the development of colour film. Instead of one layer of light-sensitive particles, colour film has three light-sensitive layers, each sensitive to a specific range of the light spectra: blue, green and red. This combination from the RGB colour model, which was based on the Young–Helmholtz[45] theory of trichromatic colour vision, was developed at the beginning of the 19th century and influenced by studies on the photoreceptor cells of our eyes[46]. Young and Helmholtz's research results guided the development of colour-film, motivating the creation and application of dyes able to absorb or reflect each of the RGB light spectra. According to Kittler, the pioneer in converting the new colour physiology into a technical ensemble was James Clerk Maxwell (1831-1879)[47], who was the first to develop long-lasting colour photography.

The figure below relates the Young-Helmhotz theory to a multilayer structure model of how an instant colour film works during exposure and after development:

45 Thomas Young (1773-1829) was a British polymath who contributed to the fields of vision, light, solid mechanics, energy, physiology, language and Egyptology. Hermann von Helmholtz (1821-1894) was a German physiologist, physicist psychologist and philosopher. His treatise on physiological optics is the basis of modern studies on vision. Gregory, Richard Langton. *Eye and Brain – The psychology of seeing*. Oxford/Tokyo: Oxford University Press, 1998. p. 103

46 Kittler 2010:204.

47 Ibid.



1.2: A schematic from human cones sensitivity to the implementation of multilayer structure of instant colour film during exposure and after development; Source: Adapted from Fujita 2004:377-378.

The model didactically shows how the three primary colours, i.e., yellow(Y), magenta(M) and cyan(C) dyes react differently to red(R), blue(B), green(G) light spectra, forming a sort of filter cascade. Y dye absorbs B light so that G and R light

pass through transparent materials and, following the same logic, M dye absorbs G light; whereas C dye absorbs R.[48]

Colour film also faced an intriguing issue in its history when professionals noticed that emulsions of colour films were based on light-skin standards[49], and denounced the Caucasian bias behind the development of such a technical object. The polemic arose when this fact became a problem for the market itself, when photographers, for instance, had difficulties making adequate pictures of darker wood furniture. The fact became even more evident when people of colour started to be represented in mass and mainstream media more frequently. This case shows why scientists working on the very material aspects of things in their laboratories should not work in isolations from the ethical and political implications of their work. Half a century later, similar problems showing the lack of diversity in technological industry still arise, as in the creation of algorithms for face, smile or blink recognition. These examples can be used as an impetus to reflect on how problematic Western culture's traditional divisions can be, where the natural sciences are opposed to the humanities, and the natural world is opposed to man-made cultural objects.

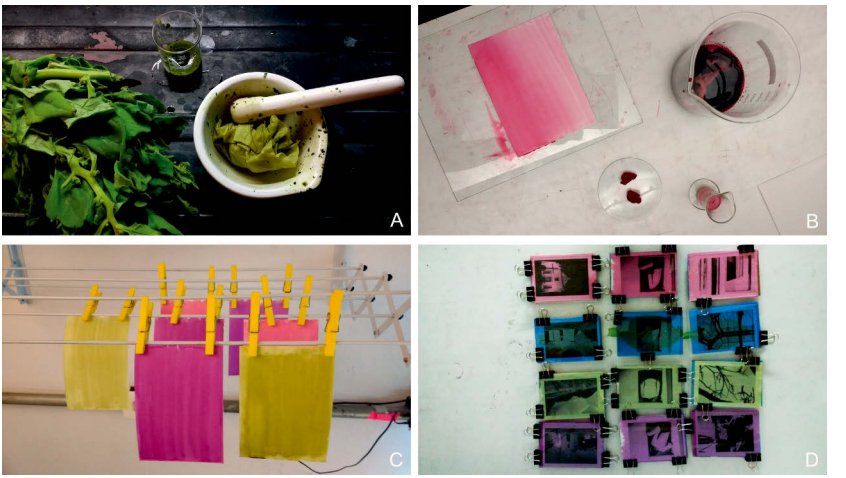
Recognizing that the absorption of specific wavelengths is colour-dependent, the use of dyes in sensitizing methods have been developed and used in several disciplines ranging from biology, to engineering, to art. An example of an aesthetic use of this can be observed in the production of Anthotypes through a technique to print photographic images using photosensitive matter from plants and sunlight. Like other image production techniques, it has emerged as the result of the inventions and discoveries of many people. Prominent historical examples include the pharmacist Henri August Vogel (1778-1867), who in 1816 noticed that plant juices were light–sensitive; and polymath John Herschel (1792-1871), who conducted extensive and systematic research on the topic, publishing it in 1842. The work by polymath Mary Fairfax Greig Somerville (1780-1872), who researched the action of rays on vegetable juices, has gained acknowledgment more recently.[50] Today the technique is still executed according to the following main steps: extracting the emulsion from the plant using either pestle and mortar or an electric blender, adding water or alcohol as diluter if necessary; coating the paper surface with the emulsion; framing the positive image or masking objects with the paper; and ex-

48 Fujita 2004:106.

49 More detailed explanation of this aspect of film colour history can be seen at <https://www.youtube.com/watch?v=d16LNHIEJzs> Accessed March 17th 2017.

50 According to Fabbri, Sommerville was not able to publish her ideas and findings simply because she was a woman. Fabbri, Malin. *Anthotypes – Explore the darkroom in your garden and make photographs using plants.* Stockholm: Alternative Photography, 2012. p. 12.

posing it to sunlight for bleaching.[51] The time of exposure and the transformations in colours vary widely depending on the light spectrum to which each pigment is sensitive, which is determined by its molecular composition (as already explained when introduced the chromophore). It is also known that pigments are generally more sensitive to UV light, the major "molecular destroyer" radiation.



1.3: Sequence of procedures for making an anthotype. A: Crushed spinach with pestle and mortar; B: Coating process with beetroot extract; C: Coated paper drying. D: Framed anthotypes ready for exposure to sunlight. From above to below: pigment from beetroot, tobacco leaves, pigment from spinach and red rose. Anthotypes produced at the workshop of Simone Wicca at Imagineiro in January 2017 in São Paulo. Photos: Graziele Lautenschlaeger.

After the anthotype is unframed, if the image formed is kept exposed to sunlight it will continue bleaching, resulting in its total disappearance. There remain difficulties even today when it comes to fixing the image from natural pigments on the surfaces, a problem encountered when using natural dyes for fabric as well. This, coupled with its non-immediate results, left anthotyping quite marginalised, but it continues to be used by artists and alternative photographers. Contemporary practitioners of this technique are the artist Malin Fabbri[52], who has systematized a series of experiments she made using fruits, leaves, flowers and roots from temperate regions and the artist Simone Wicca, who has been doing similar work using tropical plants.

51 A more detailed and didactic tutorial can be found on the webpage Alternative Photography: <http://www.alternativephotography.com/anthotypes-making-print-using-plants/> Accessed May, 5th 2017.

52 Ibid.

The search for immediacy is related to the human compulsion toward the materialization of memories and the desire for eternity, as has been frequently discussed in the history and theory of photography and the image by many authors[53]. Nevertheless, the extreme increase in the speed of image production and consumption through digital and networked technologies has contradictorily reinforced the elusive aspects of imaging. In this sense, a paradoxical outcome of media development is an invitation to revisit the elusiveness of life.[54]

Curiously standing out is the difference between the darkening effect of silver salts in photography and the bleaching effect of organic matter. In the first case, the photoreduction of silver ions into silver metal produces the effect, and the colour shade changes according to the energy and intensity of the irradiating light source. The higher the concentration of the salts is, the earlier the colour changes. In the second case, the molecules are also broken apart by UV light, in a process that is different for each pigment, and chromatophore cannot be seen anymore.

1.1.3 The knife gets sharper: fragmenting, black-boxing, converging and operating

This survey of a few of the methods and materials relating to photosensitivity in photographic techniques clarifies how photochemistry enables artists to manipulate materials on the atomic level to achieve specific, and sometimes unexpected, aesthetic results. This kind of exploration, beyond the direct capacities of the human senses, has become more and more refined. As Vilém Flusser used to state regarding the advances in precision, miniaturization and the corresponding abstractive processes in the development of cultural objects: *"The knife is getting sharper"*[55]. When diving into the molecular universe, it is the logic of quantum mechanics that rules. Matter is understood as energy, whose measurement is, incidentally, also dependent on our understanding of the nature of light and its discrete amounts of energy, called photons and quanta.

The scientific discoveries that led to nanotechnology were crucial for the development of semiconductor materials and devices. Among other properties (passing current more easily in one direction than the other, showing variable resis-

53 One of special significance for this work is Debray, Regis. *Vida e morte da imagem. Uma história do olhar no ocidente*. Petrópolis, RJ: Vozes, 1993.

54 Perhaps the emergence of more sustainable biological matter-based techniques also constitutes a side-effect of the aforementioned desire for eternity, as a human attempt to avoid the extinction of their own species.

55 From the original in German: "*Das Messer wird immer schärfer*"; Flusser's sentence was discussed and debated at panel discussion *Flusser Talks "Entwerfen" – Im Dialog mit Vilém Flusser*, as part of the exhibition *Bodenlos - Vilém Flusser und die Künste*, held in Berlin at the Akademie der Künste in Nov, 25th 2015.

tance) they are also heat and light sensitive – turning the distinctive borders of these two physical qualities blurred again. Semiconducting materials include, for instance, silicon or germanium, whose semi-conductive behaviour was first recorded with the use of silver sulphide crystal in 1833. Nowadays, technologies like CMOS (Complementary Metal-Oxide-Semiconductor), CCD (Charged-Coupled Device) and QIS (Quanta Image Sensor), which constitutes one of the essential photosensitive components of digital cameras, are completely based on the special behaviour of those materials. More details about these devices will be explored in the following chapter.

Important now is to notice that in the era of quantum physics, in which energy and matter are proportionally related and human hands are too large for the scale of atoms, it became necessary to build bridges between the capacities of the human sensory apparatus and the materialities being handled on the nano scale. Curiously, the further things are removed from the human senses, the more radical the possibilities for material modifications are.

When the miniaturization process started leading to devices becoming even more radically opaque, media history again experienced a turning point. Miniaturization triggers both the black boxing effect, as Flusser and cyberneticist Ranulph Glanville (1946-2014), each in his own way, have reflected[56], and the convergence of techniques. Black boxing refers primarily to electronic devices whose circuits and way of working are hidden in their containers. Glanville, however, expands the concept from the cybernetic perspective:

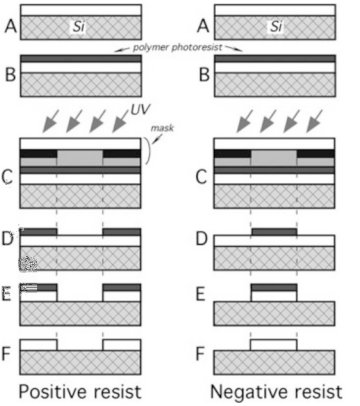
> Black Box is not a physical object, but a concept (a phantasm) we use in order to develop what Bateson calls an explanatory principle, which we evoke when we are faced with an uncertain confusion. It has no substance, and so can neither be opened, nor does it have an inside. Its function is to allow the creation of an explanation of some observed behaviour and any object/mechanism that seems to generate this about which we are uncertain. It is the invention of the observer.[57]

Convergence, in turn, concerns the merging of techniques and the emergence of multi-task technical objects. A key technique related to photosensitivity that addresses this issue is photolithography, a sort of photoengraving procedure that plays a crucial role in the transition and intersection between analogue and digital media objects. Photolithography is a microfabrication process that transfers shapes from the template of a photomask to the surface of a photoresist on a substrate. The photolithographic process demands many precisely stipulated procedures, tools and materials, executed through three main phases: coating, light ex-

56 Flusser, Vilém. *Filosofia da caixa preta*. São Paulo: Annablume, 2011. Glanville, Ranulph. *Objekte.* Berlin: Merve Verlag, 1988.

57 Glanville 2009:154.

posure and development; it is, however, a mixture of photographic and printing techniques that can be repeated many times, layer over layer, depending on the chip geometry[58].



1.4: Positive and negative photolithography steps; Source: Fraden 2004: 627.

Photoresists are photosensitive chemical substances that can be either positive, if after the exposure to light it becomes soluble to the photoresist developer, or negative, in the opposite case. The substrate, popularly called wafer, is a solid planar substance onto which a layer of the photoresist adheres. In solid-state electronics, the materials used as substrates are thin slices of silicon, silicon dioxide, aluminium oxide, sapphire, germanium, gallium arsenide (GaAs), an alloy of silicon and germanium, or indium phosphide (InP). These make up the material basis of electronic components such as transistors, diodes and integrated circuits.

From an historical perspective, according to the media theoretician Sean Cubitt, *"it is in the highly technical craft of the photographic print that the major shift toward electronic image forms begins"*[59]. In the nineteenth century, photolithography had already stimulated the industrialization of image production, *"providing fast, cheap, mass circulation reproductions of photographs that themselves were far faster and cheaper to produce than traditional etched or drawn forms"*[60]. Currently applied in microprinting electronic circuits, photolithography is among the main techniques now used in the production of printed circuit boards (PCBs), integrated circuits (ICs) and

58 Fraden 2004: 548-549.
59 Cubitt 2014: 80.
60 Ibid: 89.

microcontrollers. Each of these is based on the operations enabled by semi-conductors[61], the protagonists of the electronic and digital era.

After the 1950's, when *"photolithography ha[d] become the major tool for printing circuit boards for computer components"*[62], the automation process of image production transformed the former merely representational image into a working and functional image as well, an image whose visual content is far from having the same importance as it had been accustomed to having in media history. Scanning and photocopying techniques at the beginning of the electronic era[63] were the prelude of how electronic components, led by electronic media, triggered a transformation in the creative world. In this context, the photolithographic technique and the manifold logic-based electronic components confirm that photosensitive materiality has long been playing a major role in media development. This is even more apparent if one considers the light-sensitivity based fundamental electronic components, such as photodiodes, photoresistors, phototransistors and photomultipliers.

The idea of a printed circuit as a functional and operative image can serve innumerable purposes since one can designate its function and content, and therefore link other electronic components to create a more complex technical ensemble. By bringing the materiality and programmability of electronics together, the dichotomous distance between analogue and digital techniques becomes less formidable and could elucidate a way to see both as a continuum[64].

Another milestone related to photosensitive materialities in media history dates from the discovery of the "semiconductors' grandfather", the chemical element selenium[65]. Although it was discovered in 1817 by chemist Jöns Jacob Berzelius (1779-1848), it was only more than half a century later, in 1873, that the electrical engineer Willoughby Smith (1828-1891) demonstrated selenium's photosensitivity and its ability to transform light energy into electricity. In *The Moon*

61 According to sensor engineer Hans Meixner, "*With LIGA procedures (lithography, electroforming, molding), microstructures can be implemented from a wide range of materials, such as metals, plastics and ceramics. Silicon clearly dominates the materials used at present, but metals, plastics and glasses are gaining in importance*". (Meixner 2003: 23)

62 Cubitt 2014: 83.

63 Ibid: 5.

64 In other words, this can also be discussed through the interdependence between software and hardware, as Wendy Hui Kyong Chun has elaborated in *Programmed Visions* (2011).

65 According to the physicist Allan Mills, together with sulphur and tellurium, selenium falls into Group VI of the periodic table, sharing similar chemical properties. Sulphur has been known since ancient times since it occurs in the free state around the vents of active volcanoes. The discovery of selenium by Berzelius was based on its separation "*from a deposit formed in a lead chamber used for making sulphuric acid from roasted iron pyrites. Tellurium was isolated from the same source in 1832. Nowadays, both elements are obtained from the 'anode slimes' that are by-products of electrolytic copper refining.*" Mills, Allan. Selenium and light. In: *eRittenhouse* Vol. 24, 2013. pp. 1-7.

Element (1924),[66] the physicist and chemist Edmund Edward Fournier d'Albe (1868-1933) presented the wonders of selenium and its main known applications at that time, ranging from the construction of automatic systems, through experimental devices for voice, text and image transmission to other future speculative uses. The discovery of selenium has in fact led to the development of the technology of television as well as subsequent technologies for the transmission of images through electric current – i.e. image fragmentation for transmitting purposes. Observing this material technological episode, it is possible to confirm what Cubitt has already stated, namely that the technological transition to electronic media can also be seen as a shift of focus from storage to transmission. This coincides with the efforts made in the 1970s to concentrate strategic research and development goals primarily on microelectronics[67]. According to Kittler, it is probable that *"the history of the development of television was the first realization through electronics of all of the functions named in Shannon's information theory"*[68]. This point is likely one of the foundations of the dichotomy between analogic and digital, which Kittler clearly distinguished, without, however, sticking to any particular class of media. In his view:

> In principle there are two possible solutions: in the first case, the signal generated by the sender corresponds proportionally to the message, which means that it follows all of its changes in space and/or time. This is called analog communication, as in the case of gramophone, microphone, radio or even photography, and while it is more familiar it is also unfortunately more difficult mathematically. In the second case, the message is broken down into its pure constituent elements prior to transmission in order for it to fit the capacity of the channel, which is in principle always physically limited. These elements are entirely of the same type,

66 Fournier D'Albe, Edmund Edward. *The Moon Element – An introduction to the wonders of selenium*. New York: D. Appleton and Company/London and Aylesburry: Hazell, Watson &Viney, 1924. Bell, Alexander Graham. The Photophone. In: *Science* Vol. os-1(12), September 11, 1880, p. 130-134.

67 According to Hans Meixner, the focus of scientific research in the 1980s shifted to materials research and information engineering. The 1990s was marked by miniaturization and the integration of functionalities. Meixner, Hans. Sensors and Sensing: An Engineer's View. In: Barth, Friedrich G; Humphrey, Joseph A.C.; Secomb, Timothy W. (eds.) *Sensors and sensing in biology and engineering*. Wien/New York: Springer, 2003. p. 18. It is possible that beginning in the 2000s an intensification and simultaneity of all the previous trends occurred, culminating in the search for cross-disciplinary research and making simple linear progressions absolutely impossible.

68 Kittler 2010: 208. Shannon's general model of a communication system and its internal mechanism is based on the following elements: (a) data source(s), translator(s), channel(s), receiver(s) and data sink(s).

> such as letters in the case of a spoken message or numbers in the case of computer technology or the individual pixels of a monitor.[69]

Kittler goes on to further explain how the mathematical information processing leads to its fragmentation: *"in partial contrast to film, which consisted of a discontinuous or discrete sequence of many analog photographs, television began as radical cutting: it not only cut up movements in time, but it also disintegrates connections or shapes into individual points in space"*.[70] This disintegration is becoming more radical with the enhancement of algorithms behind the codecs currently applied to digital images[71], irrespective of the purpose they are developed.

1.2 Photosensitive materials and related operations

Sunlight is one of the prerequisites for life on Earth. It governs several biological processes in plants and animals, directly and indirectly influencing the basic cultural developments towards measuring the physical properties of the world and systematizing daily-life. Light has been perpetually used and analysed by humans, both as a means of control and as a force that controls us.

The circular dynamic between photosensitive elements and their surroundings leads to the understanding that photosensitivity cannot be conducted in isolation. Photosensitive materials and devices are embedded in broader technical ensembles in order to execute operations that are more or less pre-determined by their context. Some of the operations in which photosensitivity may be implicated are signalling, measuring, calculating, computing, controlling, automating, regulating, self-organizing, and many others.

The human appropriation of the photo-sensing phenomena in the history of culture emerges, therefore, as acting upon the contingency of the world, with expressions that can assume a variety of forms, from neglecting and resisting, to accepting and adapting to external influences. Understanding the correlations between photosensitivity and these possible operations is aesthetically valuable for media art, whose creative processes are often sustained by the interplay between accident and control.[72]

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69 Kittler 2010: 45.

70 Kittler 2010: 209.

71 Cedeño Montaña, Ricardo. *Portable moving images: a media history of storage formats*. Berlin: De Gruyter, 2017.

72 This dynamic in media art was outlined by the author in her master's thesis *Arte Programmata: entre acidente e controle*, defended at University of São Paulo in 2010. The same principle as an aesthetic motif in *Neue Musik* in the 1950's was discussed in the publication Lammert, Angela; von Amelunxen, Hubertus (Ed.) *Kontrolle und Zufall - Iannis Xenakis*. Berlin: Akademie der Künste: 2011.

An advance in the human attempt to master contingency turned sensors into protagonists of the current Internet of Things (IoT) phenomenon. In IoT all kinds of sensors can be embedded in networked objects and bodies, providing companies with the largest possible amount of data on people's actions (from personal biometric data to physical movements on the planet) in order to better understand the behaviour of their potential consumers. On the one hand, IoT represents a market-driven commoditization of the immaterial side of information society. On the other hand, the large scale of data collected and made available for analysis offers the chance for informatics experts to make new discoveries related to the implementation of algorithms in Artificial Intelligence (AI). The novelty here lies less in advancements in mathematics or programming than in the increase of infrastructures, which range from faster and faster processors to more and more widely distributed internet, and the enhanced implementation of already known techniques on the molecular level[73].

A reflex response to these two trends in contemporary media art aesthetics can be seen in the guidelines of important media, technology and society events, such as the Transmediale 2017 exhibition on *Alien matter*[74] curated by Inke Arns and Ars Electronica's 2016 *Radical atoms and the alchemists of our time*[75], inspired by Hiroshi Ishii's theory and practice at the MIT Media Lab/Tangible Media Group and complemented by comments and critiques by Joseph Paradiso, Siegfried Zielinski and others.

In order to establish a dialog between photosensitive elements, their operations and their influence on the aesthetics of media artworks, four of the manifold possible operations involving photosensitive elements have been selected: measuring,

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73 Bensaude-Vincent, Bernadette. Materials as machines. Paper read at the workshop "Science in the Context of Application: Transformations of Academic Research" at the *Zentrum für interdisziplinäre Forschung*. Bielefeld, Oct 26–28th, 2006. Later published In: Nordmann, A. Carrier, M. (Eds.) *Science in the Context of Application*. Dordrecht: Springer 2010. pp. 101-114.

74 Curatorial statement from the exhibition's program: "*'Alien matter' refers to man-made, and at the same time, radically different, potentially intelligent matter. It is the outcome of a naturalization of technological artifacts. Environments shaped by technology result in new relationships between man and machine. Technical objects, previously defined merely as objects of utility, have become autonomous agents. Their capacity to learn and network throws into question the previously clear and dominant division between active subject and passive object. 30 exhibiting artists from Berlin and around the world present works about shifts within such power structures, raising questions about the state of our current environment and whether it has already passed the tipping point, becoming 'alien matter'. Content-wise, the works cluster around four thematic focal points: Artificial Intelligence, plastics, infrastructure, and the Internet of Things – subcategories that are deemed to merge into the nascent great machine and thereby, to speak with Günther Anders, are future obsolete*". (Arns 2017: 3)

75 Stockler, Gerfried; Schöpf, Christine; Leopoldseder, Hannes. *Radical atoms and the alchemists of our time.* Linz: Hatje Cantz, 2016.

automation, controlling and self-regulating. The next sections introduce how these operations are dependent on the combination of techniques and symbols present in their specific technical ensembles. Analogously to the potential articulations of elements in a language, the combinations of technical elements are infinite and can be made to serve a variety of purposes.

1.2.1 Measuring

The earliest known use of measuring coincided with the birth of ancient civilizations in Mesopotamia and Egypt about 5000 years ago. Measuring is part of what the philosopher of technology Bernard Stiegler (1952-) intended to describe with his idea of 'prosthetic human beings', whose nature is necessarily characterized by being makers and users of tools[76]. The idea of being human has become inseparable from the behaviour of measuring the objects as a strategy to understand and act upon the perceived and the non-perceived worlds. This human behavioural trend is intensified during epochs in which rationalization dominates society. In Western culture since the Enlightenment the scientific penchant toward measuring, codifying and classifying has increased exponentially.[77] In this context, measuring has been used as a strategy for comprehending phenomena that one cannot perceive directly with the limited human sensory apparatus.

One of the most ancient uses of light as a parameter for measurement was to measure time by grading the variation of projected shadows from obelisks and solar clocks. This concerned measuring another physical entity through light, which is different from measuring light itself, a task that became the subject of early scientific experiments in the Enlightenment and continued into the modern era. It was through measuring experiments focused on the nature of light that Western thinking transitioned from geometrical optics[78] to wave optics. At the same time, such experiments have led towards the deconstruction of a concept of light based strictly on human visual perception. The current understanding of light in physics holds that: *"light is only a very small part of the enormous range of electromagnetic radiation. It is those wavelengths to which the retina of the eye is sensitive"*[79].

76 Based on Stiegler's writings, Cubitt states that humans have "an insufficient body that requires, for its survival and for its relation with the world, the supplement of technology". (Cubitt 2014: 14)

77 Hausmann, Raoul. Mathematischer Beweis ist das Hauptargument des europäischen Menschen. Berlin, 19.Feb 1927 In: *Dada-Wissenschaft: Wissenschaftliche und technische Schriften*. Hamburg: Philo Fine Arts/Berlinische Galerie - Landesmuseum für Moderne Kunt, Fotografie und Architektur, 2013. p. 140.

78 Geometrical optics deals with light as rays, exploring its behaviours in reflection (Kohen et al 1995: 3-4), refraction (Ibid: 4-5) diffraction (Ibid.: 11-13).

79 Kohen et al 1995: 3.

Only a few years after Newton's pioneering work on the particle theory of light, the astronomer Christiaan Huygens (1629-1695) proposed around 1678 that light might consist of waves. Later, at the beginning of the nineteenth century, Thomas Young empirically confirmed this proposition by measuring light wavelengths.[80] The measuring apparatus used to study light spectra individually and in combination is the spectrophotometer, a device whose construction was made possible by technical advances related to photosensitive materials. Light wavelength as a measurable parameter enabled further discoveries, such as the existence of infrared radiation by Sir William Herschel (1738-1822) in 1800 and of ultra-violet radiation by Johann Wilhelm Ritter (1776-1810) in 1801, when the latter noticed that the photochemical action of blue and violet light in silver chloride continues into ultraviolet[81].

These historical examples briefly introduce how the act of measuring has continuously led to new discoveries about light's nature and the emergence of new postulates in optics, as well as how it later contributed to the origin of quantum physics[82]. Furthermore, the field of spectrophotometry, defined as *"the quantitative measurement of the reflection or transmission properties of a material as a function of wavelength"*[83] plays a crucial role for several kinds of research concerning photosensitive materialities, due to the intrinsic relationship between photosensitivity and pigment colours, measured as wavelengths.

A much simpler light measuring technique that is nevertheless highly relevant to the photography industry is the photometer (synonymous with light meter or spot meter). It was initially produced as a separate device in the second half of the nineteenth century, with what were considered as successful models already available on the market in the 1860s.[84] Following the increase in automatic features of the photographic process, the photometer had become a built-in device in cameras for the first by the end of the 1930s, but they only became more accessible in

80 This outline of scientific experiments with light was mainly extracted from Kohen et al, 1995: 2-14 and Le Grand, 1970: 2-4.

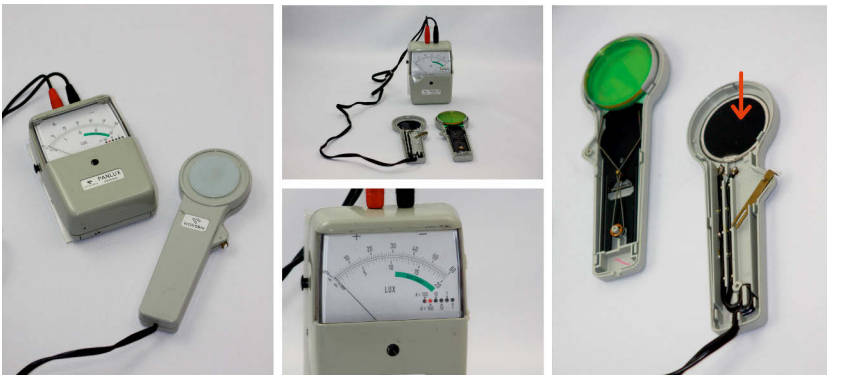
81 Kohen et al 1995.

82 Quantum theory developed from the combination of Max Plank's (1900) and Albert Einstein's (1905) theories. Plank's theory stated that "all energy exchange between matter and radiation takes place in a discontinuous manner, by multiples of a fundamental energy unit or quantum" while Einstein merged wave-particle principles, promulgating the dual nature of light and bringing "the quantum into a mainstream of scientific thought". (Kohen et al 1995: 13)

83 NIST – National Institute of Standards and Technology from the U.S. Department of Commerce. <https://www.nist.gov/programs-projects/spectrophotometry> Accessed February 15th 2016.

84 Johnston, Sean. A history of light and colour measurement: science in the shadows. Boca Raton, FL USA: CRC Press Taylor & Francis Group, 2001.

the SLR cameras of the 1960s[85]. However, since the embedded photometer could not be placed close to the photographed object, it remained a professional tool for obtaining more specific and precise data samples of light incidence.



1.5: Gossen's PANLUX Electronic Luxmeter. Photo: Graziele Lautenschlaeger; Source: Media Archaeological Fundus/Institut für Medienwissenaschaft/Humboldt-Universität zu Berlin.

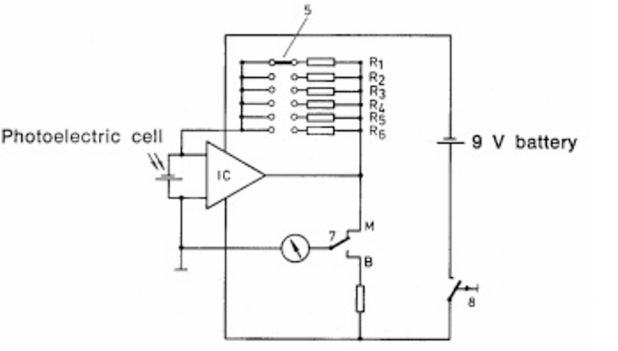
The functionality of this device is based on the material behaviour of the selenium cell, the thin dark round-shaped plate placed in the so-called cell unit by the fabricant[86], indicated in figure 1.5 by the red arrow. By means of designing selenium cells, light became measurable through changes in the material's resistance.

As one can observe in figure 1.6 below, the schematics of the photometer's circuit consist basically of a variable resistor (photoelectric cell) coupled with a switching mechanism (indicated by number 5) attached to a voltage divisor, represented by the series of resistors R_1-R_5. A voltage divisor is a typical technique used in electronics to produce an output voltage (V_{out}) that is a fraction of its input voltage (V_{in}), and it is often implemented to measure the resistance of a sensor. The sensor, in this case the photoelectric selenium cell, is wired in series with known resistances to form a voltage divider. Since a known voltage (9V) is applied across the divider, it is possible to measure the resistance variation caused by light in the

85 SLR means Single-Lens Reflex. As opposed to the Twin-Lens Reflex, SLR cameras present a mirror and prism system (hence "reflex" from the mirror's reflection) that permits the photographer to look through the lens and see an identical image of what will be captured by the camera.

86 Gossen's Panlux Electronic Luxmeter's operating instructions. April 1974. Available at <http://www.cameramanuals.org/flashes_meters/gossen_panlux_electronic_luxmeter.pdf>. Accessed April 18th 2017.

selenium cell. Changes in resistance are then transferred to the mechanical angular change of the pointer over a graduated scale in the display of the photometer, indicated in figure 1.6 by the arrow in the circle on the left side of switch number 7.



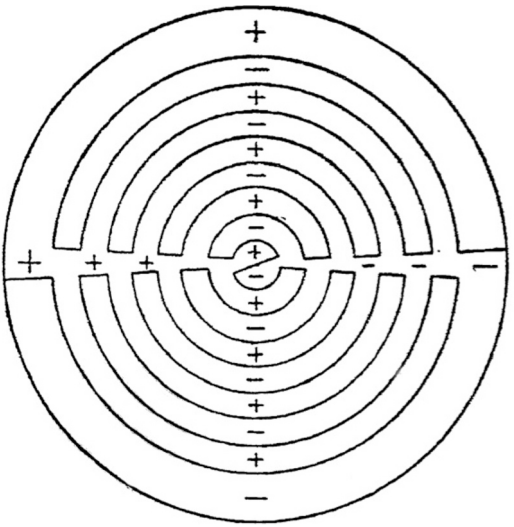
1.6: Internal circuit of Gossen's Panlux Lightmeter; Source: Gossen's Panlux Electronic Luxmeter's operating instructions p. 5.

To more sensitive cells, a crucial hurdle in the design of the cell had to be overcome. The challenge consisted in finding a bigger range of resistance variation. Presser's selenium cell, shown in figure 1.7 was considered by Fournier D'Albe one of the most successful attempts in the early 20th century, when initial experiments on the semi-conductive[87] behaviour of selenium were made. Presser's achievement was to come up with a configuration that optimized the area and the distance between the negative and positive poles of the cell.

According to Fournier D'Albe, the discovery of selenium inaugurated, among other things significant for the history of media, the possibility of measuring light independently from human eyes.[88] Before the invention of photometers, the measuring of light was based on estimations made by human eyes, which, as a biological element, is subject to the specificities of each individual being. The eye-brain system responsible for visual perception has the ability to adapt itself to new light conditions. An elucidating example is our ability to see and recognize the brightness of white either in shadow or direct light, at dawn or mid-day, under artificial or natural light sources, and so on. Photo and video cameras, on the contrary, disregard this adaptive feature and require one to set the parameter for what should

87 Among other properties, such as current flowing more easily in one direction than the other and showing variable resistance, semi-conductive materials are sensitive to light or heat. Examples include silicon and germanium, whose behavior as semiconductors was first recorded through the use of silver sulphide crystal in 1833.

88 Fournier D'Albe 1924: 36.



1.7: Presser's selenium cell; Source: Fournier D'Albe 1924: 41.

be considered white, called the white balance, in advance. Light meters likewise operate according to predefined parameters and standards, corresponding to the film or image sensor being used in the situation. Contradictorily, other defined standards in photometry, such as luminance[89] or luminous flux[90], include human senses and perceptive abilities as parameters for light measurement. This also explains the continuous efforts in image technology engineering to match machine perception with that of the human eye[91]. Radiometry, in turn, is the measuring science that insists on the supposed objectivity of the measuring act, providing unit scales for physical light, such as wavelength and frequency.[92]

89 Luminance measures the luminous intensity per unit area of light travelling in a given direction, either emitted or reflected from a specific area (cd/m²candela per square meter) (SI). It is often used to characterize emission or reflection from diffusing surfaces, indicating how much luminous power can be detected by a human eye looking at the surface from a specific viewpoint. (Fraden 2004: 129-132) In electronic imagery equipment it refers to the displays' brightness. (Kittler 2010: 204)

90 In photometry, luminous flux, or luminous power, is the measure of the perceived power of light by means of parameters that reflect the varying sensitivity of the human eye. It differs from radiant flux, the measure of the total power of electromagnetic radiation, including infrared and ultraviolet spectra. For more details see Fraden 2004: 129-132.

91 Flaxton, Terry. HD Aesthetics and Digital Cinematography. In: Cubitt, Sean; Palmer, Daniel; Tkacz, Nathaniel. *Digital Light*. London: Open Humanities Press, 2015. p. 81.

92 Cubitt 2014: 276-7.

Within this circular movement between the desire for objectivity in the act of measuring and its interdependence with subjective human perception, Cubitt also draws attention to the fact that light is measured by creating units from a continuum, just like the measurement of colour, in which polychromatic light spectra are divided into wavebands defined as a monochromatic spectrum. Another example of the fragmentation of the continuum is seen in the experiments around the photoelectric effect, which enabled the atomic "packets of light" (photon or quantum) to be measured as an electric current. In these examples, measuring as an act of fragmentation or discretization signifies the paradigmatic way that humans understand and act upon the world.

The development of increasingly complex measuring devices would not be possible without the parallel developments in operational images and circuitry formed by ever tinier elements, such as photoresistors, photodiodes and photomultipliers and phototransistors. The internal elements of a photometer are photoresistors, which can now be made of a variety of semiconductor materials, such as cadmium sulphide (CaS), cadmium selenide (CaSe), lead sulphide (PbS), indium antimonide (InSb), etc. When applied in counting and measuring contexts these materials enable a physical entity to be translated into an abstract system of units. Even though measurement strives towards objectivity, it nevertheless requires data interpretation. The act of measuring implies the abstraction of matter in such a way as to adapt the physicality of the world to the human senses and cognitive abilities.

1.2.2 Automating

To a certain extent, measuring and automating are intimately related. One cannot automate without first measuring, calculating and programming. Harking back again to the classic example of photography, in the golden age of film negatives measurement was crucial to the dawn of image production automation, from image capture to its reproduction. The integration of photosensitive materials in image production by the technical ensemble of the photographic apparatus triggers its automation process[93], which is a trend that goes hand in hand with the obsession with fixing, storing, reproducing, transmitting, and even generating the image in the fastest way possible.[94]

Behind photographic image creation, there is an intense manipulation of values and parameters[95] by professional photographers, who work hard at finding the

93 Couchot, Edmond. "The automatization of figurative techniques: towards the autonomous image". In: Grau, Oliver. (Ed.) *Media Art Histories.* London, Cambridge: The MIT Press, 2007.

94 Adams 1995b, 29ff, 181 apud Cubitt 2014: 87.

95 They are, for instance: Illumination conditions, distance to the object/subject, focal length, aperture, exposure time, lenses efficiency; film speed or image-sensor architecture and sensibility, if analog photography: type of developer, duration, temperature and agitation during

correspondences between all the technical variables and the material image that results. In *The Negative* (1948), although speaking about image values and developing "The Zone System"[96], Ansel Adam's recalls *"that photography is not only the recording of light but also its complex translation into the peculiarly granular texture of the print"*[97].

The manipulation of mathematical parameters, whether in photography or any other media, is, however, open to creative intervention, which is imperative if one wants to achieve symbolic and poetic results normally present in what is culturally understood and named as art. Sean Cubitt's analysis of Ansel Adam's work asserts that an *"obsession with technical prowess cannot substitute for an intuitive grasp of these variables (...) The richness of photography is that it is irreducible in Adam's world, to automation. (...) he (...) seems quite happy that manufacturers of light meters fail to agree on a common standard"* [98].

Nevertheless, the openness of the instantaneous photographic act can paradoxically be joined with its related automatic processes. For Flusser, who also wrote a theory of photography[99], the concept of automation entails the rapid computation of coincidences, i.e. of the blind and inert junction of atoms (and other elements) by chance.[100] From the standpoint of this definition, Flusser's concept of software *"means the automation in the precise instant in which the desired coincidence takes shape"*[101]. Flusser's definition of software suggests a compromise between automation and the openness required by aesthetic propositions. This is a powerful perspective when adopted in the context of media art, where artists aim at making poetry out of the development of automata and other automated processes through an extensive variety of techniques.

The emergence of automata, which are often based on the implementation of light-sensitive materials and devices, has followed the internal dialectic of culture and its logic of constant creation and removal of obstacles[102]. So long as human beings need to solve ever more complex problems using measured and collected data, whether from the surrounding environment or from their own body, it will

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the development process, type and duration of fixing and the care taken in washing and drying the negative; type and quality of printing materials and paper, duration of exposure for different areas of the negative, the final viewing conditions of the print and so forth.

96 Adams, Ansel. *The Negative.* Boston, New York, London: Little, Braow and Company: 1981. pp. 47-98.

97 Cubitt 2014: 88.

98 Cubitt 2014: 87.

99 Flusser 2011.

100 From the original excerpt in Portuguese: "*significa rápida computação de coincidências, junção cega e inerte de átomos (e outros elementos) ao sabor do acaso*". (Flusser, 2008: 76)

101 From the original excerpt in Portuguese: "*significa a automação no instante preciso no qual a coincidência desejada se forma*". (Flusser 2008 : 76)

102 Flusser, Vilém. O design : um obstáculo à remoção de obstáculos? In: *Uma filosofia do design: A forma das coisas.* Relógio D'Água, 2010. pp. 57-61.

be a necessity to create machines able to process that data. This is one of the reasons for the perpetual birth of new automatons and computers, as well as the increasing human dependence on automated systems. However, since wishing to stop this historical cultural engine is futile, one of media artists' duties is to engage in selecting the 'most desired coincidences'.

In the history of techno-cultural objects, automatons – self-operating machines[103] – have existed in Ancient Egypt, Hellenistic Greece and, later, in 13th century Islamic Culture, some of the exemplars of which were documented by polymath Al-Jazari (1136-1206) in the *Book of Knowledge of Ingenious Mechanical Devices* (1206)[104]. In late medieval Europe, the documented survivors of time include the praying monk automata from circa 1560, located at the *Deutsches Museum* in Munich[105] and the Jaquet-Droz family's writing and drawing puppets from the 18th century, some of which are in the collection of the *Musée d'Art et d'Histoire of Neuchâtel*, in Switzerland. The most recent examples of automata have emerged from the hybridization of machinic principles with life sciences, with the development of nanomachines and biosensors[106]. Besides the miniaturization of automated technical objects, the technology currently available points towards the physical concretization of the old dreams that have long fed initiatives on animated matter, the foundations of animism and the sensualist movement.

Automating possibilities were boosted and enhanced by the development of computing machines, the technology with which the notion of automata is most popularly associated. Early exemplars of computing machines featured a series of devices called relays, electrically operated switches able to perform logical operations that, among other things, enabled controlling a high current circuit using a separate lower current circuit as a binary actuator.[107] Historically relays stem from the last decade of the 19th century, when they were used as technical solutions for telephone networking[108] and in machines for accounting and tabulating. Among

103 In the glossary opening *Filosofia da Caixa Preta*, an automaton is defined by Flusser as "*apparatus that obeys a software that develops at random*". (Flusser 2011: 17)

104 Nadarajan, Gunalan. "Islamic Automation: A Reading of Al-Jazari's The Book of Knowledge of Ingenious Mechanical Devices (1206)" In: Grau, Oliver (Ed.) *Media Art Histories*. Cambridge, MA: MIT Press, 2007, pp. 163-178.

105 According to Siegfried Zielinski, the figure is 39cm high, can speak, move his arms and legs and roll over its 60cm² base three times, if the spring is fully wound. The figure is driven by a mechanical system based on a key-wound spring, a technology that has been used since the 14th Century in timepieces. Zielinski, Sigfried. Expanded animation: a short genealogy in words and images. In: Buchan, Suzanne (Ed.). *Pervasive Animation*. New York/Oxon, UK: Routledge, 2013. p. 41

106 Bensaude-Vincent 2006.

107 Miyazaki, Shintaro. *Algorhytmisiert. Eine medienarchäologie digitaler signale und (un)erhörter Zeiteffekte.* Berlin: Kultur Kadmos Verlag, 2013. pp. 45-60.

108 With much of the research conducted at Bell Labs. (Miayazaki 2013: 55-60)

the main figures to implement relays in computing machines were the informatics pioneer Allan Turing (1912-1954)[109], mathematician and electrical engineer Claude Elwood Shannon (1916–2001)[110], the engineer George Robert Stibitz (1904-1995)[111] and Howard Hathaway Aiken (1900-1973)[112].

As previously noted, sensors, as relational objects, have no utility if isolated and not connected to another mechanism. This is why many of the explorations conducted after the discovery of selenium were based on coupling selenium cells to relays, which were triggered when they received enough light. The applications ranged from the simple automatic lighting of harbour buoys at dusk to more complex systems such as the sorting of coloured objects by adjusting the relays to various shades of light spectrum.[113]

It is possible that artist Marcel Duchamp (1887-1968) was aware of this technology when at the *Exposition International du Surréalisme* (Paris, 1938), he

> had thought of installing 'magic eyes' so that the lights would have gone on automatically as soon as the spectator had broken an invisible ray when passing in front of the painting. Duchamp's wish proved unfeasible, but Man Ray adapted the idea for the opening night, turning out the lights and handing out flashlights at the entrance so that visitors could use them to view the artworks "on display"[114].

This case exemplifies the rise of the artistic interest in automation techniques capable of integrating the artwork and its reception. Although the installation of magic eyes was not accomplished as Duchamp initially imagined, the solution implemented retained much of Duchamp's original intention to bodily engage the audience in the artwork. Decades later, when such devices became more popular and accessible, it would have been far less difficult to carry out Duchamp's idea. The combination of photosensitive sensor and switch-relay continues to be extensively used today as an automation solution in a variety of contexts, and the mechanism can be considered among the early devices of machine vision and surveillance technology.

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109 Turing wrote On computable numbers (1936) and built a relay computer (1937). (Miyazaki, 2013: 44)

110 Under the supervision of Professor Vanevar Bush at MIT (Massachusetts Institute of Technology), Shannon wrote his master's thesis A symbolic analysis of relays and switching circuits, submitted in 1937. (Miyazaki 2013:47)

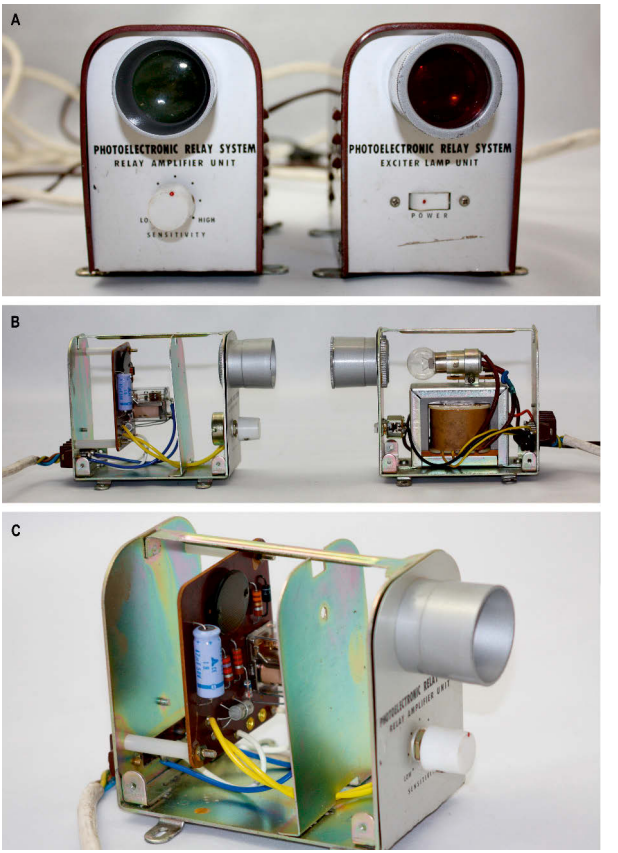
111 Since the end of 1938 Stibitz has worked at Bell Labs on the Complex Number Computers. The machines were the concretization of the emergence and convergence of relays and Boolean algebra. In 1946, the group of developers was already working on the fifth model. (Miyazaki 2013: 49)

112 Between 1943 and 1944 Aiken led the project of the Automatic Sequence Controlled Calculator (ASCC), later called Harvard Mark I, developed jointly by the US Navy, IBM and Harvard University. (Miyazaki 2013 : 50)

113 Fournier D'Albe 1924 : 67.

114 Filipovic 2009.

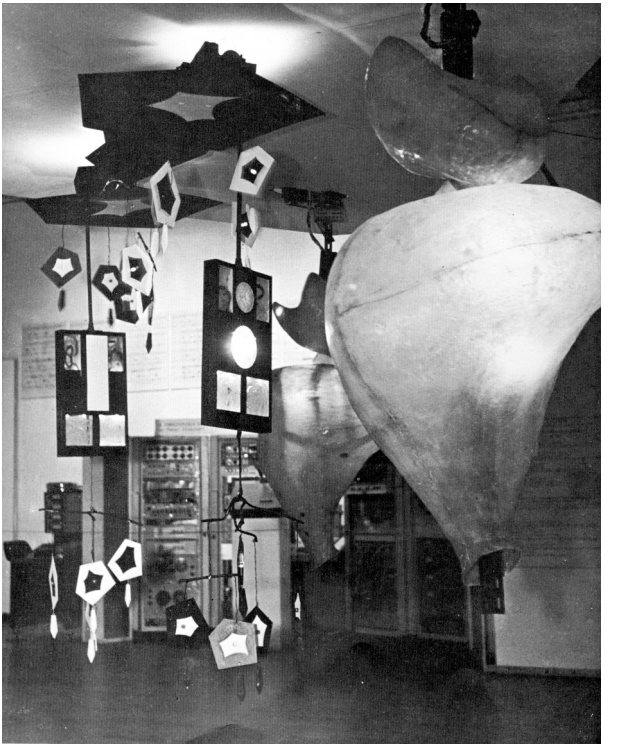
By means of detecting the presence (or absence) of an object (or subject) crossing the field, the photosensitive cell-switch relay can either serve Duchamp's notion of "magic eyes" or the panopticism described by the philosopher Michael Foucault.[115] For illustrative purposes, a popular commercial model sold in the 1960s and 1970s is shown below:



1.8: Photoelectronic relay system. A: Covered equipment: emission and reception parts; B: Lateral view of both parts; C: Detail of the circuit and the light-sensitive component. Photos: Graziele Lautenschlaeger; Source: Media Archaeological Fundus – Institut für Medienwissenschaft of Humboldt-Universität zu Berlin.

115 Foucault, Michael. *Surveiller et punir : Naissance de la prision.* Paris: Éditions Gallimard, 1975.

One of the pioneers in building automata in art exhibitions was the cybernetician and artist Gordon Pask (1928-1996), who exhibited the *Colloquy of mobiles* in 1968 at the exhibition Cybernetic Serendipity in London. This artwork was a computer-based social system, in which "male" and "female" rotating machines could establish communication through basic patterns of light and sound.



1.9: *Colloquy of mobiles* (1968), by Gordon Pask, at the exhibition Cybernetic Serendipity, ICA London. Courtesy of Jasia Reichardt, Hermione Pask and Amanda Heitler; Source: Medien Kunst Netz.[116]

According to art critic and curator Margit Rosen (1974-), the communication system created by Pask in the *Colloquy of mobiles* invokes analogy to sexual relationships. As she described it:

> after a phase of inactivity, the females (made of fiberglass) began to glow more intensely, and the three males emitted a ray of light. When the ray of light struck

116 Available at <http://www.medienkunstnetz.de/works/colloquy-of-mobiles/> Accessed August 10th 2017.

> the mirror inside the female mobile's structure, by way of rotating the mirror, she tried deflecting the ray back at the free-hanging light sensors above and below the male's aluminum body.[117]

The system was programmed so that "the goal of communicating was to achieve moment of satisfaction, and the mobiles learned to optimise their behaviour to the point where this state could be reached with the least possible use of energy".[118] Furthermore, the exhibition visitors could also take part in the conversation and learning process by using light emissions from flashlights and reflections from mirrors to assume the role of another machine.

This kind of artwork shows that intuition, openness, sensitivity and automatism can coexist simultaneously, to the contrary of fears associated with industrial trauma[119]. Indeed, in the context of Pask's artwork, the sensibility of the machine can be seen as a key element of uncertainty that introduces a margin of indeterminacy. For Simondon, it is sensitivity that enables the existence and concretization of a technical ensemble, rather than the augmentation of its automatism.[120] An argument can be made that the creative process in media art is primarily based on this paradox.

While Simondon depicts the conflicting nature of the relationship between humans and machines he also has an optimistic outlook rooted in a wish for balance and envisioning human beings as the organisers of a society of technical objects that requires being conducted in the same way as musicians in an orchestra[121]. The metaphor he uses represents something harmonious and beautifully organized, whose execution is dependent upon and takes advantage of the ability of each musician but is coordinated by a central control, represented by the figure of a conductor. Flusser used a similar metaphor for technological society when he spoke of chamber music in the conclusive chapter of Universo das Imagens Técnicas – elogio da superficialidade. However, he envisions the cooperation among the musicians as a playful activity, whose beauty and meaning emerge from the interaction itself, as an open space for unpredictability and uncertainty.[122]

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117 Rosen, Margit. 'The control of control' – Gordon Pasks kybernetische Ästhetik. In: Glanville, Ranulph; Müller, Albert (Ed.) *Pask Present. An exhibition of art and design inspired by the work of Gordon Pask, cybernetician and artist.* Wien: Echoraum, 2008.

118 Rosen: MedienKunstNetz.

119 For Simondon the conflict emerges when machines start to substitute for the human workforce: "*la frustration de l'homme commence avec la machine qui remplace l'homme*". (Simondon 1958 : 162)

120 Simondon wrote : "*C'est cette marge qui permet à la machine d'être sensible à une information extérieure. C'est par cette sensibilité des machine à de l'information qu'un ensemble technique peut se réaliser, bien plus que par une augumentation de l'automatisme*". (Simondon 1958: 12)

121 Simondon 1958: 12.

122 Flusser 2008: 198-199.

Whereas engineers avoid uncertainty and indeterminacy while they are developing sensors and functional machines, artists use these traits to aesthetic advantage. Automation is inherent to the media art aesthetic mainly due to characteristics of the tools used in media artworks. This aspect has probably fuelled the myth that technological apparatuses freed artist's hands. Friedrich Kittler was among those who promoted that idea. According to him "The era of analog media – that of optical media proper – frees the act of visual depiction from the human hand and the act of visual perception from the human eye"[123]. For those more involved in artistic practice, however, such a statement is not strictly true. Flusser stresses the issue on an existential level: "the hands do not manipulate blindly: they are under control of the eyes. The coordination of hands and eyes, of praxis and theory, is one of the subjects of human existence"[124]. Whether or not the artist stresses automation conceptually, to automate within an artwork the hands are also necessary: and, indeed, the maker and the Do-it-Yourself (DIY) cultures rose in media art when automatism was already significantly present in society.

Embedding the photometer in the camera apparatus made image production even more automatic and fast. Polaroid represents the automation of image developing. The grouping together of technical elements in technical ensembles, which later can be merged with other technical ensembles, makes the tools available for artistic expression increasingly complex. In this process one can again observe similar automating phenomena: the new tool (technical ensemble) performs the previously laborious task by incorporating a software (and/or mechanism) that executes it – which can be carried out perpetually and infinitely. This is the case, for instance, with scientific calculators, software for image processing, or even high-level programming languages which, in opposition to low-level ones, abstract and automate necessary steps to communicate with the material aspect of the machine. In this sense, the automating tools used by artists aim to shape the emergence of specific corresponding aesthetics. Reflecting on this point, one can propose that if, on the one hand, automation is an advanced stage of the human attempt to condition matter, on the other hand, it reciprocally shapes human beings and their creative attitude towards the world.

1.2.3 Controlling

Controlling is another operation enhanced by using sensors. A considerable part of the notion of control in media art is related to the uses, criticism and subversive

123 Kittler 2010: 11.

124 From the excerpt in Portuguese: *"as mãos não manipulam cegamente. Elas estão sob o controle dos olhos. A coordenação das mãos com os olhos, da praxis com a teoria, é um dos temas da existência humana*". (Flusser 2008: 17)

possibilities of surveillance media systems, which are often represented by a huge variety of devices, such as cameras, radars and presence sensors. Sean Cubitt, in his analysis of the control over light, shares this perspective:

> Control over light, and its mediations through visual technologies, matters because it alters the constitutive grounds of sensing, knowing, and relating to one another and to the world. The genealogy of visual technologies traces a historical dialect between the urge to control, even to fascistic excess, and the constant reemergence of entropy[125] in the interstices of devices designed to curtail and command the excess of light.[126]

There is a series of artworks that stresses the controlling aspect of media as an aesthetic motif forming a branch of surveillance art, which is exemplified by the situationist group Surveillance Camera Players[127] and the already classic and worldwide recognized work of Harun Farocki (1944-2014), whose documentaries and video-installations frequently stress the role of technological apparatuses and image machinery in shaping society and feeding contemporary warfare.[128]

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125 Like the cyberneticists, Vilém Flusser and Sean Cubitt base much of their reflections on the principles of the Second Law of Thermodynamics, which states that "*in all systems, entropy tends to increase over time. While this simply means that differences in heat or energy tend to equalize over time, it is also understood to mean that order breaks down overtime, and that organization decays into chaos within both individual systems and the whole of the universe*" Asaro, Peter M. Heinz von Foerster and the bio-computing movements. In: Müller, Albert; Müller Karl H. (Ed). *An unfinished revolution? – Heinz von Foerster and the Biological Computer Laboratory | BCL 1958 – 1976*. Volume 3 of the series Complexity | Design | Society. Vienna: Echoraum, 2007. p. 259. Cubitt reflects: "*an increase in an absence – as entropy increases, there will be less and less difference… in a thermodynamic logic what is increasing is lack, or loss*". (Cubitt 2014: 3-4) "*Entropy is the opposite of information, of form*" (Ibid: 4). Flusser, in turn, based on the principles of thermodynamics, asserts that everything happens by chance (Flusser 2008: 18) and it is along a series of chance occurrences that we advance towards entropy and chaos. Here, programming, also associated with the notion of controlling, is presented as a human response to disturbances and novelties in the surrounding environment.

126 Cubitt 2014: 3.

127 Surveillance Camera Players (SCP) is a collective of media activists founded in New York in 1996. Inspired by the Situationist International (SI), they performed a series of performances in front of publicly installed video surveillance cameras, inquiring and manifesting their opposition to the violation of privacy. More information available at <http://www.medienkunstnetz.de/kuenstler/surveillance-camera-players/biografie/> and at the group's official website <http://www.notbored.org/the-scp.html> Accessed August 16th 2017.

128 Although not based on light-sensitive devices, a more recent artwork that tackles similar issues and is worthy of mention is the winner of the 2016 Golden Nica prize in the Interactive Art+ category Can you hear me?, by the Swiss artists Christoph Wachter and Mathias Jud. The artistic intervention was hosted by the Swiss Embassy in Berlin, located on *Pariser Platz*, very close to the German parliament and the several other embassies; it is also the main area where the NSA (National Security Agency of the United States of America) and the GCHQ

Control here can be understood as the authoritative use of the measurement and automation of matter. The misuses of controlling or automating constantly cause conflicting reactions by artists, especially because freedom and symbolic and interpretative openness are among the most valuable requirements of the artworks and the artistic practice itself. Media artist David Rokeby (1960-), famous for his series *Very Nervous System* (1982-1991)[129] and artworks addressing digital surveillance, states that the computer stimulates people to believe that everything can be controlled. However, the essence of such an illusion relies on the fact that the control works effectively only in the ideal conditions carefully constructed in the vacuum inside the machine.[130] In his opinion, the computer is a result of the fetishism of control, and his artworks are at their base, therefore, attempts to enact the opposite paradigm by creating inexact control systems. In Rokeby's words:

> Control is over-rated... Or perhaps it is better to say that we need to learn to balance control which is very useful in surgery or driving, with other sorts of engagements with other things and otherness that are looser than control relationships where we allow ourselves to be open, engaged and willing to be surprised. Otherwise life is dead.[131]

Nevertheless, apart from the context of surveillance and other similarly negatively connotated areas, the notion of control has also been revisited by cybernetic approaches. Cybernetics emerged in the mid-1940s from cross-disciplinary meetings among scientists and humanists from a variety of fields. Despite emerging without a name under the scope of the series of Josiah Macy Conferences on *"circular causal and feedback mechanisms in biological and social systems"*,[132] it was mostly associated with mathematician Norbert Wieners' (1894-1964) book *Cybernetics or control*

(United Kingdom's Government Communications Headquarters) have long been listening to the whole district's communications, including chancellor Angela Merkel's mobile phone. The artists took advantage of the privileged position of the Swiss Embassy, in cooperation with the Akademie der Künste on the opposite side, to build a series of antennas that enabled free access to the population, inviting people to engage in communication with the security agencies anonymously and drawing attention to the lack of regulatory rules over digital communication and its subsequent control, regardless of which radiation spectrum is being used.

129 In *Very nervous system* Rokeby develops a system of visual computing to compose music with the body in space. Through this artwork Rokeby anticipates the power of ubiquitous computing much earlier than hardware that facilitated and popularized this sort of technical implementation was available on the technology market.

130 Rokeby 2003 apud Glynn 2008: 2.

131 Ibid: 3.

132 Scott, Bernard. Second-order cybernetics: An Historical Introduction. In: *Explorations in Second-order Cybernetics: Reflections on cybernetics, psychology and education.* Vol.17 of the series: Complexity Design Society. Wien: Echoraum, 2011. p. 385

and communication in the animal and the machine (1948). It was Wiener who first gave a name to the new field of study, parallel to the emergence of the General Systems Theory.[133] Nevertheless, the appropriations of cybernetic conceptual models by contemporary interlocutors of the post-war period[134] were still characterized by an objectivist worldview. This led Heinz von Foerster at the end of the 1960s to distinguish first-order from so-called second-order cybernetics:[135] cybernetics subjected to its own concepts and able to acknowledge the role of the observer in the act of observing a system. Since then cybernetics has been used continuously as an inter- and transdisciplinary framework to handle issues on control and communication, learning and adaptation, self-organizations and evolution.[136]

Cybernetician artist Gordon Pask, who presented second-order concerns in relation to education and epistemology in *A comment, a case history and a plan* (1968), stated that *"man is prone to seek novelty in his environment and, having found a novel situation, to learn how to control it"*[137]. This premise, according to Pask, links the notion of control to the human fascination for solving problems, which constitutes the basis of human curiosity and the construction and assimilation of knowledge. Pask's artworks approach technological tools as an element to trigger curiosity and conversations by implementing propositions in which the controlling dynamic of a machine goes far beyond an authoritative perspective.

The revised idea of control elaborated by the cyberneticists and revitalized by the media criticism of Flusser and Simondon places the notions of automation and control outside the simplistic and linear logic of cause and effect. Suggesting circular models of comprehension and constant changes of perspective between humans, other living beings, machines and environments, they consider more complex relationships. Less dichotomous approaches to technological apparatuses are possible when material and technical issues cease to be seen only as misused weapons in the hands of a "controller" against the "controlled". From a systemic and cybernetic standpoint, controlling is much more closely related to the self-regulating and self-organising properties of complex systems. By approximating the complexity of machinic and biological entities, this paradigm is able to formalize

133 Ibid.

134 Kittler's scientific investigations related to media development, too, have much to do with his post-war experience, identifying the concept of information as a component of military strategy. His argument is clearer when he addresses the origin of radar technology and its abstractive act, as, for instance, when he approvingly quotes Paul Virilio's (1932-) statement that, *"radar is an invisible weapon that makes things visible", "because it converts objects or enemies that do not want to be seen or measured at all into involuntary and compulsive transmitters".* (Virilio 1989: 75 apud Kittler 2010: 216)

135 Foerster, Heinz von. *Cybernetics of Cybernetics: The control of control and the communication of communication.* Minneapolis, MA: Future Systems, 1995.

136 Scott 2011: 383-398.

137 Pask 1968: 76.

a common ground, and thus offer a more appropriate framework, to create and analyse media artworks as aesthetic and social systems.[138]

1.2.4 Self-regulating and self-organising

Sensors fundamentally operate recursively through spatio-temporal transformations that occur when elements exchange updates of their previous physico-chemical states. If one considers biosensors, for instance, this exchange is significantly complex beginning at the molecular level and involving chains of transducing processes.[139] In their material and operational dynamic, sensors are commonly inserted into self-regulating and/or self-organizing systems.

Self-regulatory principles in media art emerge parallel to the criticism of authoritative uses of technology and its associations with controlling and automating. Much of this appropriation was introduced and supported by second-order cyberneticists[140], who embraced principles from biology and ecology, such as the autopoiesis (self-creation)[141] and self-organization of living organisms.

Self-organization has been a valuable concept for some artists, designers and scientists, especially those influenced by cyberneticist and founder of second-order cybernetics Heinz von Foerster (1911-2002) and his work at the BCL Biological Computer Laboratory, which he founded in the late 1960s at the University of Illinois.[142] Discussions on self-organization emerge from studies on thermodynamic laws and paradoxes between organization, chaos and entropy. In the book *What*

138 Lautenschlaeger, Graziele; Pratschke, Anja. Don't give up! Media art as an endless conversational process. In: *Kybernetes*. Vol. 40 n.7/8, 2011. pp. 1078-1089.

139 Fraden 2004 (1996) 519.

140 *"Second-order cybernetics (...) was developed between 1968 and 1975 in recognition of the power and consequences of cybernetic examination of circularity. It is cybernetics, when cybernetics is subjected to the critique and the understandings of cybernetics. It is the cybernetics in which the role of the observer is appreciated and acknowledged rather than disguised as had become traditional in western science: and is thus the cybernetics that considers observing, rather than observed systems".* (Glanville 2001: 03)

141 For cyberneticist biologist Humberto Maturana (1928-) *"a circular, autopoietic form of organization distinguishes living beings, from the amoeba to humans. Living systems form a network of internal and circularly enmeshed processes of production that make them bounded unities by constantly producing and thus maintaining themselves. Autopoietic systems are autonomous"* (Poerksen, Bernhard. *The certainty of uncertainty: Dialogues introducing contructivism*. Charlottesville: Imprint Academic: 2004. p. 47). Glanville adds to this that *"the basic consequence of the autopoietic organization is that everything that takes place in an autopoietic system is subordinated to the realization of its autopoiesis, otherwise it disintegrates".* (Glanville 2001: 15)

142 Müller, Albert. A brief history of the BCL. Heinz von Foerster and the Biological Computer Laboratory. In: Müller, Albert; Müller Karl H. (Ed). *An unfinished revolution?—Heinz von Foerster and the Biological Computer Laboratory | BCL 1958—1976*. Vol. 3 of the series Complexity | Design | Society. Vienna: Echoraum, 2007. pp. 278-299.

is life? (1948), physicist Erwin Schrödinger (1887-1961) challenges the second law of thermodynamics by stating that biological systems, instead of losing information, tend to increase in complexity over evolutionary time. Facing this objection, von Foerster contends that *"biological organisms and other complex systems consume energy and order from their environments. And so, while entropy will steadily increase globally, locally organisms can capture and transform energy and produce islands of increasing order"*[143]. His philosophical statement recalls the existential of 'being-in-the-world' and the dynamics and mutual influence of the observer (subject) and system being observed (object). The body organizes the world to organize itself and the interface between subject and object are the senses. The attention towards the sensors of non-human organisms and the variety of sensitizing techniques of objects is therefore a sort of concretization of the post-humanist ideals. Considered by many as an esoteric perspective, von Foerster's ideas led to an innovative scientific agenda at the BCL, influencing the next generation of artificial intelligence and neural network researchers in the following decade, and serving as a source of inspiration for cyberneticist artists today.

Among the pre-organizing tasks involved in self-organising mechanisms – filtering, periodic functions, pattern recognition –[144] filtering is probably the one in which sensors are most directly related, since *"systems, organisms or machines, did not deal with the totality of the universe, but only dealt with certain aspects of it and filtered the rest out"*[145].

There are numerous artists, designers and architects[146] whose aesthetic experiments also approach cybernetic understandings of self-organization and adaptive systems. In order to acknowledge non-mainstream artists, the artwork selected to address the topic is *Equilibrium* (2008), by Guto Nóbrega. As a hybrid organism, the piece is a system in which a plant and an artificial mechanism share a mutual relationship based on self-regulating principles. As described by the artist, the system consists of two motors, solar cells, microchips, light beams, photoelectric sensors and a plant. A central axis holds two opposed sides in a symbiotic relationship: On the one side, there is an artificial system, a simple BEAM[147] robot equipped with

143 Foerster 1960 apud Asaro 2007: 259-260.

144 Asaro 2007.

145 Ibid: 262.

146 To mention only a few, there are the Gordon Pask's followers Ruairi Glynn, Usman Haque and many others who have attended the Bartlett School of Arts and Design in London. Glanville, Ranulph; Müller, Albert. (Ed.) *Pask present. An exhibition of art and design inspired in the work of Gordon Pask, cybernetician and artist.* Wien: Echoraum, 2008.

147 BEAM robotics (acronym of Biology, Electronics, Aesthetics and Mechanics) refers to a branch in robotics that primarily uses simple analogue circuits instead of microprocessors favoring simple design. Although not as flexible as microprocessor-based robotics, BEAM robotics can be more robust and efficient at performing the assigned task. A set of the analog circuits and

propellers and programmed to move clock- or anticlockwise according to photovore[148] behaviour. On the other side, there are a plant and two solar cells responsible for feeding the artificial system. A circular symbiotic interaction is established: The robot needs the energy collected by the plant while the plant needs the robot's mobility. The plant signals the robot when light is needed, activating its engines to turn the system towards light.

1.10: *Equilibrium* (2008), by Guto Nóbrega. Courtesy of the artist.

With autonomous behaviour, Equilibrium "belongs to a class of artificial hybrids emerging from contemporary art practices concerned with the creation of new man-made organisms"[149]. The artist suggests that such a proposition might push the interaction between artwork and audience to a more complex level than mere cause-effect. An inattentive observer can perceive Equilibrium as a simple plant-based kinetic sculpture. However, with this sort of artwork appearance is not the only parameter for interpretation, and a systemic approach is required. The formal combination chosen by the artist frames a dynamic interaction between two light inter-dependent entities, placing the hybrid technical ensemble in a self-regulatory context in which the recursion of feedback exchange dissolves the initially diametrical opposition.

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mimicking biological neurons can be implemented in order to facilitate the robot's response to its environment.

148 Biological term for "searching for light".

149 Nóbrega, Guto. *Equilibrium.* Available at <http://cargocollective.com/gutonobrega/Equilibrium> Accessed December, 4th 2015.

Directly influenced by writings by the biomathematician Sir D'Arcy Wentworth Thompson (1860-1948),[150] Nóbrega manages to implement, via his artistic and academic practices, systems that consider matter through its activity and its corresponding diagram of forces.

Due to their relational characteristics, artworks based on the creation of hybrid systems are very good at elucidating how it is possible to overcome the series of dichotomies that surround media art. Moreover, they exhibit new approaches to how sensitive elements and their inherent operations mirror the current paradigmatic changes in contemporary material culture. They are particularly related to new materialist ideas like Karen Barad's "agential realism", a theory that merges epistemology and ontology while strongly embracing ethics in its acknowledgment of relational dynamics.

A preliminary conclusion gleaned from this brief discussion is that self-regulation and self-organization are models of abstraction that provide a theoretical framework able to deal with materialities as dynamic systems, and thus, as active matter.

1.3 (Im)materiality of an informational aesthetic

Each of the operations related to (photo)sensitive matter discussed above is naturally prone to intersect and interact with the others. They were discussed separately for didactic purposes, as useful elements to understand, produce and analyse media artworks and their operational aesthetics.

Viewing photosensitivity as electric and electrochemical changes in materials, one can grasp how media artworks result from the tension and friction between the abstractions of mathematical and physical models and their material instantiations. The selected examples of light-sensitive elements have provided an idea of how operations of abstract models (data, information, ideas, knowledge) physically shape contemporary electronic and digital technical ensembles and vice-versa.

Moreover, the technical and aesthetical transformations experienced since the advent of technical images testifies to the relevance of photosensitive materials in cultural development, reinforcing the interdependence between materiality and immateriality. In the material-immaterial dynamic of creative processes, one

150 Wentworth Thompson's book *On growth and form* (1917) has strongly influenced a series of artists that were prone to work in the intersections between biology and mathematics. He considered that his contemporary scientists overestimated Darwin's evolutionary perspective in relation to the form and structure of living organisms, to the detriment of up to then available knowledge in Physics, Mathematics and Mechanics. Therefore, the aforementioned book consists of establishing similarities between biological and mechanical structures through the applications of mathematical transforms.

jumps to the realm of information production and exchange by manipulating matter in the form of energy. That is the reason why the media art niche is imbricated with communication theories, and why here one can discuss the materiality of media artworks through the lenses of an informational aesthetics.[151]

The possibility of aesthetically combining elements that exchange information makes media artworks communication systems.[152] Reflecting more deeply on (photo)sensors' roles in operations of measuring, automating, controlling, self-regulating and self-organizing, one realizes that they are simultaneously material and epistemological objects, whose exchange of phsycochemical stimuli may generate data that leads toward the production of relevant information.[153] This process of exchange is a natural way that complex systems attempt to inhibit the tendency to move toward chaos and disinformation.

In *Forma e matéria* (2010)[154], reacting to misuses of the notion of 'immaterial' culture, Flusser suggests that a more appropriate term for materialities on their atomic and molecular levels would be 'high energy', based on the scientific fact that matter can be transformed into energy (fission) and vice-versa (fusion). Through the wordplay "information/in-formation" and by explaining that information could then be stored and transmitted through electromagnetic fields, he proposes that the field of informatics has obliged humankind to reconsider the concept of matter as the *"temporary fulfilment of eternal forms"*[155] – thereby prefiguring a new materialist approach already in the 1980s. Flusser's argumentation is useful to approach (photo)sensitive materials in terms of the physical capacity of each object and/or subject to communicate and interact. Through the understanding of photosensitive interfacing qualities, the material-immaterial interplay becomes a key aesthetical parameter for creating and analysing media artworks. Nevertheless, despite the obvious interrelationships, one can still identify vestiges of conceptual frameworks in media art history that cling to one or another side of the material-immaterial dichotomy. What is at stake if one or another pole is emphasized? Here lies a central

151 Bense, Max. Das Existenzproblem der Kunst. In: *Augenblick*. Stuttgart/Darmstadt, n.1, März, 1958.

152 Luhmann 2000.

153 There is an important distinction between data and information. Data can be only noise. Information is more valuable because meaning and/or functionality has been attributed. Information is activated, "useful", actualized data, which belongs to the realm of virtual/potential. A more detailed analysis on the topic can be consulted at Moles, Abraham. Information und Redundanz. In: Ronge, Hans. *Kunst und Kybernetik. Ein Bericht über drei Kunstwerziehertagungen Recklinghausen 1965 1966 1967*. Köln: DuMont Aktuell: 1968. pp. 14-27.

154 Flusser 2010: 15-22.

155 From the original excerpt in Portuguese: *"Actualmente, porém, com o impulso da informática, estamos a voltar ao conceito inicial de 'matéria' como enchimento temporário de formas eternas"*. Flusser, Vilém. Forma e matéria. *Filosofia do Design – A forma das coisas*. Lisboa: Relógio d'Água, 2010. p. 16.

crux. Were this not the case, there would not be polarization between, on the one hand, contemporary scholars pleading for more embodied scientific and artistic initiatives and attention to the materiality of communication,[156] and on the other hand, media art practitioners and theoreticians asking for better comprehension of the immaterial facet of media artworks while pointing out the current challenges facing the field.[157] The following discussion lays out possible reasons for this polarization and examples that simultaneously flourish within, resist and challenge it.

1.3.1 Vestiges of the material-immaterial dichotomy

There is something to learn about the material-immaterial dichotomy by looking back at pioneering exhibitions dealing with electronic and digital media, like *Cybernetic Serendipity* (1968, London/UK), *Ars Electronica* (1979, Linz/AT) and *Les Immaterieux* (1984, Paris/FR).

The *Cybernetic Serendipity* exhibition curated by art critic Jasia Reichhardt (1933-) at the Institute of Contemporary Arts (ICA) in London, and later touring in the United States of America, showed a series of pioneering computer-based artworks[158] from a time far before electronic and digital media had been considered as something immaterial. Reichhardt's exhibition featured electronic devices and *"environments that seemed to fulfill the promises of the epoch of communicating machines"*[159], which is a deeply provocative challenge to the bourgeois paradigm of art perception of that time. [160]

Documentation of the exhibition has demonstrated Gordon Pask's installation to be an outstanding example of dealing with the specificities of the formerly new media, enabled by his ability to materialize cybernetic principles such as feedback and self-regulation, as well as his own Conversation Theory into artworks, as exemplified by his *Colloquy of Mobiles*. Media art historian and curator Margit Rosen

156 Hayles 1999; Gumbrecht 1995.

157 Paul, Christiane. "From Archives to Collections: Digital Art in/out of Institutions" Lecture held at the conference "Challenges of Digital Art for Our Societies" at MUMOK, Vienna on Dec 4th, 2015. More detailed information is found in her book Paul, Christiane. *Digital art.* Berlin, München: Dt. Kunstverlag, 2011.

158 Among the artists participating in the exhibition were Gustav Metzger, Bruce Lacey, Nam June Paik, Jean Tinguely, Edward Ihnatowicks, Wen-Ying Tsai, Rowland Emett, John Whitney and others.

159 Rosen, Margit. Gordon Pask's Cybernetic Systems: Conversations after the end of the mechanical age. In: Bianchini, Samuel; Verhagen, Erik. *Practicable: From participation to interaction in contemporary art*. Cambridge, MA: The MIT Press, 2016. p. 25.

160 Ibid.

called attention to the posthumanist and new materialist approach of Pask's work, stating that, indeed, "*Pask decides to make the most of the freedom of things*"[161].

One decade later, at the first edition of Ars Electronica, the introduction by former Linzer mayor Franz Hillinger (1921-1991) presented an attractive sensuous and material discourse related to the new possibilities of sound composition through electronic technology recently transformed into aesthetic tools:

> Music is known worldwide as a language understood across all borders. In the "ars electronica" a new acoustic colour has grown forth, in which modern technology is intimately intertwined with human thought experiments to open up unimagined possibilities. Human beings have turned computer technology into an instrument in the service of their musical ideas, creating a substantial renewal and extension that was unthinkable before. I am sure that this new language melody will ultimately also be understood by all people, who can, with the help of electronics, even make music visible, translated into colour, contour, line and rhythm, which can be followed on the screen.[162]

An interesting element of Hillinger's presentation is the implicit connection between an elusive immaterial human mind and the possibility of making it tangible through the construction of electronic machines (computer) and their operations. Hillinger's words resemble Flusser's theory of the zero dimensionality of electronic and digital media, which has been a crucial conceptual framework for both the articulation of material and immaterial aspects of media artworks and the exploration of the particularities of their media. Flusser inserts media development in the history of culture as part of a history of four abstracting gestures.[163] The first human gesture was to abstract time, transforming the world into circumstance, a three-dimensional experience. Later, circumstances were abstracted into scenes, images, two-dimensional representations. The third gesture consisted of abstracting images into texts, which gave birth to history and linearity, the one-dimensional experience. Lastly, the linearity of texts was abstracted into numbers and

161 From the original in German: "*Pask entscheidet sich, die Freiheit der Dinge auszukosten*". (Rosen 2008: 179)

162 From the original in German: "*Die Musik gilt weltweit als Sprache, die über alle Grenzen hinweg verstanden wird. In der 'ars electronica' ist uns eine neue Klangfarbe zugewachsen, in der die moderne Technik sich mit dem Gedankenspiel des Menschen aufs innigste verbindet und ungeahnte Möglichkeiten eröffnet. Der Mensch hat die Computertechnologie zu einem dienenden Instrument seiner Klangvorstellungen gemacht und damit eine Substanzerneuerung und -erweiterung kreiert, die vorher nicht denkbar war. Ich bin sicher, daß auch diese neue Sprachmelodie letztlich von allen Menschen verstanden wird, läßt sich doch mit Hilfe der Elektronik Musik sogar sichtbar machen, umsetzen in Farbe, Umriß, Strich und Rhythmus, die auf dem Bildschirm mitverfolgt werden können*". Hilllinger, Franz. Zum Geleit! 1979. In: *Ars Electronica Center Online Archive.* Available at <http://archive.aec.at/print/#1> Accessed March 22nd 2016.

163 Flusser: 2008: 16-19.

calculations: the zero-dimensionality of electronic media. The zero-dimensionality of electronic media offers the possibility of grouping all materialities together in terms of their lowest common denominator and, in a second step, transforming them into other possible materialities[164]. It is precisely in reference to this media specificity that Hillinger envisions artists using electronic means to "*make music visible, translated into color, contour, line and rhythm, which can be followed on the screen*".

Through (photo)sensing, the world's materiality can be abstracted into its zero-dimensional form, the fundamental condition for all other potential characteristics of electronic and digital media: non-linear and algorithmic (instruction-based executions), immediate (real-time data processing) and therefore, time-based, automated and interactive (due to the openness of the involved systems).[165] Furthermore, electronic and digital media's zero-dimensionality also leads to a convergence culture[166], enhanced by the possibility of editing and programming matter. When light sensitive materials are transformed into sensors by their ability to translate luminous stimulus into electrical signals, an enormous field of possibilities for the transformation of light into other kinds of physical manifestations opens up. This condition invites (media) artists to play with light-sensitive optical media beyond the limits of the sense of sight, thereby expanding the concept of image and traditional mimetic approaches. In the creative processes of media art, this extreme openness requires media artists to systematically contextualize their choices in relation to the technical, aesthetic and semantic layers of their work.

The material-immaterial dichotomy within media art is also influenced by the diverse backgrounds of the artists. Since electronic and digital media are pervasive across all disciplines, artists usually display a broad range of formal paradigms of thinking and acting. Flusser has suggested the verb 'to inform' as a kind of unifying way to describe the creative field dealing with electronic media. The notion of information may dissolve the opposition between matter and energy, and Flusser suggests the ways in which approaches favouring one(matter) or another(energy) correspond to material and formal paradigms of thinking, respectively. The material paradigms that fed creative movements from antiquity (Plato) until the advent of electronic media were rooted in giving shape to the material available. In contrast, formal paradigms are based on materializing shapes from previously created abstract and conceptual models.[167]

Remarkably, both Hillinger's and Flusser's viewpoints are structured on distinguishing between immaterial minds and material bodies, as had been the tra-

164 This specific operation will be discussed in detail in chapter three through the analysis of light-to-sound translations.

165 Paul 2011.

166 Jenkins, Henry. *Convergence Culture: where old and new media collide.* New York: New York Univ. Press, 2008.

167 Flusser 2010: 15-22.

dition in Western philosophy at least until the embodied realism introduced by John Dewey (1859-1952) and Maurice Merleau-Ponty (1908-1961).[168] Similarly to the philosophic mind-body dichotomy, which also divides reason from the senses and overvalues the former to the detriment of the latter, discourses in neuroscience and informatics frequently correlate the human body and computers[169], as well as mind and memory, even though they still face arduous challenges to define where and how material and immaterial hook up. The still quite unknown potential of electronic and digital media has thus unsurprisingly triggered a great deal of science fiction concerning the simultaneously exhilarating and frightening coupling of disembodied minds and its utmost possible extension:[170] the collective mind[171] in cyberspace. In his book *Neuromancer* (1984), e.g., William Ford Gibson defines cyberspace as a consensual hallucination, as graphic representation of data abstracted from every computer in the human system.[172] Such representations of cyberspace have led to it frequently being associated with virtuality and immateriality in the popular imagination.

Simply by recalling the etymology of the term 'virtual', the philosopher of information Pierre Lévy (1956-) emphatically clarified that there is no opposition between the virtual and the concrete, but rather between virtual and actual.[173] According to him, 'virtus' refers to 'potential', i.e. to the realm of possibilities yet to be actualized. Using the example of a tree being virtually contained in a seed, Lévy tries to undo the misunderstandings behind the frequent association of digital with immaterial. Nevertheless, there remains an abstract notion of human mind

168 Lakoff, George; Johnson, Mark. *Philosophy in the Flesh: The embodied mind and its challenge to Western thought.* New York: Basic Books, 1999, p. 97.

169 Current research on neuroscience and cognitive robotics, such as that by Prof. Dr. Jakob Macke, holds that there are indeed surprising correlations, despite there being many more differences between biological neural networks and artificial cognitive neural networks than there are similarities. He expressed this position in his lecture "Making Sense of Light: Processing Visual Information in Neural Systems" at the Wo/Man Mind Machine – Interdisciplinary Conference. The event was held at the Berlin-Brandenburg Academy of Sciences and Humanities, organized by *Die Junge Akademie* and The Israel Young Academy. Berlin, June 13-14th 2016.

170 Clark, Andy; Chalmers, David. *The extended mind*. In: *Analysis* Vol.58 (1) Jan 1st 1998.

171 Lévy, Pierre. *A inteligência coletiva: por uma antropologia do ciberespaço.* São Paulo: Loyola, 1998.

172 Another strong example is *Ghost in the shell* (book: 1989; film: 1995) and, within media art, valuable paradigmatic changes can be observed in the evolution of statements by artist Stelarc on the relations between body and technology. The artist systematizes the following narrative: Absent body/Obsolete bodies/Redesigning the body/The hum of the hybrid/The anaesthetised body/The sheding of skin/high-fidelity illusion/phantom body/Fractal flesh. <http://stelarc.org/?catID=20317> Accessed June 12th 2018.

173 Lévy, Pierre. *O que é o virtual?* São Paulo: Editora 34, 1996.

in his philosophy, too, since Lévy considers the realm of concepts, meanings and symbols, whose materiality is still ungraspable, as immaterial.[174]

In the 1990s cybernetics was still strongly criticized by postmodern literary critics like Katherine Hayles (1943-) for its disembodied discourses that constantly failed to be put into practice. Except for the concrete machines built for scientific, artistic or design purposes, cybernetic abstractions created in order to depict and reflect on information exchange and interactions among working systems often end up stretching more their immaterial models. Hayles dedicates a chapter of her book *How we became post-human?* (1999) to discussing the materiality of informatics, criticizing cybernetic approaches that had emerged since the Macy Conferences as well as Foucault's archaeology and the erasure of embodiment. According to Hayles,

> it is not coincidental that the Panopticon abstracts power out of the bodies of disciplinarians into a universal, disembodied gaze. On the contrary, it is precisely this move that gives the Panopticon its force, for when the bodies of the disciplinarians seem to disappear into the technology, the limitations of the corporeality are hidden.[175]

To a certain extent, Hayles characterizes Foucault's viewpoint as grounded in a disregard of matter as an active entity that also constantly shifts power structures. Her criticism of the cybernetic discussions points to how information became a theoretical entity divorced from meaning.[176] Later in the same decade, in a similar attempt to dissolve the immaterial-material borders of the human mind and body the cognitive linguist George Lakoff (1941-) and the philosopher Mark Johnson (1949-) published *Philosophy on the Flesh: the embodied mind and its challenge to western thought* (1999) to propose a new materialist approach to mind and other conceptualization processes. The authors conduct a substantial review of philosophical statements based on the body-mind division through the lens of the most recent discoveries in neuroscience.

To return to media art exhibitions, the highly influential *Les Immatériaux* (Centre George Pompidou, Paris, 1984) curated by Jean-François Lyotard (1924-1998) in collaboration with design theorist Thierry Chaput, already gave a sign of the emerging crisis related to the modern concept of materiality. The exhibition's name at first glance suggests that the French post-structuralist basis of *Les Immateriaux* might emphasise characteristics of disembodied technological artefacts and society, as Hayles' critique has suggested. Moreover, according to Yuk Hui and Andreas Broeckmann (1964-), the exhibition aimed to express that

174 Ibid.

175 Hayles, Nancy Katherine. *How we became posthuman: virtual bodies in Cybernetics, Literature and Informatics.* Chicago and London: The Chicago University Press, 1999, p. 194.

176 Hayles 1999: 50-83.

> the immaterial is fundamentally material. The point was not to appreciate the new materiality brought by the telecommunication technologies, but rather to question the relation between man and his desire to become the master of matter. The aim of calling it "immaterial", like the designation of the "post-modern", was to liberate man from the modern paradigm, and to release material from the prison of the industrial revolution.[177]

The role of art in this context was to anticipate and deepen the discussion of the current cultural situation and the discursive oscillation between material and immaterial. Similarly to what was presented at *Les Immateriaux*, this first group of photosensitive elements and their operations introduces what might be the (im)materiality of media artworks and how media artists can play with it. At the nanoscale, the 'manipulated' elements are called data rather than matter. As media theorist Wendy Hui Kyong Chun (1969-) explains, data refers to signals that propagate in space and time,[178] and *"logic gates can only operate 'logically' – as logos – if they are carefully timed."*[179] Chun corroborates her statement by citing Philip E. Agre's *Computation and Human Experience* (1997), which elaborates in detail how the materiality of data operates inside the integrated circuits of machines: *"the digital abstraction erases the fact that gates have 'directionality in both space (listening to its inputs, driving its outputs) and in time (always moving toward a logically consistent relation between these inputs and outputs)."*[180] Digital media are thus also based on space-time manipulation, although this 'manipulation' is done indirectly. In digital media, as a further development of electronic media, the semantic coincidence between finger and numeral in the word 'digit'[181] alludes to indirect manipulations, mediated relationships.

In consonance with Flusser's mindset, the abstractive processes of digital media described by Chun and Agre have their roots in Western culture in the birth of the atomist perspective in antiquity and Democritus' first atomic model.[182] The

177 Hui, Yuk; Broeckmann, Andreas. *30 Years after Les Immatériaux: Art, Science and Theory*. Lüneburg, Germany/Milton Keynes, UK: Meson Press, 2015, p. 10.

178 Chun, Wendy Hui Kyong. *Programmed visions: software and memory*. Cambridge, Massachusetts/London, England: The MIT Press, 2011.

179 Chun 2011: 26.

180 Agre 1997: 92 apud Chun 2011: 26.

181 Following Flusser's zero-dimensionality concept, the French term for digital art – *Art Numérique* – is more precise in addressing digital specificity, meantime it is a term that emphasizes the abstract side of it. Discourses pointing towards the idea of the "post-digital" are also present in the current material turn. Nevertheless, if one considers the specifics of digital media and the operations related to it, especially regarding Flusser's and media-archaeological perspectives on digital media, the currently fashionable concept 'post-digital' makes absolutely no sense.

182 Barad, Karen. Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter. In: *Journal of Women in Culture and Society*. Vol. 28, n. 3. The University of Chicago, 2003. p. 806.

search for the existence of an indivisible part of matter is part of the foundation of Western science. Under the influence of the Rutherford-Bohr atomic model and the experiences mediated by electronic-based technologies, a review on materiality and its operations has been progressing ever since the pioneers of electronic and digital art exhibitions.

Despite all effort to rectify misunderstandings about the nature of electronic and digital media, there still have been cases in which renowned and influential media artists and theoreticians have reinforced the idea of the supposed immateriality of electronics and digital media. Edmond Couchot (1932-), for instance, once claimed that *"the image-making processes are no longer physical (material or energy related)"*[183]. This affirmation suffers from two main neglects: firstly, that it does not take all scientific knowledge on quantum mechanics and related topics into consideration; and secondly, that it ignores all existent materialities that human senses cannot perceive.

The primary factor to be aware of in beginning to implement a post-humanist perspective is that there is an inherent gap between the capacity of the human sensory apparatus and the full apprehension of the world.[184] It is possible that some influential theoreticians and practitioners of media art, like Couchot, were introduced to the new possibilities of electronic and digital media without being aware of the interdependence of software and hardware and the physicochemical processes in the background. However, the presence of this false premise in texts used in many languages to introduce electronic and digital media to art students is severely problematic, especially when few or no other contrary perspectives are available.

Another possible association of media art to immateriality is inherent to art history discourses. On the one hand, one can identify it as a part or further development of conceptual art, which has been contributing to the dematerialization of art since the onset of modernism.[185] Through frequent conceptual confusion in artistic experiments based on electronic and digital media, media artworks have likewise been associated with immateriality,[186] contributing to the diminishing relevance of art objects.[187] At the technical level, one can argue that automatic programming, represented by abstract machines like interpreters, assemblers, compilers and ge-

183 Couchot 2007: 182-3.

184 Haraway 2000; Barad 2003; Bennett 2010.

185 As the art critic and curator Lucy R. Lippard (1937-) has shown at: Lippard, Lucy R. *Six years: the dematerialization of the art object from 1966 to 1972; a cross-reference book of information on some esthetic boundaries.* New York: Praeger, 1973.

186 Shanken, E.A. Art in the information age: technology and conceptual art. In : *Leonardo* 35. n°4. 2002. pp. 433-438.

187 Popper, Frank. *Le déclin de l'objet.* Paris: Chêne, 1975.

nerators, which are software designed to operate on or produce other software[188], could be considered as immaterial attributes of digital media.[189] However, although data and its operations are intangible, they are not properly immaterial. According to Kittler, who believed that *"there is no software"*[190], *"all code operations, despite their metaphoric faculties such as 'call' or 'return', come down to the absolutely local string manipulations and that is, I am afraid, signifiers of voltage differences"*[191]. The fact that software necessarily works interdependently with hardware is the existential condition of every electronic and digital media expressions. Even the meanings of conceptual artworks endure through their materiality.

On the other hand, when the communicative aspects of media artworks are emphasized, they have been seen in art history in the context of Relational Aesthetics[192], as participatory, performative and process-based. Still, this interpretation never implied the denial of their materiality. On the contrary, for media art curator and theoretician Christiane Paul, the negotiation with materialities is among the main challenges for curating and preserving electronic and digital art.[193] As an informational aesthetic manifestation, there is no way to escape from embracing the complex and conflicting movement between abstract and concrete instantiations in media artworks, a problem present not only when producing media artworks but when archiving them as well.[194]

A plurality of discourses is more than welcome. Nevertheless, dichotomous perspectives tend to impoverish the complexity of artworks' potentialities. The maturity of media art production seems to depend on the development and systema-

188 Chun 2011: 41. In other words they are higher-level programming languages.

189 In this case, electronic engineers and programmers managed to operate machines by creating abstract and metaphoric levels. Still today in an age of massive 'datafication' of human behaviours, this abstractive practice may induces the belief that digital technology is immaterial. The perception of an immaterial instance of life is understood by Katherine Hayles as the emergence of a new sort of subjectivity, rooted in the mesh between the immateriality of information and the materiality of informatics. (Hayles 1999:193)

190 Kittler, Friedrich. There is no software. In: Kroker; Arthur and Marielouise (Ed.) *CTheory.* 1995. Available at <http://ctheory.net/printer.aspx?id=74>. Accessed August 10th 2016.

191 Ibid. Quoted also at Parikka, Jussi. *What is Media Archaeology?* Malden/Cambridge: Polity Press, 2012. p. 80

192 Bourriaud, Nicolas. *Relational Aesthetics.* Dijon : Presses du Réel, 2009.

193 Paul, Christiane. From Archives to Collections: Digital Art in/out of Institutions. Lecture held at MUMOK, Vienna, at the conference "Challenges of Digital Art for Our Societies", organized by the Department for Image Science. Dec 4th, 2015. Available at <https://www.youtube.com/watch?v=283LtZNmy5M> Accessed July 30th 2016.

194 Tracking the historical paths and archiving issues of media art bring its materiality even more to the fore. Developments in the understanding of its nature provoked changes in the names of laboratories and media centres. An example is Oliver Grau's project and research group ADA – Archive of Digital Art, the former Database of Virtual Art. Available at <https://www.digitalartarchive.at/> Accessed July 28th 2016.

tization of an informational aesthetic through the convergence of material and formal ways of thinking. Cyberneticist philosopher Max Bense's (1910-1990) theoretical framework for aesthetical analysis focusing primarily on the artwork's materiality (*Materialitätsthese*) followed by its organizational (*Ordnung*), communicational (*Kommunikationsthese*) and symbolic (*Zeichentematischetehse*) levels, is an example of approach that overcomes the opposition between materiality and immateriality and supports a critical and relational perspective.[195] Considering all these variable elements and their dynamics one is well equipped to analyse media artworks.

1.3.2 (In)visible and (in)tangible: Blurring borders

Relational lights

As soon as one enters the dark room, one's eyes can just barely perceive two simple white lines projected onto the floor from above. The closer one approaches to them, the more one realizes that smoke lends an apparent solidity to those lines, turning them into curtains of light. One's body immediately wishes to touch this mysterious object, but one is surprised when one notices that they react to visitor's position and movement in the room. Other surprises await if one engages in play. The installation enacts a sort of magic on the senses, enthralling them in a highly immersive situation. As soon as another visitor approaches, the artwork can become even more playful. The line modes change and the challenges for the perceptual game are updated.

This is the prize-winner installation *Luzes Relacionais (Relational Lights)* (2010)[196], by artist Ernesto Klar, whose title and conception are a direct reference to Lygia Clark's (1920-1988) series of participatory artworks *Objetos Relacionais* (1975)[197], and specifically to her concept of the organic line. The main difference between Clark's and Klar's artworks has to do with the specific materials they used, which was a result of the totally different technological contexts in which they were created.

Klar's artwork is especially provocative in relation to the notion of a tangible interface, a concept spread mostly by computer scientist Hiroshi Ishii (1956-), head of the Tangible Media Group at the Massachusetts Institute of Technology (MIT).

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195 Bense, Max. Einführung in die Informatioinästhetik. In: Ronge, Hans (Ed). *Kunst und Kybernetik – Ein Bericht über drei Kunsterziehertagungen. Recklinghausen 1965 1966 1967.* Köln: M.DuMont Schauberg Verlag, 1968.

196 More information and videos about the artwork available in the official website of the artist: <http://klaresque.org/?p=63> Accessed March 14th 2016.

197 In the mid-1970s, Lygia Clark began to use her previous sensorial objects (developed since 1966) as therapeutic practice. She named them *Relational Objects* because the existence of the object occurs only in the relation with the participant. More information available at Butler, Cornelia; Péres-Oramas, Luis. (Eds.) *Lygia Clark: The Abandonement of Art 1948-1988.* New York: MoMA, 2014.

1.11: *Relational Lights* (2010), by Ernesto Klar. Photo: Mário Ladeira. Courtesy of the artist and photographer.

According to Ishii, tangible interfaces are those that explore the tactile richness of interactivity by embedding sensors in all kinds of objects for use as mediators[198] for person-to-person and/or object-to-object or object-to-person communication. By playing with the illusion of light's tangibility through smoke, Klar ironically sublimates the interface into an intangible and reconfigurable light beam. The lack of a graspable physical object, however, does not entail that the artwork does not have a

198 Ishii, Hiroshi. Radical atoms: Beyond the pixel empire. In: Stocker, Gerfried; Schöpf; Leopoldseder, Hannes. (Eds.) *Ars electronica 2016 - Festival for art, technology, and society. Radical atoms and the alchemists of our time.* Linz: Hatje Cantz, 2016: 20-21.

specific materiality. None of the magical effects emerging from the data exchange between the audience and the technological apparatuses would be feasible without both photosensitive structures (device and visitor's eyes), which enable the openness of each side of the proposed feedback-based system. It would be interesting to hear how a visually impaired person would describe her/his experience with the installation, which seems to offer considerable evidence of how sight and tactile senses are intimately related.

Max Bense's analytical categories (materiality, organization, communication, symbolization) can be used to explore the aesthetic aspects behind Klar's installation in a way that sheds light on the material-immaterial relationship.

On the material level, *Luzes Relacionais* consists basically of a dark room, a camera, a computer, a projector, loudspeakers and participants' bodies. These elements form a working system whose autonomy is completely based on the interdependency between each of them. In this sense, its materiality cannot be detached from the communication level: The system's responsiveness is based on visitors' movements, which are translated into light variations sensed by the camera hanging on the ceiling. The data received by the camera is processed by visual computing algorithms and sent to another software, programmed to give specific feedbacks to participants' movements, visualized in the lines' movements and heard through their corresponding sounds.

In interactive relational artworks the flow state of aesthetic appreciation simply does not happen if any of the elements fails to operate. That is why media artists' major concern is the proper functionality of the whole system they have created. How many times has one returned from media art exhibitions disappointed with the fact that many of the artworks unfortunately were not working? It is precisely in this working/not working dynamic that human confrontation with things and their materialities is located. Critical theorist Bill Brown, who in his 'thing theory' qualifies and examines thingness through the medial role of things while also observing the implications of the point in time when the interaction flux is interrupted, has written in this connection:

> A thing (…) can hardly function as a window. We begin to confront the thingness of objects when they stop working for us: when the drill breaks, when the car stalls, when the windows get filthy, when their flow within the circuits of production and distribution, consumption, and exhibition, has been arrested, however momentarily. The story of objects asserting themselves as things, then, is the story of a changed relation to the human subject and thus the story of how the thing really names less an object than a particular subject-object relation.[199]

199 Brown 2001: 4-5 apud Chun 2011:11.

Brown's perspective is a reminder that movements of human culture are strongly based on the creation and removal of obstacles. Within the larger cultural movement, creating media art has been characterized by a continuous effort to deal with things while taking into account the relational aspect between subjects and objects. In this sense, the practice of media art indicates a possible constructive alternative for enacting a materialist theory of relation. [200]

The organizational layer of Klar's installation can be considered in terms of its spatial and temporal distribution. Spatial and temporal elements are arranged according to what is called interaction design, which constitutes the elaboration of a strategically open structure sufficiently attractive to invite people to engage and interact with the artwork. The activation and operationalization of this structure[201] allow people to make sense of the experience. In *Luzes Relacionais* Klar had the perspicacity to choose a few simple elements capable of guiding interactions towards more complex situations. A variety of configurations of the lines suggested different interaction possibilities. The elements were also cleverly repeated, generating slight variations that altered the play modes once the saturation point had been reached, but with an open enough structure to allow the interaction to grow incrementally through coupling with other participants in the room.

Since symbolic forms[202] emerge from the combination of external reality inputs and internal perceptual-cognitive organization, it may be misguided to attempt a general interpretation of the symbolic layer of Klar's work. Since each visitor is free to make their own specific associations, I can only speak from my viewpoint as a participant observer at Klar's installation at the FILE (*Festival International de*

200 Cybernetics as theoretical framework has also advanced in this direction, however has being failing to be put in practice, as already pointed cybernetic anthropologist Margaret Mead (1901-1978) in her critics to cybernetic community itself that was not able to behave cybernetically. Glanville, Ranulph. Cybernetics: Thinking through technology. In: Arnold, Darrell P. (Ed.) *Traditions of Systems Theory: Major Figures and Contemporary Developments.* New York: Routledge/Taylor and Francis Group: 2014. p. 58.

201 in other words: an abstract machine, an algorithm, a software.

202 Ernest Cassirer's (1874-1945) concept of symbolic forms is here the grounding reference. At his lecture at the Warburg Library in 1921 Cassirer defined: "By 'symbolic form' I mean that energy of the spirit through which a mental meaning-content is attached to a sensual sign and inwardly dedicated to this sign. In this sense language, the mythical-religious world, and the arts each present us with a particular symbolic form. For in them all we see the mark of the basic phenomenon, that our consciousness is not satisfied to simply receive impressions from the outside, but rather that it permeates each impression with a free activity of expression. In what we call the objective reality of things we are thus confronted with a world of self-created signs and images." Cassirer, Ernst. *Der Begriff der Symbolischen Form im Aufbau der Geisteswissenschaften*. In: *Internet Encyclopedia of Philosophy.* Available at <http://www.iep.utm.edu/cassirer/> Accessed July 14th 2018.

Linguagem Electrônica) exhibition in São Paulo and Porto Alegre in 2010 and 2011, respectively.

Firstly, I appreciated the perceptual trick of the simple white lines gaining volume and provoking the spontaneous wish to touch them; and, once touched, the surprise of discovering that the curtains of light were movable. Secondly, I associated the experience to an inversion of Flusser's trajectory of increasing abstraction: from the zero-dimensionality of computing, bidimensional lines evolve into a evanescent three-dimensional presence, which is interrupted immediately when the tactile sense is frustrated by the hands searching for something to touch and finding only light and smoke. I also reflected about how the lines, although intangible, still split space into two opposing sides. It was a barrier, albeit a mobile one, which was under my control and easy to transgress. The lines state the limits between oneself and another participant, but, through interaction, connections and reconnections may occur – opening a space for contact and improvisation. In my experience, an incredible flux of philosophical questions was stimulated by the very sensuous experience interacting with the installation. I left the space amazed, wishing to prolong the recently experienced ecstasy for as long as possible. Once outside of the dark room, I immediately realized that the piece also takes advantage of its immaterial-material trick to ironically address the "touch/do no touch" signs of art museums and galleries, as means of molding audience behaviour.

Each of the operations discussed previously in the chapter can be identified by observing the artwork. The technical implementation of the hardware and software for tracking people's movements, triggering changes of the line positions and synthetizing real-time sounds are based on measuring, controlling and automating procedures. The self-regulating operation, however, only becomes effective when the visitor participates as part of the system. For effective interaction to occur both an investigative engagement by the audience as well as software and setups whose answers and updates are simultaneously accessible and challenging, on both the sensorial and cognitive levels, are required. The interplay between certainty and uncertainty is crucial to establishing the necessary balance. In media artworks a big part of this balance is achieved by how (photo)sensitive elements within technical ensembles are filtered and programmed. Once software is written to execute the responsiveness of the technical ensemble in a specific way, it is, contradictorily, the arbitrary act of programming that creates the element of uncertainty in the experience of the artwork.

Whether approaching the aesthetics of the interface or the technical solutions of the artwork, Klar's work offers a window into the typical dilemma faced by media artists dealing with interactive installations: how to find the optimal material organization to engage the audience within an informational system in a symbolic and meaningful way? Many other media artworks besides *Relational Light* could be used as examples to stress the relationships visible-invisible, tangible-intangible, mate-

rial-immaterial. Even if these relationships are not the main emphasis of the work, the creative process in media art always involves the interplay between materiality and immateriality. Max Bense's categories and the various uses of the operations discussed in this chapter are aides to thinking about the challenge embedded in the question above.

Ernesto Klar's *Luzes relacionais*, Gordon Pask's conversational machines and Guto Nóbrega's hybrids artworks series are all examples that challenge the automation of interactions, pushing the audience to search for the implicit relationships created by the artists, and arousing their interest in the technical and scientific knowledge that enabled such a construction. Instead of provoking alienating action-reaction behaviours between artwork and visitor, their work requires an attention and engagement from the public and has the potential to trigger curiosity, reflection and learning about the symbols materially organized. Creating and criticizing media art are therefore investigative practices conducive to knowledge production and sharing.

Relational aesthetics in the coming material revolution?

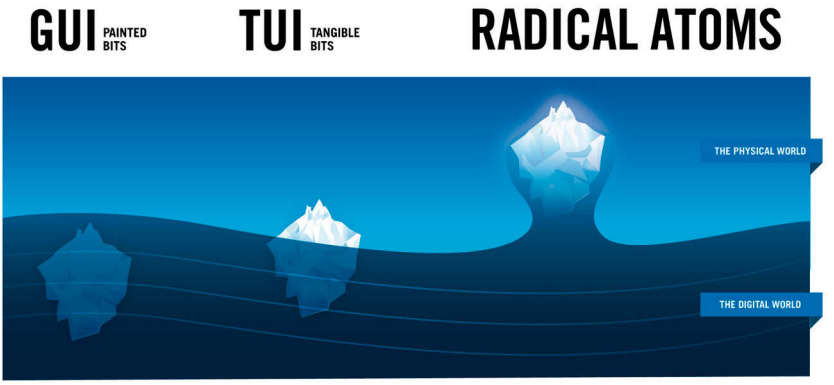
Looking in more detail at photosensitivity and its functions served to show that the communicational feature of media artworks implies the notion of an informational and relational aesthetics. This is why the in-between quality of communication processes has been the focus of cybernetic approaches to media art and is the basis of a theoretical framework that perhaps most closely approximates a post-humanist approach and the notion of active matter in relation to arts.

Nevertheless, the human drive to name and objectify things and phenomena in order to understand them has led to the objectification of the medial quality of sensing and communicating. This human mechanism to constantly distinguish object-subject – the phenomenological fundament of being-in-the-world – also led cyberneticists to fall into the same duality, expressed in their concepts of 'black-box' and 'second-order observer'.

Analogously to the objectification of software that occurred in patent offices in the 1970s[203], the notions of interface and interaction design have also been subjected to a blurring or annihilation of their relational qualities, due to the demands of the creative media industry. This can be observed, for instance, in the Hiroshi Ishii's conceptual-historical review in relation to his own group practices. To describe changes in the way they have been digitally handling materials, Ishii created a narrative based on the evolution of the various human-machine interaction

203 In opposition to Flusser's history of abstractive gestures, Chun identifies abstract to concrete processes in software history when, for instance, in the bosom of programming industrialization, US-American patent offices guided the "*transformation of software from a service, priced per instruction, to a thing*". (Chun 2011: 4)

approaches they have been working with. Using the over-simplified metaphor of an iceberg, Ishii discusses the interface's role in opposing 'digital' (the unknown and dark blue underwater world) and 'physical' (the known atmospheric light blue cosmos). Within this dichotomous metaphor, Ishii denotes a supposed linear progression from Graphic User Interface (GUI), to Tangible User Interface (TUI) and Radical Atoms.



1.12: Self-reflection of MIT Tangible Media Group on their own production according to changes in technological possibilities and their respective discourses; Source: Ars Electronica catalogue 2016 Radical atoms.

In the case of the immersed iceberg, which he calls GUI, Ishii criticizes the dominance of the visual features associated with digital media, calling pixels 'painted bits'. A superficial knowledge of the formation of technical images and the differences between colour as light and as pigment reveals the lack of scientific principles behind his narrative. While a metaphor is not to be confused with an explanation, in this case it is nevertheless difficult to understand the reasons why a scholar would use such simplified statements, ignoring the historical, scientific and aesthetic path of what he is discussing. Though it serves to sustain his questionable timeline, this kind of statement does not contribute to a mature and critical perspective on media creation or its valuable relational qualities.

By depicting TUI as an iceberg rising above the surface, Ishii refers to creations of interfaces that tend more to explore the tactile sensory possibilities, i.e. the shapes and dynamics of interfaces that go beyond mouse and keyboard, old-fashioned metaphors based on office work. The notion of tangible interfaces opened up promising creative possibilities for interaction designers simply because it presupposes that data can be exchanged between every material or object through the coupling of an increasing number and variety of materials, techniques and

sensors available on the technological market.[204] Nevertheless, Ishii omits alternative paths, such as merging visual and tactile stimulations through touch screen devices, and fails to consider that the tactile emphasis of their works is also extremely sight dependent: "extruded painted pixels". In terms of how it is digitally manipulated, there is practically no difference between a pixel on the screen or a solenoid motor in a machine.

As a further step in the development of digital interfaces, Ishii introduces the notion of 'radical atoms' to refer to an emergent technique of material science called "high-throughput computational design", which aggregates information and massive computations at the molecular level of material properties to synthetize new responsive materials.[205] According to his own words,

> Radical atoms symbolize our vision for the future of interaction with hypothetical dynamic materials, in which all digital information has a physical manifestation so that we can interact directly with it – as if the iceberg had risen from the depths to reveal its sunken mass. [206]

His interpretation envisions a Material Users Interface (MUI) based on material synthesis, where materials are dealt with as coded structures whose properties are predefined (hartness, conductivity, light refraction and others)[207] through parametric design[208] and often made of, inspired by or merged with organic matter,

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204 Concerning experimentations on tangibility of interfaces beyond office metaphors, besides the work of the Tangible Media Group at MIT Media Lab, it is also important to acknowledge the invention and world-wide distribution of the analogue-digital conversion boards, the hacking and do-it-yourself-cultures, circuit bending practices and the emergence of the 'Internet of Things' (IoT). Meanwhile, let us also remember that mobile technology and social media became pervasive as well, feeding the 'datafication' process of life. That aspect is the advanced aspect of what Paul Valéry has foreseen in his essay La conquête de l'ubiquité, dreaming a philosophy encountering the situation of delivering the sensible reality at home. Original excerpt in French : "*Je ne sais si jamais philosophe a rêvé d'une societé pour la distribuition de la Réalité Sensible à domicile*". (Valéry 1928 : 4)

205 Lecture "Matter, Material, Immaterial: Art, Philosophy and Curating Thirty Years After Lyotard" by Robin Mackay presented at the "Speculations on Anonymous Materials symposium held at the held at the Fridericianum in Kassel, Germany, Sept 29th, 2013–Jan 26th, 2014.

206 Ishii 2016: 21.

207 A sort of 'materials genome project" has been under collective construction at Materials Project. Available at <https://materialsproject.org/> Accessed June 7th 2016.

208 Parametric design techniques associated with special regard given to material behaviours also enhance the possibilities of manipulating pre-existent materials, as expressed in the use of wood in the work of the architect Achim Menges. Working within the computational material culture, Menges has explored the behaviours and properties inherent to the material through parametric design to create a series of sensitive and responsive architecture. In the fields of architecture and design, a variety of researchers are working on the question of how the computational practices in design processes trigger another kind of material awareness.

such as is the case in the production of biosensors. The technique encompasses a new age of material design in which matter is no longer fixed entity. Ishii's statement that *"all digital information has a physical manifestation so that we can interact directly with it"* thus amounts to an illusion associated with the birth of electronic and digital media as well as the GUI paradigm he depicts. The notion of *"direct"* interaction cannot be accomplished since humans are conditioned and limited by the subject-object dichotomy. Furthermore, the material design of 'radical atoms' is still mediated in the manufacturing process by traditional digital programming processes. What might be disruptive in the manipulation of 'radical atoms' is that the experiments being executed point toward the coincidence of input (sensors) and output (actuators) in the same structure, as is the case in living beings, thereby exponentially increasing the possibilities of creating hybrid systems.

One can see that this potentially revolutionary paradigmatic change is still difficult to imagine in practical terms in contemporary media artworks. To this date there has been no relevant documented artistic use of these techniques to enhance light-sensitive matter and light-based man-made biosensors. Relevant aesthetic experiments have mostly been based on material changes provoked by heat and humidity.[209]

Despite apparently overcoming the immaterial approach to digital manipulation, the new material turn still acknowledges the material aspect in a way that is attached to its pragmatic functional applications. While this is certainly a gain for the practice of relational approaches to materialities, however, the movement still lacks symbolic explorations that would enable advances on the communicational level as well. In this sense, Katherine Hayles' critique of cybernetics and the dissociation of information from meaning is still valid.[210]

Looking further at the issues at stake in the passage depicted by Ishii, some questions remain: Does the metaphor of the rising iceberg correspond to the wish to make the black-boxes of Flusser and the cyberneticists transparent? In other words, do these paradigmatic changes in the way matter is handled indicate that humans will have a more integrated relationship to the black boxes (or icebergs, or

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For more information about this topic see: Menges, Achim, Computational Material Culture. In: *AD Architectural Design*. Vol. 86(2), 2016, John Wiley & Sons, Inc., pp. 76-83 and Oxman, Neri. Programming Matter. In: *AD Architectural Design*.Vol.82 (2), John Wiley & Sons, Inc. 2012. pp. 88-95.

209 Besides the work of Achim Menges with wood, the series of objects bioLogic (2016), in which similar effects are achieved through the hygromorphic transformation of natto cells, also deserves mention. Yao, Lining; Ou; Jifei, Cheng, Chin-Yi; Steiner, Helene; Wang, Wen; Guanyun; Ishii, Hiroshi. Chin-Yi Cheng, Helene Steiner. Natto Cells as Nanoactuators for Shape Changing Interfaces. In: *ACM - CHI 2015*, Crossings, Seoul, Korea. pp. 1-10.

210 Hayles 1999.

interfaces, or things)? Does the relationship with the black-boxes change depending on whether they are manifestations of nature or knowledge condensed in the form of technical objects?

Whether they are named black boxes or icebergs, they refer to the eternal human endeavour to become integrated into the surrounding environment. The 'radical atom' technique cannot bridge the perceptual gap between the capacities of the human senses and the full apprehension of the physical world. Therefore, it also cannot dissolve the primordial object-subject relationship. This remains true even if one sees the iceberg as playing the role of imagination, as a bridging-element between material and immaterial levels of the creative process. This understanding is relevant to approach media art as a form of expression that emerges precisely between the rationalization of methods and the magical effects that take advantage of the limitations of the human senses[211]; in other words, through the articulation of what is, for humans, unknown.

Electronic and digital technology has enhanced the possibility of manipulating matter on a scale that the human senses cannot perceive, and many aesthetic experiments with the tools and techniques now available have driven artists, curators, art critics and educators to view media art as consisting of symbolic material arrangements based on the animation and 'editability' of matter. Yet, the physical properties of atoms have, of course, remained the same. *"Das Messer wird immer schärfer"*, and what one is witnessing is a deepening of the possibilities of *Ars combinatoria*.

In addition to misunderstandings due to ignorance of physical and chemical principles and the limitations of the human sensory apparatus, there is also the question of whether the changes are based on human relationships with matter or on the discourses surrounding them. Discourses like Ishii's, which simulate a linear progressive narrative regarding the materiality of interfaces, not only fail to consider previous media theories, histories and perspectives, but also fail to acknowledge properly the prior relational subject-object paradigm that grounds media art and its role in knowledge production.

Contrary to Ernesto Klar's *Luzes Relacionais*, Ishii's approach is more prone to eradicate the oppositions found between the physical and the digital worlds than to use them to aesthetic advantage. Ishii's perspective lacks engaging in dialogue with initiatives outside his context, diminishing the potential of grounding an aesthetic education upon it. In linear narratives of media development, the production

211 The fascination provoked by the magical effects of optical media is an established discussion in media history and theory. A brief panorama addressing this problem is available, for instance, at Hick, Ulrike. *Geschichte der optischen Medien.* München: Wilhelm Fink Verlag, 1999. p. 139.

of disruptive technologies can only serve as pretence to feed the demands of the technological market.

In conclusion, one can assert that both materiality and immateriality have always been essential elements in art. What differs is the attention devoted to each of them in the discourse of art critics, theoreticians and artists. The material-immaterial dynamics of media art's informational aesthetic are enigmatic but cannot be avoided in the process of creating significant artworks in the field. Sensitive apparatuses are one of the core elements for bridging the poles of this dichotomy and enabling, through communication strategies, relational material perspectives that can accommodate unknown otherness irrespective of the material actualization it presents. Even once an objects' agency has been acknowledged, as demonstrated here with photosensitive elements, it still remains the media artist's responsibility to regard the ethical and environmental implications of such a posthumanist approach.

Chapter 2
Photosensitivity shaping hybrid systems

"Anything said is said **by** an observer."
Humberto Maturana [1]

The nature-culture divide has long grounded Western thinking and remains strong well beyond the confines of anthropology. Since media artworks have often been produced in the intersection of this dichotomy, I have thus far not distinguished between organic and man-made photosensitive elements. They are, however, an essential element of the aesthetics of contemporary media artworks, and this chapter is dedicated to analysing their hybrid condition. This analysis will look at the unfolding materialities and operations of the organic and machinic photosensitive elements deployed within and by media artworks, considering them as operating systems rather than enclosed objects.

Most living organisms are light sensitive, and photobiology has several branches that cover photosensitivity in plants, unicellular organisms, invertebrates, human and non-human vertebrates, etc. Within the field of sensor engineering, the variety of photosensitive electronic components, sensors and other technical ensembles is no less impressive. Due to the immense variety of photosensitive elements, therefore, the analysis is initially narrowed down to focus on light-sensing as vision, and, even more specifically, the confrontation of eye and camera.

Additionally, other aesthetic explorations of photosensitivity with non-human living organisms are acknowledged from a post-humanist perspective. Aside from the general relevance of hybridity, they point towards a sort of decoding and recoding that human beings enact upon the environment and all its constituent parts through the creation of complex interspecific engagements.

Following a similar structure as the first chapter, the discussion is focused on the materiality and modes of operation of specific selected cases, highlighting relevant issues for the comprehension of media art aesthetics.

1 Maturana, Humberto apud Foerster, Heinz von. At each and every moment, I can decide who I am. In: Poerksen, Bernhard. *The certainty of uncertainty.* Charlottesville,VA USA: Imprint Academic, 2004. p. 12.

2.1 Light-sensing as vision

Photosensitivity as the core aspect of vision is a complex topic that requires an essentially cross-disciplinary approach. Interactions between the component parts of a system are more complex than the parts themselves. This principle of the theory of complexity is what makes it possible to distinguish the physiology of the eye from visual perception. Although both are intertwined, they are not the same thing, as psychologist and neuroscientist Richard Langton Gregory (1923-2010) has shown in his book *Eye and brain* (1998)[2] by compiling the results of a rich variety of experiments conducted on vision and cognition.

In evolutionary terms, the diversity of photoreceptors and their developments that preceded what we call eyes is immense. Simpler forms of photoreceptors can be reactive to the presence of or changes in the intensity of light, which is the case with several unicellular organisms, plants and funghi. The development of more complex forms led to adapted cells that are sensitive to movement. According to Gregory, *"these cells may be scattered over the skin (as in the earth-worm) or they may be arranged in groups, lining a depression or pit, which is the beginning of a true image-forming eye"*[3]. According to the latest biological taxonomy, image-forming eyes are a feature only of molluscs, arthropods and vertebrates.[4]

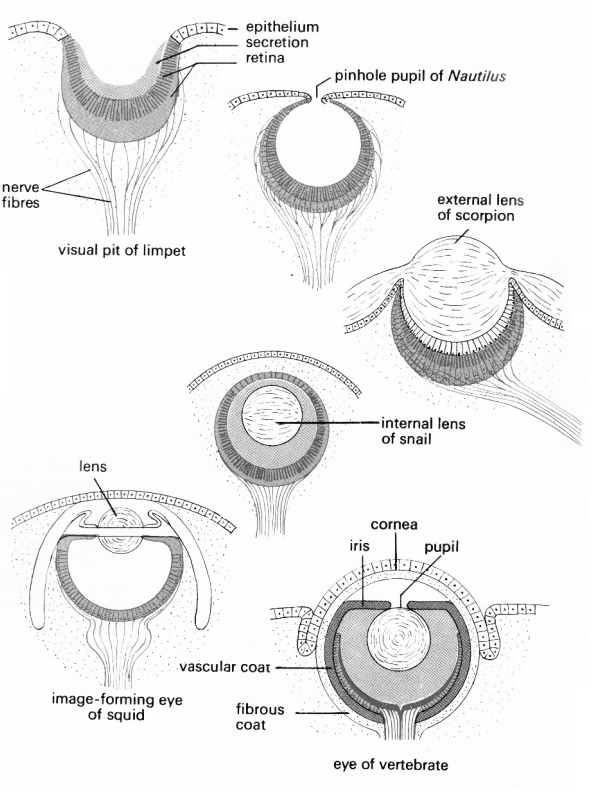
From a biological perspective, an eye is a physiological structure able to form an image; otherwise, light-sensitive structures are simply called photoreceptors. In the animal kingdom, the rich diversity of light-based sensorial apparatuses called eyes are classified according their anatomy and the type of image they generate (see fig. 2.1). Thus, there is no standard eye, the forms are elected through evolutionary principles conforming to the context in which they emerge.

On the cultural level, the diversity of interpretations and paradigms of the eye and vision have depended on the cultural contexts and empirical possibilities of a given time and place. For a couple of centuries in antiquity, philosophers defended the emission theory of vision, which held that visual perception was possible because light was emitted by the eyes onto the objects. The Presocratic philosopher Empedocles (495- 444 b.C. ?) thought the world was formed of four basic elements – fire, earth, water and air – and believed that the goddess of love, Aphrodite, cre-

2 Gregory, Richard Langton. *Eye and brain: The psychology of seeing*. 5th edition. Oxford/Tokyo: Oxford University Press, 1997.

3 Gregory 1997: 25.

4 Gualtieri, Paolo. Rhodopsin-like proteins: the universal and probably unique proteins for vision. In: Musio, C. (Ed.) *Vision: The approach of Biophysics and Neuroscience.* Series on Biophysics and Biocybernetics. Vol.11 – Byophysics. Singapore, New Jersey, London, Hong Kong: World Scientific, 2001. p. 23.



2.1: Diversity of eyes' anatomies; Source: Gregory 1998: 26.

ated the human eye[5] using these four elements, making vision possible only after lighting the element fire on it. As the media theorist Siegfried Zielinski (1951-) has observed:

> Empedocles combines poetically the anatomical components of the eye – retina, pupil, vitreous humor – with the most important factor for perceiving the other: the notion of perception as a continuous flow presupposes the existence of a rich, burning energy within that is inexhaustible. [6]

5 Zielinski, Siegfried. Attraction and repulsion: Empedocles. In: *Deep Time of the Media: Toward and Archaeology of Hearing and Seeing by technical means.* Cambridge, MA/London, England: The MIT Press, 2006. p. 47

6 Zielinski 2006: 47.

Also according to Zielinski, Empedocles made no distinction between understanding and sensory perception, considering the roles of the senses and perception as active ones. Media artist and designer Joachim Sauter(1959-) and the ART+COM Studio[7] used a similar conception in the artwork *Zerseher* (1992), in which the observer, while looking at the image of the artwork, simultaneously transforms, destroys and deconstructs it. The piece is also a didactic materialization of the cybernetic concept of the second-order observer and the acknowledgement of subjective vision. The observer necessarily influences and is part of the observed system, and, through the feedback loop between artwork and the eye of the second-order observer, a creative power of vision that endows the eye with attributes akin to the wonders of the ancient emission theory is revealed.

2.2: Participant at the artwork *Zerseher* (1992), by Joachim Sauter and ART+COM Studio. Courtesy of the artists.

The emission theory remained a main model of explanation for centuries, until Euclid asked how it could be possible that the light emitted by the eyes could reach the stars instantaneously every time we blinked. The intromission approach that followed, by contrast, focussed on the receptive side of the eye, stating that vision was based on the reception of light reflected by external objects. Although emission theory is now considered a fallacy in current scientific discourse, intromission theory can also lead to the understanding of vision as something passive, and the

7 Available at <https://artcom.de/project/zerseher/> Accessed August 23rd 2017.

eye as a mere input organ. Yet the visual system also cannot be reduced to the optical functions of an eye since the brain and the other senses play a crucial role in the process. Perhaps what Empedocles believed was the emanating fire of the eye can be interpreted as the highly complex levels of information provided together with the rest of the body gesture – e.g., the surrounding muscle system of the face and all the symbolic layers that anatomical and physiological characteristics can convey.

Artistic explorations of the eye's photosensitivity and the forces behind light-matter interaction that overcome the idea of passive or active roles are also found outside of media art. One elucidative example is the Japanese theatre-dance butoh, whose proposal, roughly summarized, is that dancers are danced rather than dance; i.e. that they be entirely open and susceptible to influences of both the inner and outer environments. Yoshito Ohno (1938-), son of butoh co-founder[8] and dancer Kazuo Ohno's (1906-2010), stated this perogative as follows:

> We, as performers, need to give careful consideration to how the eye and the body interact. It is essential to grasp where exactly the eye is located and how it functions. Moreover, there are things that cannot be seen with eyes. For a butoh dancer, the entire body must become a receptor organ for light.[9]

The post-World War II context in which butoh, literally "the dance of darkness", emerged lends this statement added significance. Aside from the physiological aspect, there is a symbolic level involving the search for light. Through its slow, hyper-controlled movements that reflect the endeavors of a body to resist fixity and efforts to define it, butoh's aesthetics manifest life's active materiality. Endowing the whole body with the qualities of the eye can also be understood as aesthetically embracing the complexity of what science terms the embodied mind. This is an approach that blends the physicality of sensorial phenomena and the abstraction of cognitive processes – what in other historical and philosophical contexts has been called 'spirit' or 'soul'.[10]

In the context of modern science, the pioneering experimental studies on vision by Hermann von Helmholtz (1821-1894) represented a turning point in our understanding of visual perception[11], preparing the path for the current scientific model of vision and the accompanying challenges regarding the embodiment of perception. Further studies on the physiology and psychology of vision also called

8 with Hijikata Tatsumi (1928-1986).

9 Ohno, Kazuo; Ohno, Yoshito. Kazuo Ohno's World: From Without and Within. Translated by John Barrett. Middletown, CT: Wesleyan University Press, 2004. p. 24

10 Lakoff, George; Johnson, Mark. *Philosophy in the flesh. The embodied mind and its challenge to western thought.* New York: Basic Books, 1999.

11 Crary, Jonathan. *Techniques of the Observer – On Vision and Modernity in the nineteenth century*. Cambridge, Massachusetts/London, England: MIT Press, 1990.

attention to cultural differences, with the recognition and reproduction of forms becoming understood as subject to cultural idosyncracies. An example of which, for instance, is seen in the contrast between the affinity to rectilinear and rectangular forms in Western urban society and the circular perspective of the South African Bantu ethnic group.[12]

From the large array of models found in nature, the human eye has been the main parameter for the construction of optical media devices, which, in turn, have served to better our understanding of the human body and senses. As Friedrich Kittler (1943-2011) asserted in his lectures on optical media: "*we knew nothing about our senses until media provided models and metaphors*"[13] . Kittler's statement[14] is to a certain extent in line with early assertions of constructivist epistemology, also represented in Giambattista Vico's (1668-1744) axiom. By introducing the Latin aphorism *Verum esse ipsum factum* (what is true is what is made/done), Vico meant that one can only understand what one has produced[15] – an important paradigm for media artists, whose creative process frequently starts with the physical construction of conceptually challenging objects, installations and performances.

The following sections provide a technical discussion of the material and operative elements of the eye and camera – the primary references for organic and machinic vision – as a background for discussing photosensitive hybrid systems in media art.

2.1.1 Elementary structures, concepts and operations

Anatomical, physiological and projected structures

The human eye is both the primordial human reference for photosensitivity. To this day, the anatomical and physiological properties[16] of the human eye are often understood and modelled through the metaphor of a camera – Plato's cave with a lens, as Gregory puts it, although his book sets out to deconstruct such a poor metaphor.[17] The problem with this type of simplification is that it does not provide

12 Gregory 1997: 150.

13 Kittler 2010: 34.

14 A contemporary counterpoint to Kittler's reducionist perspective on the understanding of human senses and cognitive processes is the work by media theoretician Wendy Hui Kyong Chun, who discusses software and hardware as an interplay between visible and invisible, using analogies ranging from computer science and biology to broader cultural and economic relationships. Chun, Wendy Hui Kyong. *Programmed visions: software and memory.* Cambridge, Massachusetts/London, England: The MIT Press, 2011, p. 101.

15 Bredekamp, Horst. The Picture Act: Tradition, Horizon, Philosophy. In: *Actus et Imago. Bildakt at the Warburg Institute.* Berlin/Boston: Walter de Gruyter, 2014. p. 10.

16 Here anatomy is understood as the study of the structure and relationship between the body parts, whereas physiology is the study of the function of body parts and the body as a whole.

17 Gregory 1998: 1.

a hint of the complexity found in the tiny elements that comprise the human eye. The human eye is a typical vertebrate eye, which works in close partnership with the brain. Though many animals have more complex eyes, humans have the most evolved brain, and it plays a crucial role in our visual perception. The human eye is a sphere of flesh filled with a gel called vitreous humour between the adjustable pinhole called the pupil and the retina. The pupil is surrounded by a coloured iris and by refractive elements that form a lens complex comprised of the cornea, the aqueous humour and the crystalline lens. Historically, the spherical piece has continuously inspired philosophers, writers and poets to write about it[18], as well as lovers to fall in love.

The figure below illustrates the common anatomical model of the human eye presented in biology books today:

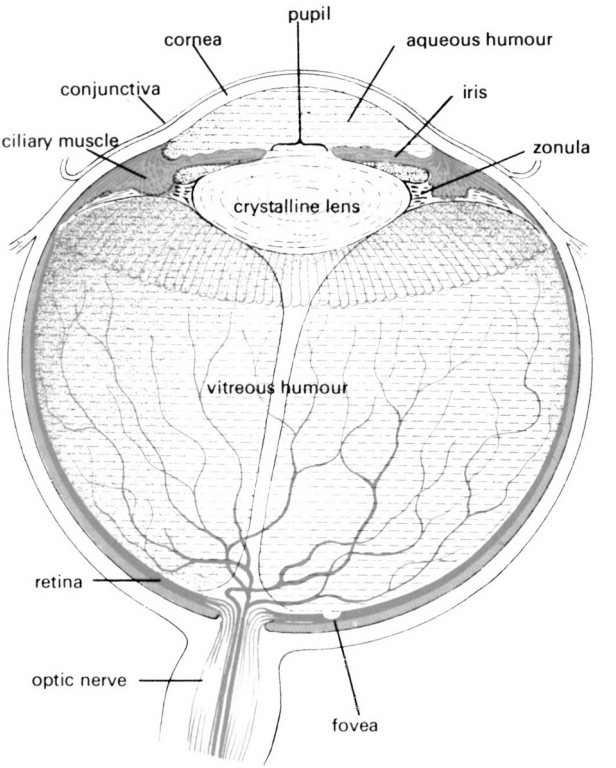
Of special interest here is the retina (from Latin *rēte*, meaning "net"), the thin light-sensitive tissue placed on the opposite side of the pupil, where the images from the outer world are formed and captured.[19] It is also where the confusion between what is seen and what is thought occurs, which constantly requires the other senses to provide evidence telling it whether or not what is seen is valid according to a common shared reality.

However, the main retinal functionality – its role as an interface quality for the photoreceptors' activity – is invisible to the naked eye. The discovery of retinal cells only became possible after the developments in microscopy, namely, the invention around 1835 of the ophthalmoscope, an optical instrument dedicated specifically to the visualization of the eye fundus. Observations made through the new device, however, did not assure complete objectivity. The very first descriptions were strongly biased by the researchers' imagination. Natural scientist Gottfried Reinhold Treviranus (1891-1837), for instance, reported that light-sensitive cells directly faced the light. According to Gregory, further research revealed that before reaching the rods and cones, the light rays have to cross the tissues of blood vessels and other layers of supporting body cells and nerve fibres. This explains why when human eyelids are closed the image seen is predominantly red. Studies on embryology attribute this characteristic to the fact that vertebrate retina originate from the surface of the brain.[20]

18 Especially noteworther here are George Bataille's *L'histoire d'oeil* (1928) and Merleau-Ponty's *L'oeil et l'esprit* (1964).

19 In the aforementioned didactic metaphor, the retina plays the role of a film or of an image sensor in a camera: it is the structure in the human eye responsible for transforming the image formed from projected external objects into information that can be read by the brain. In material terms, luminous input data is transduced/translated into neural-coded signals (electric pulses) by photosensitive cells called rods and cones.

20 Gregory 1997: 53.



2.3: Schema of the anatomy of the human eye; Source: Gregory 1998: 36.

Curiously, also using the metaphor of a film camera, Gregory contends that the evolutionary path that provided this feature to human eye was a "mistake":

> Optically, the retina is inside out, like a camera film put in the wrong way round (Figure 3.20) [2.4 here]. Given the original 'mistake' however (which seems to result from the embryological development of the vertebrate retina from the surface of the brain), the situation is largely saved by the nerve fibres from the periphery of the retina.[21]

This is another example of how the human construction of technical apparatuses plays an important role (perhaps even serving as an evolutionary strategy) in the understanding and organization of the body and the surrounding world. A man-

21 Ibid.

2.4: Illustration representing the retinal structural layers; Source: Gregory 1998: 54.

made device, namely a camera, becomes the parameter of what is 'normal' and what is a 'mistake' made by nature. A similar phenomenon occurs with the use of the concept of software, specifically in the interchanges between biological and computing knowledge. Based on the work of historian of science Lily Kay (1947-2000), media theoretician Wendy Hui Kyong Chun (1969-) asserts that in the 1950's there was an expressive paradigm shift in the discourses of molecular biology by absorbing the informational metaphors nourished by concepts from techno-sciences, such as cybernetics, bionics, and informatics. The shift mainly consisted of the displacement of the rhetoric of 'biological specificity', formerly dominated by mechanical lock-and-key metaphors. This phenomenon became even stronger with the development

of genetic engineering, when scientists began to contend that *"genes transferred 'information' and the correlation between nucleic acids and proteins catachrestically became a 'code'"*.[22] Chun's criticism of the displacement of biology, in which *"bodies became reduced to messages"*,[23] is similar to Katherine Hayles's critique in *How we became posthuman* that information was categorized as something *"conceptually distinct from the markers that embody it, for example newsprint or electromagnetic waves"*[24]. Considering the rapid rate of technological advances, their criticism is a reminder of why it is important to look at the materiality of things, even when developments are happening on a scale that humans are not able to sense. This is a challenge not unlike the current challenge for media artists to find compromises in the interaction between the materiality of bodies and machines.

Returning to the structural features of the retina, the larger or smaller concentration of photoreceptor cells divides the retina into specific parts. The optic disc, for instance, is a tiny blind spot present in each eye, marked by the absence of those cells; it is also the place where the optic nerves are located, which are in charge of transferring the electric pulses to the brain.[25] A larger concentration of optic nerves is found in the retinas' central area, the fovea – a teeny pit not much bigger than 1mm^2 that enables the high accuracy of human vision. Interestingly, as a biological evolutionary solution to what Gregory called a "natural error", in the fovea the internal layers of the retina are laterally displaced, in order to optimize the reception of light stimuli and to avoid noise production by the blood vessels and other tissues.

Located on the outer edges of the retina, rod cells are responsible for the reception of small-intensity light and for peripheral vision. Cones, in turn, highly abundant in the fovea, are further classified into three kinds of cells, with each type responding to visible light of different wavelengths on the electromagnetic spectrum. Long cones respond to light of long wavelengths, peaking at the colour red; medium cones peak at the colour green; and short cones are most sensitive to wavelength of the colour blue[27]. An up-to-date depiction of these cells can be seen in the following figure:

Rod and cone cells are embedded with visual pigments, whose molecular activity was already introduced in the previous chapter. Visual pigments share the

22 Chun 2011:104-5.

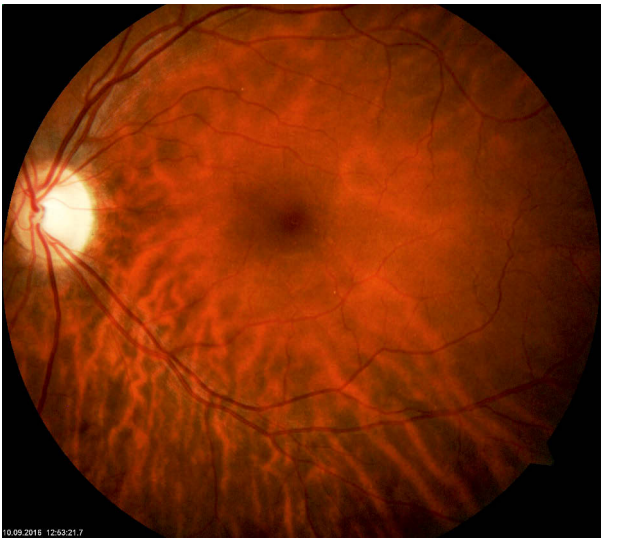
23 Ibid: 105.

24 Hayles 1999: 25.

25 According to Kittler, *"the blind spot where the optic nerves leave the eye – was only first discovered by physiological experiments in the seventeenth century"*. (Kittler 2010:136)

26 Curiously Ars Electronica Center's device for photographing the eye fundus of visitors was not able to make pictures of my blind eye's retina. This is another concrete example of how technological development plays a significant role in determining normativity.

27 Guyton & Hall 1996: 577-589.



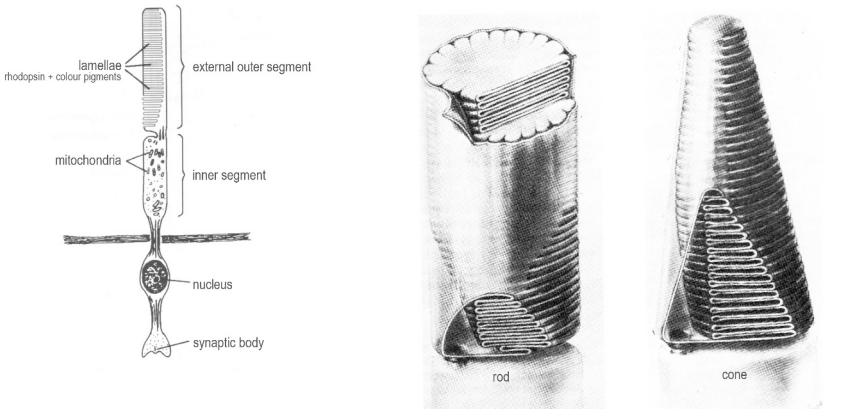
2.5: Picture of the author's retina.[26] Highlights for the blood vessels in red rhizome shape, the optic disc (yellow spot on the left side), the point of exit for ganglion cell axons leaving the eye, the highest acuity area called fovea and the macula (blind spot) Photo: Ars Electronica's Brain Lab, 2016.

same structural features, formed by an opsin (a group of light-sensitive proteins) plus an apoprotein and a chromophore. In the rods of human eyes, as in the eyes of the majority of vertebrates, photosensitivity occurs as the result of the reaction of a light-sensitive receptor protein named rhodopsin[28], which is a highly specialized G-protein[29] coupled receptor (GPCR) able to detect a single photon.

The first known studies on the properties and functions of rhodopsin were published in 1876 by physiologist and histologist Franz Christian Boll (1849-1879). This directly followed the discovery by biologist Max Schulze (1841–1915) that vertebrates' eyes present the two kinds of aforementioned visual receptors; and it, in turn, was followed by the more detailed studies of physiologist Wilhelm Kühne (1837-1900) and his co-workers. Kühne determined the makeup of rhodopsin and postulated its

28 Etymological roots from the ancient Greek ῥόδον (rhódon), meaning "rose", due to its pinkish color, and ὄψις (ópsis), referring to "sight" <https://en.wiktionary.org/wiki/rhodopsin> Accessed September 5th2017.

29 Guanine nucleotide-binding protein that works as a molecular switch/relay.



2.6: Schematic diagrams of the anatomic structure of the rods and cones. A generalized conception of the important features of a vertebrate photoreceptor cell (left) and the anatomical differences between the structure of rod and cone outer segments (right); Source: Adapted from Young 1971 apud Guyton et al 1996: 578-9.

protein part. His experiments and observations on photochemical reactions with rhodopsin proved that it was dependent on both wavelength and light intensity.[30]

Physiologically, the photo-bleaching chain processes in rods and cones are similar, aside from using slightly different pigments[31], and their principle is like that of an on-off switch. Rods are initially turned on and light turns them off. The phototransduction cascade of the rhodopsin is essentially based on the isometrization of the retinal molecule from its 11-cis to its all-trans form. This shift triggers a series of molecular changes in the rhodopsin molecule that provoke the hyperpolarization of the cell, closing its ion channels and turning the rod cell off.[32] Furthermore, as reported by biophysicist Paolo Gualtieri, the retina-opsin complex has an intense absorption band (340nm-640nm) and its light isomerization operation is very efficient (less than 1picsec) due to its: barrierless excited state potential surface; high signal-to-noise ratio; remarkable structural changes that enable the reliability and reproducibility of signals; and its derivation from ß-carotene, which is broadly distributed in the natural world.

The extreme accuracy of the eyes would not be effective if the cells did not also count on the quantum efficiency of rhodopsin: *"Approximately 20% of photons at a wavelength of 500nm that strike the human retina lead to a transduction event, an efficiency*

30 Giese, Arthur C. (Ed.) *Photophysiology General Principles; Action of Light on Plants.* New York/London: Academic Press, 1964. p. 9.

31 Guyton & Hall 1997: 579.

32 More detailed information of the process at Guyton & Hall 1997: 580.

comparable to that of best photomultiplier tubes"[33]. Here again, the understanding of biological models is driven by the comparison between organic and man-made devices, by means of invoking the most photosensitive man-made element yet invented. Photomultipliers are phototubes[34] *"capable of multiplying the single photoelectrons several million times, each time generating a larger current pulse".*[35] Through the presence of a series of dynodes – electrodes with a voltage level between that of the anode and the cathode – the electrons are accelerated in a chain process producing kinetic energy.

More accessible comparisons to the way photosensitive matter is implemented in contemporary devices are the semiconductor-based image sensors Charged-Coupled-Devices (CCDs) and Active Pixel Sensors (APSs/CMOS) used in digital cameras, both of which *"are pixelated metal-oxide semiconductors. They accumulate signal charge in each pixel proportional to the local illumination intensity, serving a spatial sampling function"*[36]. According to the biophotonics experts Rainer Riesenberg and Andreas Wuttig: *"CCD image sensors are an array of photodiodes with an internal capacitance for accumulating photocharges and a capability to shift these charges through the array".*[37] CCDs were created in 1969 as an analog shift register for data storage purposes. They were originally intended to replace the former magnetic memories, and its subsequent use as image sensor was a secondary but revolutionary development. Media theoretician Sean Cubitt's (1953-) definition of a CCD in the end notes of *Practice of Light* (2014) is useful for situating the device within the larger context of technological developments in media history:

> The CCD chip of a digital camera comprises a p-doped (positively charged) thin crystalline lattice deposited on a transmitting layer. Light arrives from the lens onto the lattice, each cell of which acts as a capacitor accumulating an electric charge according to the value of light referred to as luminance, arriving at that cell. The charges at each pixel are in effect the latent image, similar to the undeveloped filmstrip in a traditional camera. The array is linked to a control circuit that, after exposure, instructs each capacitor to pass its charge on to its neighbour. The last capacitor in the array then passes its charge to an amplifier that converts the charge into voltage. The process is repeated until all the charges have been con-

33 Ibid.

34 Phototubes are among the man-made light detectors that work based on the photoelectric effect. They consist of a gas-filled or vacuum tube with a cathode and an anode. (Riesenberg, Rainer; Wuttig, Andreas. Optical Detectors. In: *Handbook of Biophotonics. Vol. 1 Basics and techniques.* Weinheim, Germany: Wiley-VCH Verlag: 2011. p. 299.

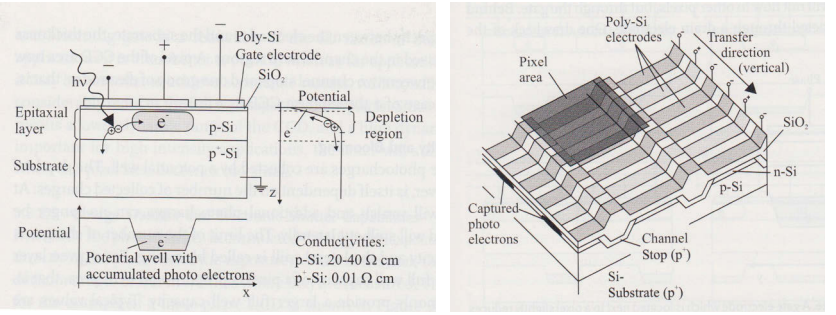
35 Ibid: 299-300.

36 Litwiller, Dave. CCD vs. CMOS: Facts and Fiction. In: *Photonics Spectra*. Lauring Publising CO. Inc. January 2001.

37 Riesenberg & Wuttig 2011: 322.

verted to voltage, digitized, sampled, and stored – in a matrix sharing the same grid structure – by the underlying CCD semi-conductor.[38]

The illustrations below of a single pixel unit in a CCD by Riesenberg and Wuttig (Fig. 2.7) clarify Cubitt's description. As a metal-oxide semiconductor (MOS) device, its base (substrate) is made of a relatively good conductor in certain conditions (e.g. silicon) and is coated with a layer of a metal-oxide (e.g. silicon dioxide) and an insulator. On the very top, there is a polysilicon, a highly pure form of silicon.[39]



2.7: A pixel unit in a CCD; Source: Riesenberg & Wuttig 2011: 323.

Silicon is a special material because it can be doped with small amounts of other materials in to modulate its electrical properties. Depending on the type of chemical bonds, it is possible to produce p-type or n-type material to embed in a photodiode[40]. Similarly to carbon, silicon has four valence electrons that it can share with other chemical elements to form bonds. If bound to another silicon atom forming a crystal, there are neither extra electrons nor places where electrons are

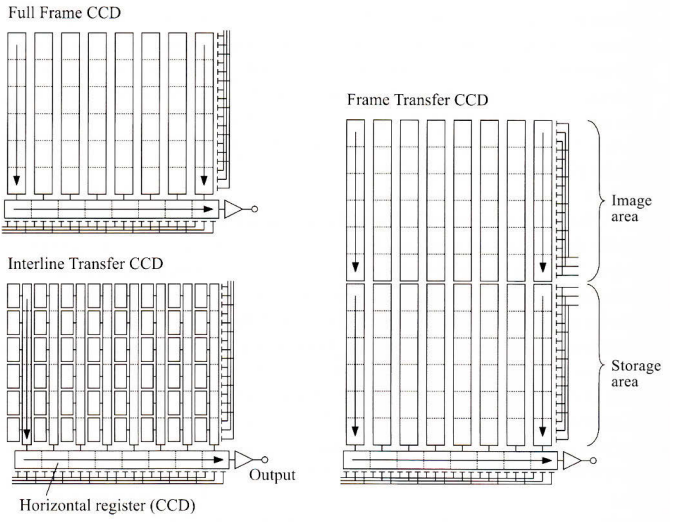
38 Cubitt 2014: 276.

39 Also called polycrystalline silicon, used as a raw material by the solar photovoltaic and electronics industry.

40 In the Handbook of Biophotonics, a basic type of photodiode is defined as *"formed by a p-n junction in a semi conductor, that is, by a contact between a p-doped region in which charge transport only takes place in the form of hole conduction, and an n-doped region, where electrons are responsible for charge transport. Between these two regions an insulating zone without free charge carriers builds up due to diffusion processes of electrons and holes, because free electrons will recombine and be captured in the p zone (loading it negatively) and free holes will the same in the n zone. Inside the insulating zone, called the depletion zone, an electrical field is generated due to the capture of the two types of charge carriers on the two different sizes of the p-n junction. Finally, the system o n zone, p zone, and depletion zone effectively forms a charged capacitor. Similarly to the case of photoconductor, incident light with a photon energy higher that the bandgap energy E_G generates electron-hole pairs, which without an electrical field would diffuse through the device but with an electrical field will generate a photocurrent".* (Risenberg and Wuttig 2011: 323)

missing.[41] The situation changes when adding other elements (impurities) to a semiconductor in order to produce or modify its properties. Introducing the element galium, for instance, which has only three electrons available for bonding, means that the molecule formed will have three normal bonds and one bond with a 'hole', i.e. missing an electron. This condition generated a sort of "musical chairs" among the neighbouring electrons, as this hole is able to move around just a freely as a mobile electron. This characterizes a p-type material, whereas a material with extra electrons is named a n-type material.

Once these technical details have been clarified, the fundamental key to the operation of a CCD also becomes clearer: Through the incidence of luminous stimuli, the movement of the available hole or the free electron can be directed. The way the electric current is conducted through the lattice, and posteriorly to the rest of the circuitry, has a direct influence on the architecture of the image sensor, as exemplified in the pictures below:



2.8: CCD's charge transfer modes; Source: Riesenberg and Wuttig 2011: 323.

Furthermore, the differences in the architecture of image sensors are what generate distinct data quality, as can be observed in the differing modes of transferring charges between CMOS and CCD image sensors. For each complete exposure

41 Peterson, Courtney. How it works: The Charged-Coupled Device, or CCD. In: *The Journal of Young Investigators*. 1999. Available at <http://www.if.ufrgs.br/~marcia/ccd.pdf> Accessed October 12th 2016.

in a CCD, each pixel's charge is transferred sequentially in packages to an output structure – where the charge is converted to voltage, buffered and sent to an off-chip;[whereas] in a CMOS, the charge-to-voltage conversion takes place in each pixel.[42] This difference has direct implications for both chips and the device's capabilities and limitations, which are evaluated for each context according to parameters like responsivity, dynamic range, uniformity, shuttering, speed, windowing, anti-blomming, biasing and clocking, reliability and, if relevant costs.

This brief summary scientific and technological developments already enable one to better understand how the manipulation of photosensitive matter on the atomic level works. One can also notice a sequence of correspondences: a pixel corresponds to a retinal photoreceptive cell; the lattice to the whole retina; the transmitting layer to the optical nerve. Yet, although these metaphors might be didactically useful for explaining the operations behind the processes, the physicochemical laws and processes in each case are, in fact, not the same: since retinal cells evolved from brain cells, they are able to operate locally as logical gates, but time processing in retinal cells is much slower than in image sensors due to its chemical basis.

What organic and machinic structures certainly do have in common is the human approach to them, specifically regarding the processes of abstraction through which we understand specific phenomena and construct new cultural objects. It was the convergence of a series of discoveries – ranging from the physical properties of semi-conductors, through the mathematical operationalization of lattices to the physiological observations of the retina – that made the construction of CCD and its subsequent use as an image sensor possible. Organisms and man-made devices for generating and processing data through light variations seem to be distinct, but follow similar operating patterns. These patterns have been astutely observed, categorized and analysed by information engineers such as Claude Elwood Shannon (1916-2001) and the media-archaeologist Friedrich Kittler and his followers, who view the basic operations – capturing, processing, storing and transmitting – as ruling mechanisms in information exchanges within and between biological and technological systems. The theoretical framework of cybernetics additionally emphasises the circularity inherent in these processes.

Resolution and verisimilitude

The search for the maximal resolution of viewing machines (photo or video cameras) reflects the desire to find technical solutions that most closely approximate human visual perception, thereby closer to verisimilar modes of representing reality. This is apparent in the way digital three-dimensional models and animations

42 Litwiller 2001.

are aesthetically handled in the visual arts. Instead of taking advantage of the freedom of unreal physical situations, the techniques are frequently used for the sake of hyperrealist special effects in entertaining movies.[43] This is part of a long tradition of creating devices and techniques marketed as a means of achieving the 'most real' experiences, while masking their limitations. Stereoscopic devices and their volumetric tactile appeal, for instance, are sold as "*some of the most pervasive means of producing 'realistic' effects in mass visual culture*"[44], when, in fact, it is a technological apparatus based on eliminating the connection between the human senses of sight and touch.

Despite the discourses marketing great advances towards achieving the 'most real effects', current optical apparatuses are far removed from the qualities of a human eye. The efficiency demonstrated by visual pigments in chemical reactions is optimized by the considerable amount of actants in the process: A human eye has approximately 100 millions rods and each *"rod has approximately 4*10^7 rhodopsins"*, which represents a much higher resolution photo-sensor than that of amphibians, which have only 10^{7}rhodopsins per rod.[45] The human retina has an even higher resolution when compared to a contemporary device from the machinic world: a *"high-resolution photographic purpose CCD chip CCD595 from Fairchild Imaging has a pixel number of 9216x9216, giving a total about 85 megapixels"*[46]. In this case, a whole CCD chip has a bit more than double the quantity of units of a single rod. Furthermore, the resolution attained by the human eye is by no means the only indicator of its magnificence or its limitations. Their flexible features and adaptability endow eyes with almost magical abilities. For instance, unlike the specialized tissue architecture of a retina, a digital camera's pixel-based image sensors present a limited Cartesian arrangement, simply due to production facilities and the need to be profitabile. This condition leaves the quality of image sensors highly dependent on the photosensitivity of semiconductor materials and the size of the image sensors themselves. Solving this problem is one of the promising avenues of research for scientists working with photosensitive biomaterials.

Operations

Fragmenting: forming, processing, transmitting and converging

The concept of resolution can also be comprehended as resulting from the process of fragmentation that both bodies and media have been subjected to since at least

43 Klein, Norman M. *The Vatican to Vegas: A history of special effects.* New York: The New Press, 2004.

44 Crary 1990: 9.

45 Gualtieri 2001: 27.

46 Riesenberg and Wuttig 2011: 315.

the nineteenth century. The increasing accuracy of scientific studies on living bodies led to the emergence of physiology, and the knowledge produced in this field has directly informed the development of diverse media devices. This cultural mechanism is in line with Vico's axiom that one can only comprehend what one has constructed. However, to construct, one also needs to abstract, isolate, fragment. This is the observation underlying Vilém Flusser's media theory based on the cultural history of abstraction and philosopher Peter Sloterdjik's (1947-) metaphor of the knife[47] to epitomize the human attitude toward the world. Specialization inevitably involves a movement towards abstraction, and therefore fragmentation.

In *Techniques of the observer* (1990), art critic Jonathan Crary (1951-) depicted this phenomenon in relation to vision and optical media. Crary depicts the path leading to the abstraction of vision, and how the work of Helmholtz and his contemporaries on human vision was part of efforts to describe the functioning of living beings in precise physicochemical terms.[48] One of the consequences of the fragmentation of the senses has been the separation of the seeing act into two parts: forming and processing images. Whether in retinas or in image sensors, photosensitive elements bridge the two distinct processes of image formation and image processing.[49]

A device that remained for centuries the reference for image formation in media history was the camera obscura.[50] Mirroring the processes that occur in the eyes, the insertion of photosensitive elements into the *camera obscura* opened up several paths for image processing and, through its further fragmentation, potential means of image transmission, which caused drastic changes to the nature of images themselves.

The technological longing for long-distance image transmissions that culminated in the invention of television and its derivative serial image techniques, enabled image formation independently of a pinhole and a black box. The idea that an image could be fragmented before being transmitted harks back to the work of the French engineer Maurice Leblanc (1857-1923), who in 1880 proposed that they could be broken into lines, translated into electric signals, and later be sequentially reconstructed in a receiver apparatus[51]. In Germany, among inventions that fragmented images into lines, especial attention should be devoted to Nipkow's disk, a device developed by Helmholtz's young student Paul Gottlieb Nipkow (1860-1940).

47 From the original excerpt in German: *"Der Mensch ist ein Tier, das schneiden kann"*. (Sloterdijk 2015: 40)

48 Crary 1990: 148.

49 Crary 1990; Fournier D'Albe 1924.

50 Crary also depicts how the camera obscura and its derivative techniques and devices together with the emergence of physiology contributed not only to the abstraction of vision but also to the makeup of the modern observer.

51 Parrika 2012: 41.

On his patent, the inventor wrote that *"the purpose of the apparatus described here is to make an object at location A visible at any location B"*[52]. The experiment is simply the concretization of the human abstractive gestures described by Flusser, especially the transition from a three-dimensional captured image, through a linear unidimensional form, to the zero-dimensionality of electric current. In Kittler's words, *"Nipkow imposed the discrete line form of a book or telegram onto images with sweeping success."*[53] It is crucial to note that the experiments of that epoch were mostly fuelled by the discovery of selenium's photosensitive properties, which played a significant role as an interface in the discoveries and inventions concerned with image transmission.[54]

In the media-archaeological artwork *A Parallel image* (2008)[55], artist Gebhardt Sengmüller didactically makes a variety of issues related to media technologies of image formation and image transmission tangible in a single piece. As shown in figure 2.9, Sengmüller's installation offers the audience a material magnification of a space between the sensing of an image and displaying it somewhere else. Sengmüller suggests the simplest but most impractical way of connecting image capture and transmission – processes that are commonly hidden in the darkness of the electronic black boxes found in photo and video cameras, televisions, digital displays and so forth.

2.9: *A Parallel Image* (2008), by Gebhardt Sengmüller. A: Overview; B: Detail of lamps in the monitor side (output); C: Detail of LDRs (Light-dependent Resistors) lattice (input). Courtesy of the artist.

52 Rings 1962: 37 apud Kittler 2010: 209.
53 Kittler 2010: 210.
54 Primitive forms of television are also discussed at Fournier D'Albe 1924: 75-83.
55 Sengmüller, Gebhard. *A Parallel Image.* <http://www.gebseng.com/08_a_parallel_image/> Accessed October 8th 2017.

According to the artist's statement:

> This media-archaeological, interactive sculpture is based on the fictive assumption that the currently still valid principle of electronically transmitting moving images, namely by breaking them down into single images and image lines, was never discovered. The result is an apparatus that attempts a highly elaborate parallel transmission of every single pixel from sender to receiver. This is only possible by connecting camera and monitor using about 2,500 cables. Unlike conventional electronic image transmission procedures, A Parallel Image is technologically completely transparent, conveying to the viewer a correspondence between real world and transmission that can be sensually experienced.[56]

A *Parallel Image* casts doubt on the standard principles behind optical devices, whose procedures cannot be perceived by the human senses. The artist imaginatively poses a 'what if' question as a strategy for causing reflection on how media work, their historical development and their aesthetic appropriations. Sengmüller elegantly subverts the principles of black boxes by expanding and opening them. The invisibility of the light path is made tangible through the floating mass of 2,500 shining copper wires. Despite their clearly metallic materiality, a quick glimpse at the workmanship reveals a quasi-convincing organic aspect, amplified by both the lightness and the fragility of the extremely thin copper wires.

There are also other technological and aesthetic subversions: the LDRs lattice that resembles a CCD or a CMOS image sensor does not operate like one; and the fetish with display resolution for achieving a more verisimilar experience plays absolutely no role in the reception of *A parallel image*. Last but not least, Jussi Parrika's comment on the piece confirms the effectiveness of the sequence of frustrating subversions entangled in the artwork: Firstly, *A parallel image* is absolutely unrelated to any of the norms of technological consumerism, where electronic technology is usually packaged in sleek opaque cases.[57] Secondly, the installation setup does not permit the visitor to directly access the image she is producing. The spatial conditions Sengmüller designed create an interaction modality in which the reactivity of the system and its mirroring effect between sensors and actuators denies the participant immediate gratification. A second and third participant are are necessary for one to decipher how the installation functions as a whole.

Although Sengmüller's piece does not address image processing, it indirectly suggests that sensing and image forming make no sense when separated from another linked system(s). Whether in the retina or in image sensors, image processing is only partially local. At the same time, there is no inner eye in the brain nor any analogous structure within the integrated circuits of the camera (or the system to

56 Ibid.

57 Parrika, Jussi. *What is Media Archaeology?* Malden, USA: Polity Press, 2012. p. 41.

which it can be connected). Light sensitive cells in the retina are responsible for translating the luminous stimulus into electric pulses to be read and processed in the brain. Human visual perception is special precisely due to this eye-brain combination. In fact, as Gregory explains, retinal cells are extensions of brain cells:

> The retina has been described as an outgrowth of the brain. It is a specialized part of the surface of the brain which has budded out and become sensitive to light. It retains typical brain cells which are functionally between receptors and the optic nerve. (…) Some of the data processing for perception takes place in the eye, which is thus an integral part of the brain. [58]

In comparison to predators, for instance, the local efficiency of human eyes is not that optimal and is highly dependent on the brain's data processing.[59] Therefore, although there is some local processing in the human eye, the act of seeing does not happen exclusively in the retina or in image sensors. For this reason, visual perception is more analogous to visual computing than to the mechanism of a camera. Research into how humans and animals learn how to see, and even into what happens when this faculty is limited or damaged, has contributed immensely to refining the understanding of the eye-brain relationship and how raw luminous stimuli are transformed into meaningful information for human beings.

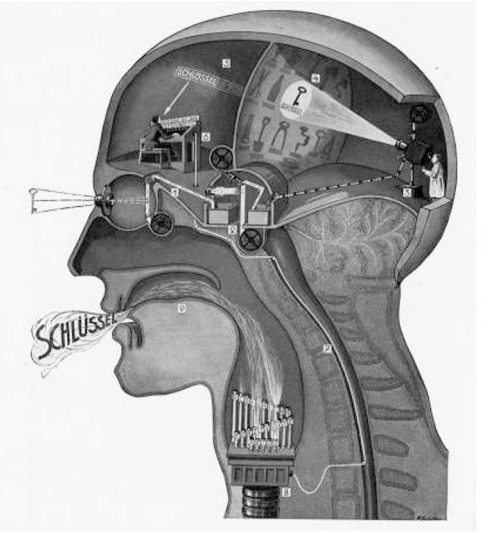
There are major differences in the way images are processed in electronic cameras depending on the context in which these devices are intended for use, and these processes have been continually reviewed and recombined in light of the new scientific discoveries and inventions that formed the standards of each era. While the development of series of optical media devices has been used both to enhance the human sense of sight and to profit from its limitations, their creation exemplifies the mutual influences and overlaps between natural and man-made models. Picture 2.10 below shows the role of media as imagined at the beginning of the 20th century[60], when cinematographic metaphors were used to model relationships between seeing and language:

With the eyes of today one notices how naïve human understanding of vision was at that time, and one can easily imagine that we are probably still using metaphors that are not appropriate to describe the phenomenon of vision in its entirety, as our construction of models is still subject to the limits of our media.

58 Gregory 1997: 53-4.

59 It has not always been obvious that vision and other sensations and perceptions are dependent on the brain's activity.

60 Zielinski, Siegfried. *Deep time of the media: Toward an archaeology of hearing and seeing by technical means.* Cambridge, Massachusetts/London, England: MIT Press, 2006.



2.10: Der Sehakt. Example of the use of media as metaphors for explaining the process of seeing; Source: Kahn 1929, Vol. 4, plate VIII apud Zielinski 2006: 49.

The translation of the image formed in the eye into electric pulses represents another potential way to bring organic matter into closer contact with a machinic and computational perspective. However, neuroscientists insist that organic and machinic correspondences are neither adequate nor suitable. Among the reasons are the countless material specificities of biological elements; the electric conduction through chemical processes, for instance, besides being sometimes reversible, are much slower than those in transistors and copper wires. On the other hand, if the zero-dimensionality of computation is also found in living beings, it might provide the ground for the dissolution of the image as a representation that results solely from vision. Sound artists are also constantly incorporating image-based associations in their compositions, using metaphors from the visual arts, referring to sound as sculpture that can be composed in an additive or subtractive ways, etc.

Zooming out to collective aesthetic manifestations, one emblematic artistic movement that highlights the enthusiasm of artists for the emerging possibilities created by scientific and technological development is video art. Video art flourished at the end of the 1960s, with the aspirations of video artists[61] ranging from freeing both artist and artworks from the traditional representational canons of

61 Meigh-Andrews, Chris. *A history of video art: the development of form and function*. Oxford/NewYork: Berg, 2006. pp. 73-74.

the visual arts, to making political statements against what had been done in the TV broadcast industry. They were at the same time spurred on by contemporary theoretical perspectives, such as those of the media theorist Marshal McLuhan (1911-1980), cybernetics and information theory[62]. On the one hand, considered as an intermediate and transitional stage between television and digital computing, the aesthetic language of video is strongly based on the potentialities of the fragmented aspects of this media, which are reflected in the mergence of its technical, conceptual and aesthetic layers[63], as is evident in McLuhan's famous statement *"the medium is the message"*.[64] On the other hand, there were those, such as the scholar Henry Jenkins (1958-) and the TV producer John Wyer[65], who saw audio-visual media history as a path towards media convergence and believed that the fragmentation processes of media would also subsequently lead to the dissolution of the isolation of senses and thus favour synaesthetic aesthetic experiments. This also explains the intimate relationship between video art and experimental music. Together with the ephemeral quality of the media itself, video art can also be read as an art movement related to process-based artwork, aligned with principles also embraced by the Situationists and the Fluxus group.

Although the primary stimulus for the "man with a camera" was the sense of sight, the zero-dimensionality of electronic media and its potential open connections with other media led to more radical experiments with space-time variables, enabling a camera to be used to break free of the constraints of realism. A master in overcoming these constraints by addressing the very materiality of video in his lyrical film-making practice, was the avant-gardist Stan Brakhage (1933-2003). In his *Metaphors on vision* (1963)[66] Brakhage formulates the core of his aesthetic statement around the hypothesis that: *"if vision is the highest value of film, then camera (and its man) must allow visions to occur rather than force them (by script) upon subjects."*[67] From this point of departure, the artist created *Anticipation of the night* (1958), a video composed of reflections on *"the nature of seeing; how one encounters a sight, how it is recalled, how it affects later vision, and where it leads the visionary"*.[68]

The emergence of electronic image sensors and the operations related to them opened the way for brand new means of expression that have become ubiquitous

62 Meigh-Andrews 2006: 101-110.

63 Just to recapitulate, video technology inaugurates image processing on several levels, such as non-linear and real-time editing, application of filters and other effects, modulation, loops, etc.

64 McLuhan, Marshal. *Understanding media*. United Kingdom/New York: Routledge, 1964/2001.

65 Meigh-Andrews 2006: 8.

66 Brakhage, Stan. *Metaphors on vision*. Film Culture: 1963. Scanned from the collections of Niles Essanay Silent Film Museum. Fremont, CA Available at <https://archive.org/details/metaphorsonvisio000brak> Accessed October 10th 2017.

67 Brakhage 1963: 8.

68 Ibid.

and taken for granted in todays digital age. Art historians and critics who have addressed core issues of video art aesthetics, for instance, naturally related it to its technical aspects. For technical reasons, it is also well known that for many artists video art represented a liberation from standard mainstream[69] ways of making both cinema and visual art; it served as a means to transgress the traditionally established language of the art and cinema industries. This became easier as the necessary equipment became lighter and more compact and portable. Video art simultaneously destroyed and reinvented the tradition of image production, also incorporating new techniques of imaging, such as x-ray, thermic and magnetic resonance images.

The intent here is not to establish a connection between the history of video art and the corresponding technical developments of the equipment; many authors have already covered this, as well as the political and activist aspects of video art history and aesthetics. What is important to the argument of this thesis is making the freedom behind machinic aesthetics explicit, bringing to attention the aesthetic uses that have become not only easier to implement but more accessible: the latent image in the CCD, e.g., opens possibilities for recombination and reinvention, even, if the artist desires, as something other than an image. The presence of photosensitive electronic devices in the arts has challenged artists to turn exact and objectivist knowledge and technical operations into enquiries, doubts and uncertainty. Through purposeful displacement and unlikely reconnections, that artists' decisions represent what Flusser termed straining off the possibilities of the apparatuses[70] in the search for symbolic and interpretative openness and desirable levels of uncertainty.

In summary, the human fragmentation of the world can be considered on several levels and constitutes, at the very least, the abstractive mechanism of Western thinking. The zero-dimensionality of media does not operate independently; it is a human invention[71] to enhance the possibilities of manipulating, combining and organising matter – material as well as symbolic. Both materially and symbolically, therefore, fragmenting stems from a biological feature that has been instrumental in shaping human culture. It is a strategy that mankind uses to accomplish a series of tasks – understanding, comparing, classifying, constructing, analysing, deconstructing, reconstructing, etc. In approaching the structural levels of the human eye and optical sensors, a similar process is underway. Rather than striving

69 For female artists inclusive, through the rising and diffusion of feminist voices.

70 Flusser, Vilém. *Filosofia da caixa preta*. São Paulo: Annablume, 2011.

71 On the implications of the invention of the concept of zero see: Deacon, Terrence William. Calculating with absence. In: *Incomplete Nature: How mind emerged from matter.* New York/London: W.W. Norton&Company, 1992.

to discover similarities, more can be achieved by acknowledging differences and learning how to deal creatively with them.

Filtering, mapping and noise reduction

The path between retina and brain, between image sensor and microprocessor is made possible by operations that cannot be explained solely through the anatomical or architectural qualities of isolated elements. In this sense, the scientific paradigms that emerged and suggested that problems can be handled holistically while taking into consideration the interdependence of the parts of the whole were extremely useful for dealing with problems created by new technological and scientific discoveries.

Experiments and theoretical attempts to understand vision also take part in the process of rationalization of sensation and its many intangible psychic affects. The endeavours by Gustav Theodor Fechner (1801-1887) and Ernst Heinrich Weber (1795-1878), who attempted to formulate a *"mathematical equation that expressed a functional relation between sensation and stimulus"*[72], is an example of this process. Studies with this objective have endeavoured to measure and mathematically formulate the relationships between objectivity and subjectivity, revealing that, although the firing rate of receptors increases as the intensity of light is increased, the *"sensation of light does not increase as quickly as the intensity of the physical stimulus"*[73]. Fechner's law suggests a logarithmic relationship between the actual change in physical stimulus and the perceived change.[74] This, in turn, has been interpreted as suggesting that photosensitive cells play the role of filters.[75]

A primitive sample of machine vision developed by the physicist Paul Weston (1935-) at the Biological Computer Laboratory (BCL), a seeing-counting machine called *Numarete* (1960), already demonstrated the difficulties and challenges faced in attempting to mimic the above-mentioned filtering quality of organic photosensitive cells. *Numarete* is a simple but very instructive example of the interplay between photosensitive materials and applied mathematics and represents one of the countless possibilities of man-made filtering operations.

Able to count the objects placed onto it, *Numarete* was supposed to be a simulation of a Pitts-McCulloch cell network, operating through the arrangement and

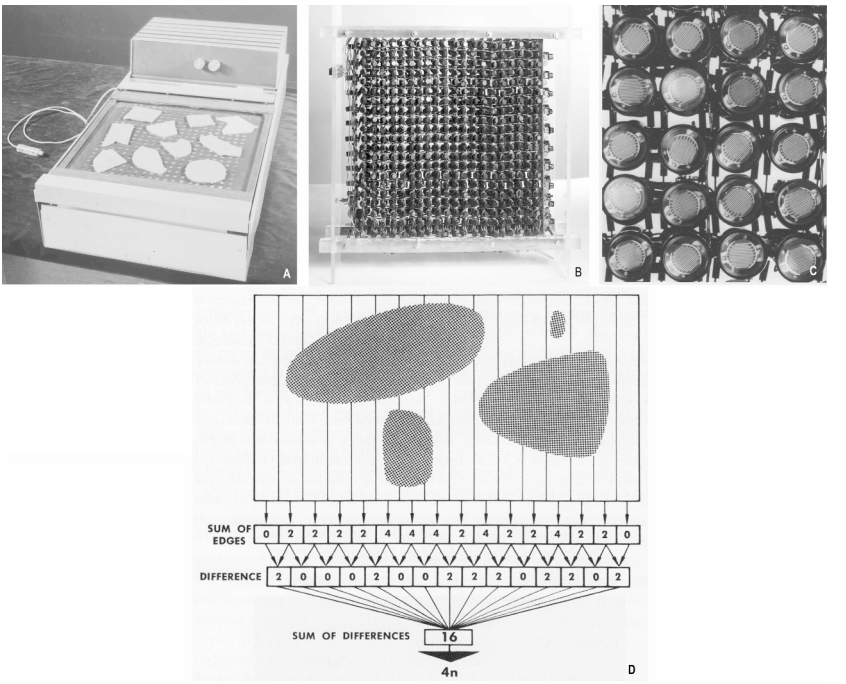
72 Crary 1990: 145.

73 Ibid: 146.

74 Experiments done with the horseshoe crab limulus polyphemus, whose eye receptors are connected directly to separate nerve fibres, showed similar results. (Gregory 1997: 92)

75 According to Gregory, *"the highest number of impulses a nerve can transmit is under a thousand per second, while the frequency of light is a million million cycles per second. The problem is: How are the high frequencies of light represented by the slow-acting nervous system?"*. (Gregory 1997: 122)

interconnection of photoresistors and electronic elements that could assume one of two states (on or off, or 0 and 1)[76], as show in the picture below:



2.11: *Numarete* (1960), by Paul Weston. A: The device; B: Array of LDRs (Light-dependent resistors); C: Details of the LDRs; D: Schema of mathematical operations made by the machine. Courtesy of Paul Weston and Heinz von Foerster Archive, Institute of Contemporary History, University of Vienna.

Understanding photosensitive cells as filters, i.e. as membranes that select what the internal system can (or cannot) administer, is pertinent to the issue of how the form and function of living bodies are the result of an evolved solution to absorb and transform a specific range of high frequency radiations (far higher than nerves can directly follow) into a visible spectrum. Every organism needs to limit the amount of input data according to the body's limits and survival needs. For the same reason, the processing activities of eye-brain cells are split in phases, presenting different anatomical characteristics according to the path that the electric

76 A more detailed technical description of Numarete can be found at: Weston, Paul. A walk through the forest. In: Müller, Albert. (Ed.) *An unfinished revolution? Heinz von Foerster and the Biological Computer Laboratory | BCL 1958-1976*. Wien: Echoraum, 2007. pp. 93-96.

pulses pass through. According to Gregory, the *"pre-processing funnels 120 000 000 receptors down to 1 000 000 optic nerve fibres, no doubt reducing the thickness and stiffness of the optic nerve so that the eye movements are possible"*[77]. Similarly, from the perspective of image sensor engineering filtering could be considered as an optimal manner to process a huge amount of information. In a very simplified way, this is also what the mathematical model behind the *Numarete* does (see frame C at figure 2.11).

The correspondences between the form and filtering function of cells also reveal a sort of media specificity[78] of each part of the body. This fact was of notable interest to cyberneticists. While conducting studies on frogs' vision between 1958 and 1960 at MIT, cyberneticist Humberto Maturana (1928-), in collaboration with Jerome Ysroael Lettvin (1920-2011), a specialist in neurophysiology and electronics, *"realized that the shape of the nerve cells and the retina specified what the retina saw, so to say."* [79]

Neuroscientist António Rosa Damásio (1944-), in *Self comes to mind* (2010), describes a variation of the filtering method of eye-brain cooperation through the immediate correspondences between the retinotopy and the activated patterns in the visual cortex, suggesting the notion of mapping as a metaphor to explain the dynamics between sensorial input and brain stimulation. Suggesting that the concepts of image, map and neural pattern are interchangeable, Damásio analyses equivalences between the two-dimensional square grid architecture of retinal neurons and the three-dimensional cerebral cortex. According to his findings, the inscription of lines on a brain map is the *"result of momentary activity of some neurons and of the inactivity of others"*[80] and *"can be rapidly drawn, redrawn and overdrawn"*[81]. He explains:

> The same kind of 'drawing' also happens in an elaborate outpost of the brain called the retina. It too has a square grid ready to inscribe maps. When the light particles known as photos strike the retina in the particular distribution that corresponds to a specific pattern, the neurons activated by the pattern – say, a circle or a cross – constitute a transient neural map. Additional maps, based on the original retinal map, will be formed at subsequent levels of the nervous system. This is because

77 Gregory 1997: 55.

78 As demonstrated by experiments conducted by physiologist Johannes Evangelista Purkinje (1787-1869), retinal photoreceptors have certain specific features – the cones are anatomically and physiologically more apt to filter the light spectra when the eye is light-adapted, whereas the rods are more apt to filter the light spectra when the eye is dark-adapted. (Gregory 1997: 90)

79 Maturana, Humberto R. Interview on Heinz von Foerster, Autopoiesis, the BCL and Augusto Pinochet. In: Müller, Albert; Müller, Karl H. (Eds.) *An unfinished revolution Heinz von Foerster and the Biological Computer Laboratory | BCL 1958-1976*. Wien: Echoraum, 2007. p. 41.

80 Damasio 2010: 66.

81 Ibid: 67.

> the activity at each point in the retinal map is signalled forward along a chain culminating in the primary visual cortices while preserving the geometrical relationships they hold at the retina, a property known as retinotopy.[82]

Damásio's interpretation of eye-brain dynamics asserts that, although abstracted into electric pulses, the information provided by inputs preserves a spatial quality of the senses, and by extension perception and memories, inside the body.

Filtering and mapping features, from either biological or machinic systems, are also indirectly related to the notion of noise reduction, a mechanism usually working to optimize input data in order to turn it into more useful and/or meaningful information for the system. In fact, *"all sensitive detectors are subject to random noise, which degenerates signals, and limits the sensitivity of detectors*"[83]. Confirming the cooperative work between eye and brain, it is known that even after light stimulation on the eyes has ceased, neural activity continues to occur in the brain. Therefore, finding strategies to reduce the harmful effects of noise is an everyday task of living beings.

According to studies on experimental psychology, moreover, *"the smallest difference in intensity that can be detected in the retina is proportional to the background intensity."*[84] This demonstrates the relativity and quasi-instantaneous adaptability of the human eye to a variety of light conditions. In Gregory's words:

> the old idea of a threshold intensity, above which stimuli need to be if they are to have any effect on the nervous system, is wrong. We now think of any stimulus as having an effect on the nervous system, but only being accepted as a signal of an event when the neural activity is unlikely to be merely a chance increase in the noise level. (...) The problem for the brain is to 'decide' when a given increase is merely noise and when it is due to the increased intensity of the signal. If the brain accepted any increase from the average activity, then we could often 'see' flashes of light that are not in fact present.[85]

In this sense, the recalibrating feature of vision works as a strategy to generate perception constancy, as a biological reaction against irrelevant repeated signals.[86] On the one hand, the eye's adaptability and its noise reduction features might also constitute a body's strategy to optimize the consumption of energy. On the other hand, although living beings find ways to reduce the harmful effects of noise, it is unavoidable that the visual system's internal noise increases with age, causing

82 Ibid: 67.
83 Gregory 1998: 93-4.
84 Ibid: 94.
85 Ibid: 95.
86 Ibid: 149.

gradual loss of visual discrimination as well as subsequent problems with motor control and memory.[87]

Noise reduction strategies in machinic systems, setting aside their role in the optimization of energy consumption, can be approached as an arbitrary adjustment aimed at finding a compromise between input signals and a certain verisimilitude to human perceptive skills. Although it is known that engineers have been struggling to achieve the most efficient results for media and communication technologies, as already noted long ago by Claude Shannon and Warren Weaver (1894-1978) in their *Mathematical Theory of Communication* (1948), *"mediation is not necessarily efficient, in the sense of translating data from A to B undamaged"*[88]. In technological environments, moreover, noise is understood as an intrinsic characteristic of any system, i.e. as a permanent condition of communication[89]. Although organisms and machines are subject to the same rules of the physical world, noise reduction is a matter of survival for living entities, whereas for communicational devices this is not the case.

Furthermore, considering that the intense and dynamic *"changes in the brain maps also reflect the fact that we ourselves are in constant motion"*[90], due to the eyes' movements and biofeedback processes, the recalibrating feature of vision becomes even more powerful, providing a degree of adaptability that even the smartest robots by Boston Dynamics still do not possess. This also explains why recent computational neurotechnology studies on the syntax of behaviour have focussed on the perception-action loop and on the role of movement, which neuroscientist Aldo Faisal considers crucial for decoding intentions.[91]

In addition to this systemic perspective, one can also observe that the initial scientific impetus to artificially segregate image forming from image processing has been recently dissolved by the mergence of computer vision and machine learning techniques. In this connection, it is intriguing to think about Jonathan Crary's critique of the pragmatic approach of the 19th and 20th century psychophysicists and and its possible relevance to the current approach to vision engineering.

Concerning media art, it is worth questioning what kind of knowledge paradigm media artists are adopting to make their audience – to use Crary's terms – "manageable and predictable". A frequent challenge in the development of sensor-based artworks is the problem of removing noise from the sensor in the interest of

87 Gregory 1998: 95.
88 Shannon & Weaver 1949: 3.
89 Serres 2007 apud Cubitt 2014: 9.
90 Damasio 2010: 67.
91 Faisal, Aldo. *Perception, action and the grammar of behavior.* Lecture held at WO/MAN MIND MACHINE Interdisciplinary Conference at the Einstensaal/Berlin-Brandenburg Academy of Sciences and Humanities on June 13th 2016. The event was co-organized by *Die Junge Akademie* and The Israel Young Academy.

both the stability and intelligibility of the system's reactivity. Decisions on this level cannot be made without some notion of a 'model visitor'[92] and have direct influence on the openness and fluidity of the system. Depending on the context, it can be desirable to have either a precise and clean, hence less noisy, or a random, dirty and unintelligible, therefore noisier, reaction from the programmed system. These choices concern fine adjustments that artists must think about in order to make their artworks more or less communicative. There is no unanimity on this topic because such decisions depend on the context and on how knowledge is implemented and actualized in praxis. Artists are free to incorporate previously developed optical tools in a more diverse and critical way. It is also, however, the responsibility of artists to analytically reflect upon the level of noise they use in their artworks.

2.1.2 Parameters of vision

Image formation and processing relies on a variety of parameters concerning the elements to be detected, or perceived, such as shape, brightness, contrast, depth and perspective, among others. This section will address the parameters of colour and movement detection in order to enhance understanding of the close relationships between human vision and optical media. Colour and movement have been chosen for three main reasons: (1) the immediate functions of photosensitive cells, (2) their pertinence in the process of unboxing media history through the lens of photosensitive materials and (3) their strong resonance in media artworks.

Colour detection

The ability to perceive colour emerged relatively late in the evolutionary process of mammals, dating to the existence of primates. Like vision itself, the perception of colour is the product of a shared phenomenon happening between object (or surroundings), eye and brain. Understanding this phenomenon requires distinguishing colour as sensation and colour as wavelength (or set of wavelengths). Newton's experiments at Trinity College, in Cambridge, which lead to the compilation of his book *Optiks* (1704), were important to drawing this distinction. The physician's discovery that white light was made up of all the colours of the spectrum triggered the subsequent development of the wave theory of light, which holds that each monochromatic colour corresponds to a given frequency of radiation. While the dual nature of light (wave-particle) is acknowledged as the current scientific paradigm, the radiation spectra named light is not coloured *per se* but rather is the source through which sensations of brightness and colour can be perceived by a suitable eye and nervous system working in cooperation. Therefore, technically speaking,

92 Direct teference to Umberto Eco's (1932-2016) concept of 'model reader'. Eco, Umberto. *The Role of the Reader: Explorations in the Semiotics of Texts*. Bloomington: Indiana Univ. Press, 1992.

it is preferable to refer to colours as 'hues', which essentially depend on subjective impressions.[93]

The subjective aspects of visual perception stand out even more when colours come into play. How does one know that the sensation of what one calls blue is the same for someone else? Although humans have the same type of retina, one cannot conclude that people see the same colour. This is a great and unresolvable paradox for studies on colour, despite the constant efforts to objectify what is essentially – physiologically – subjective. This fact has not always been obvious and its realization is part of the history of discoveries related to light and human vision. Furthermore, it reveals the influence of subjectivity in cultural formation and the importance of colour perception to visual aesthetics. A classical example of the cultural layer of visual perception is the ability of Eskimos to distinguish sixteen shades of white. Besides the ability of the eye to adapt to light conditions almost instantaneously, specific environmental factors have a demonstrable influence on the perception of colour. The highly accurate adaptation to light conditions is still very difficult to achieve in seeing machines. It is not accidental that professional video cameras offer the manual set up of white balance, a feature that in human eyes is so natural and automatic that it is very hard to even think about it. Perceptual psychologist Rudolf Arnheim (1904-2007) has related the example of how humans can simultaneously perceive a white sheet of paper close to the window in daylight and a similar one on the nightstand close to an incandescent lamp. The colour white works as the ground reference for the desired colour temperature to be recorded in digital video cameras. However, in the course of media history adjustments of this level have not been easy to achieve. The diversity of techniques implemented in the history of colour photography and moving images[94] demonstrates that both colour perception and the implementation of colour in media devices are in fact also a sort of filtering process.

According to Friedrich Kittler, it is very likely that the development of colour images in media technology – the RGB system, as well as luminance and chrominance – only became possible after the discoveries made from research on the photosensitive cells of human eyes.[95] In this process leading roles have been played by the work by Thomas Young (1773-1829) and Hermann von Helmholtz (1821-1894), both of whom are responsible for the trichromatic colour vision theory, also known as the Young-Helmholtz Theory. [96] This theory was further developed by Ja-

93 Gregory 1997: 84.

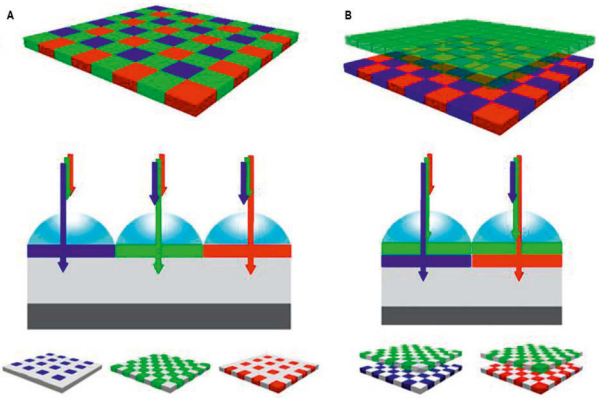
94 Flückiger, Barbara. *Timeline of historical film colors*. Since 2012. Available at <http://zauberklang.ch/filmcolors/> Accessed September 23rd 2018.

95 Kittler 2010: 36.

96 The theory defended the view that human eyes presented "*three colour-sensitive kinds of receptors (cones) which respond respectively to red, green and blue (or violet), and that all colours are seen by a mixture of signals from the three systems*." (Gregory 1997: 126) According to Gregory, the

mes Clerk Maxwell (1831-1879), who in 1861 demonstrated one of the first documented colour photographic images. The implementation of the trichromatic theory of vision into image techniques remains the basis of most colour images in optical media today. As with the techniques for enhancing the resolution of optical devices, the issue of colour has also been accompanied by the search for the maximal verisimilitude of the device's response, i.e. as close as possible to human vision.

On a CCD, for instance, the technique found to apply the trichromatic theory of colour in single-chip digital image sensors was Bayer masking, a system that consists of an array of colour filters placed over a square grid of photodiodes, as depicted in figure 2.12:



2.12: Schematic diagrams of the CMOS colour image sensors using Bayer mask colour filter. A: Conventional two-dimensional CMOS colour image sensor. Each pixel measures the intensity of light passing through B, G, and R colour filters; B: A three-dimensional, multi-stacked, organic-on-Si hybrid CMOS colour image sensor; Source: Nature 2015.

Bayer masking, however, does not guarantee image quality in agreement with the exigencies of the quest for verisimilitude. Media historian and theoretician Sean Cubitt has observed that:

> In addition to Bayer masking, expensive models code colour by splitting the light with a prism toward three separate CCD chips, but high-resolution chips are still very expensive, so that 3CCD architecture tends to be used more in high-end video

process of isolating the basic response curves has been surprisingly difficult for the available technology of the time. More recent and specific books on the physiology of vision since the 1960s have determined precise measurements of the curves. (Guyton et al. 1997: 582)

> than still imaging. Another solution, using a rotating filter, is useful only for still image of immobile objects: any movement of the object produces colour-fringing effects.[97]

Discussions of possible better and more efficient solutions are unfruitful in the realm of art, since the choice of one or another type of equipment is always subject to the constraints of circumstance and not merely the concepts and aesthetical values being developed. One can imagine the "colour-fringing effects" referred to by Cubitt being easily incorporated in video art as a form of glitch aesthetics, for instance.

Furthermore, the apparent failure of those artificial colour systems is due to the narrow perspectives that ignore that seeing is done not only by the retina but by the combination of eye and brain. Specificities of photosensitive cells in the eyes help to figure out how the body can achieve various neural responses for different light radiation frequencies. However, that is only a very tiny part of a complex system, whose mystery is constantly challenging neuroscientists and other researchers engaged with the subject. Neuroscientists have also speculated that the brain deals with visual characteristics in specialized 'modules', with neural channels dedicated to form, movement, stereo depth, colour, and so on. According to Gregory, for instance, *"processing form and colour is largely separate physiologically, colour being by 'broad brush' low spatial frequency channels, operating quite slowly*".[98] However, due to the astonishing plasticity and complexity of the human brain, it is still dubious to reach conclusions about any absolute features of the brain regions. The current categorization of visual area[99] as a core part for the perception of colour is still uncertain, despite lots of research on its mechanisms, constancy of locations and functions.[100]

In addition, returning to media history, the scientist Edwin Herbert Land (1909-1991), the inventor of the instant Polaroid camera, raised the issue of the complexity of colour perception and the concomitant participation of the cognitive faculties. Land has demonstrated that *"what is true for colour mixture of simple patches of light is not the complete story for all perception of colours. Odd things happen when the patches are more complicated, and when they represent objects*"[101]. Land's experiments on colour vision in more complex empirical contexts have contributed to the theory of colour perception to the extent of offering an alternative system to the Young-Helmholtz

97 Cubitt 2014: 276.
98 Gregory 1998: 71.
99 Guyton et al 1997: 665.
100 Cowey, A. Heywood, C.A. There is more to colour than meets the eye. In: *Behav Brain Res.* 1995 Nov; 71(1-2): 89-100.
101 Gregory 1998: 133.

trichromatic system. Moreover, by reducing the projected colours in the experiments to only two wavelengths, he also discovered that an ample range of colours could be perceived when they were associated to patterns or pictures.[102]

To a certain extent, what Land suggests marks a convoluted return to what Jonathan Crary noted about the emergence of a new modern observer through optical studies and the invention of new optical apparatuses. In order to depict the process through which cutting-edge attitudes placed perception as the primary object of vision, Crary calls attention to the work of past figures such as Johann Wolfgang von Goethe (1749-1832), Arthur Schopenhauer (1788-1860), John Ruskin (1819-1900) and Joseph Mallord William Turner (1775-1851)[103].

Goethe, by closing the hole of the camera obscura, began the neglect of its supposed objectivity, affirming that the three primary colours were not in the nature of light, but rather in the constitution of man. Following Goethe's lead, the young philosopher Schopenhauer, published his treatise *Über das Sehn und die Farben* (1816), a reflection on the active role of the retina in the process of colour perception. Schopenhauer's propositions and the emergence of physiology as a field of study also aided the consolidation of the notion of subjective vision and the parallel deconstruction of the objectivist approach modelled on the camera obscura. It was only natural that such reflections on the physiological and philosophical grounds of subjectivity resonated in the arts. J.M.W. Turner, by merging the image of eye and sun through a circular structure (the sun, the pupil, the retinal field) in his painting *Light and Colour (Goethe's Theory) - The morning after the Deluge* (1834) explicitly represents the sun and the retinal process of vision, directly citing the influence of Goethe's work on afterimages in the title of his piece.[104]

Contradictorily, although the emergence of physiology can be interpreted as the spread of rationalization over the human body, these examples simultaneously show that it led to the emergence of subjectivism, as the studies on colour perception intimately associated with physiology revealed its many idiosyncracies. Through a series of empirical studies on afterimages on the retina, scientists realized that what is seen is conditioned by the retinal structure and how it functions. When the photo-pigments present in retinal cells are bleached by light and chemically stimulate the receptors, despite how efficiently the recovery of the initial state of the photo-chemicals within the cells occurs, it does not happen immediately[105].

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102 Ibid: 133-4.

103 Crary 1990: 138.

104 Crary 1990: 139. Curiously, some of the scientists who conducted experiments on the eye and the retina have suffered severe loss of the living retinal cells in their own body. Sir David Brewster, Joseph Plateau, Gustav Fechner have damaged their own eyesight while staring into sunlight in order to research retinal afterimages. (Crary 1990: 141)

105 Gregory 1998: 57. Moreover, according to Gualtieri, the photobleaching effect of the Rhodopsin (probably the unique type of protein for vision), as a complex series of reactions,

The remaining images caused by these phenomena are called after-images, which can be positive or negative, depending on whether the eye is adapting to light or darkness.[106] According to Kittler, a positive after-image

> occurs when the eye continues to see an object in the same place a moment after it has already disappeared or moved away. This happens because the stimulation of the nerve fibers only wears off gradually, and the after-image remains in the same color as the original image rather than the complementary color, as with a negative after-image.[107]

Although the in-between quality of seeing has been recognized in both intromission and extramission theories since ancient Greece (as, e.g., in what Claudius Ptolemy (c. AD 100 – c. 170) in his *Optics* (unknown year) called 'visual flux')[108], it was only with the emergence of physiology that explanations of how subjectivity influenced the perception of colours were formulated. This fact supports Kittler's argument that the limitations of human senses prepare the terrain for media development and that it is through the knowledge of the causes and effects of after-images, persistence-of-vision[109] and phi phenomenon[110] that the creation of illusionistic media devices has been stimulated.

One can see the phenomenological stream in philosophy as an attempt to find a compromise between the usually opposed objectivism of the exact sciences and subjectivism of philosophy. Through the publication of the iconic book *Phénoménologie de la perception* (1945), Maurice Merleau-Ponty (1908-1961) refused the Cartesian division of body and soul as well as the separation between consciousness and world and subject and object – dichotomous relationships that have held sway in epistemology up to the present day. From the perspective of phenomenology, any sort of absolute analysis of colour perception will fail. Artworks dealing with colour perception, whether by distorting, emphasizing, heightening or removing a certain human ability, inability or disability, can also be understood and analysed as the materialization of phenomenological thinking. Moreover, dealing with doubt, relativity and perceptive confusion is pervasive in the arts, a field that has

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provokes the expulsion of the isomerized chromophore from the binding protein site. The whole recycling process of the protein lasts around twenty minutes. (Gualtieri 2001:25)

106 Kittler 2010: 146.

107 Kittler 2010: 149.

108 Smith, A. Mark. "Ptolemy's Theory of Visual Perception: An English Translation of the 'Optics' with Introduction and Commentary." In: *Transactions of the American Philosophical Society*, Vol. 86, n. 2, 1996, pp. iii-300.

109 Often shortened to POV, it refers to the 1/8s of the image permanence on the retina after exposure to light.

110 Described by Gestalt theoretician Max Wertheimer (1880-1943), the phi phenomenon theory refers to the human cognitive ability of completing the gaps between static images and thus allowing movement perception. (Gregory 1998: 118)

historically been partially based on the exploration of illusions and other sorts of tricks to deceive and expose the limits of the human senses.

Desvio para o vermelho (1967-1986)[111] by Cildo Meireles (1948-) is a masterpiece proposing a 'red shift' for the visitors, consisting of an installation that embraces a variety of layers of interpretation simultaneously through its three sessions: *I: Impregnação* (impregnation) (Fig. 2.13); *II: Entorno* (surroundings) and *III: Desvio* (deviation). Meireles, considered by art historians and art critics as a conceptual artist, provides visitors with a perceptual and immersive experience in a room completely decorated in red, opening up an aesthetic experience of the physiological, emotional and symbolic developments with which the colour red can be associated.

2.13: *Desvio para o vermelho. I: Impregnação* (1967-84), by Cildo Meireles. Mixed media. Variable dimensions. Photo: Eduardo Eckenfels. Courtesy of the artist, Galeria Luisa Strina and Inhotim.

As soon as one enters the room *I: Impregnation*, an unusual feeling is prompted by the experience of being immersed in a monochromatic environment. Slowly as one's retina adapts to it, one starts to perceive a huge variety of shades of red. The

111 The artist first thought about this artwork in the second-half of the 1960s; however, it was only at the beginning of the 1980s that he started working concretely on it. It was assembled for the first time at the Museu de Arte Moderna in Rio de Janeiro in 1984. A version of the installation has been permanently exhibited at the contemporary art centre Inhotim, in Brumadinho, Brazil since 2016.

first step is an essentially sensorial experience and refers literally and directly to the physiological aspects of the sense of sight and its ability to filter and accommodate colour. The room reveals that perceiving colour not only depends on the wavelengths and intensities of the stimulus, but also on differences and intensities within the details and the specific regions, shapes and patterns to which they are associated. A seeing machine could certainly detect and classify all those shades of red much faster than a human, but it nevertheless lacks the joy of perceiving the self-regulating and learning processes of a living body.

What happens next is that the dominant sensorial experience gives place to reflections on the symbolic openness suggested by the emotional and ideological appeal of the colour red – ranging from love and violence to leftist ideals.[112] Moreover, 'red shift' in astronomy, whether or not this connotation was intended by the artist, signifies a shift in the spectra of very distant galaxies toward longer wavelengths (toward the red end of the spectrum), an indicator, according to physicists, that the universe is expanding.

Rooms *II: Entorno and III: Desvio* complement the physiological-symbolic experience. An enigmatic scene of a leaking bottle spreading a red liquid on the floor (*II:Entorno*) is an intermediate space on the way to *III: Desvio*, a dark room where an afterimage experience is offered, followed by the discovery of a sink, where a red liquid flows from the tap. Once adapted to red colours, entering the dark room offers the visitor unusual abstract images that are translations of the chemical compensations in the retina and brain, and constitutenafter-effects resulting from the previous immersion in the red room. Each section of the installation's name suggests a strong mix of material and conceptual elements. According to curator and art critic Caroline Menezes (1979-),

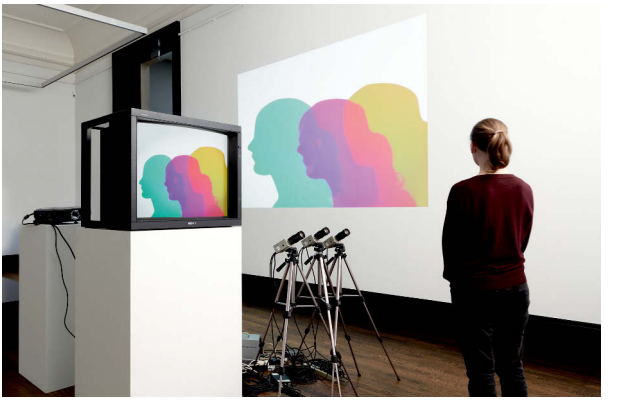
> each element composing Meireles's installations unpacks parables and tales as if to test his audience's ability to discover meaning. Establishing a strong poetry of substances, this seductive approach enlists viewers to draw out narratives by using their senses and perception.[113]

In the context of media art, colour issues and their interplay on the technical level also became creative material for pioneer video artist Nam June Paik (1932-2006) in his *Three-camera participation* (1969/2000) (Fig. 2.14). In this installation the artist

112 The artist has declared in an interview that he could have done it in blue or yellow and that no specific political orientation was intended in this artwork. (Menezes, Caroline. Materiality and Memory: An interview with Cildo Meireles. In: *Studio International*. March 28th 2009. Available at <http://studiointernational.com/index.php/materiality-and-memory-an-interview-with-cildo-meireles> Accessed November 7th 2017.

113 Menezes, Caroline. Cildo Meireles: From Sense to Concept. In: *Studio Internacional*. <http://studiointernational.com/index.php/cildo-meireles-from-sense-to-concept> Accessed November 7th 2017.

created a closed-circuit video, in which three adjacent cameras capture real-time images of the visitor(s). Each camera captures a colour channel, and the three single images are merged while projected onto the wall and displayed in a monitor set off to the side.



2.14: *Three-camera participation* (1969/2001), by Nam June Paik. Kunsthalle Bremen – Der Kunstverein in Bremen. Photo: Tobias Hübel. © Nam June Paik Estate.

The artwork plays with the visual perception of the audience through mirroring, colour-decomposition effects, displacement, and object multiplication, revealing how the senses of sight and touch are intimately connected. The simple play with the video colour system offers a confusing and challenging sense of presence that simultaneously addresses the subjective and objective aspects of colour perception. On the one hand, the form chosen by Paik is a reference to the fragmentation of the senses and their elements, a procedure inherent to the objective method of scientific investigation. On the other hand, the fragmentation can only be perceived through the subjective experience within the installation. The superimposed images created from the video's three primary colours (RGB) makes Paik's work conceptually and technically instructive in the context of media history. The artwork was displayed as part of the 2014 exhibition *Schwindel der Wirklichkeit* at the *Akademie der Künste* in Berlin, whose stated aim was to present artistic strategies and methods focussing on the visitor's perception and the confrontation with oneself.

Movement detection

The most immediate association to come to mind concerning the relation between light-sensitive matter and movement is the birth of cinema through the illusion

of movement generated by the animation of photograms. Media historians often relate the emergence of time-based media technologies (film, television, video and others) to Éttiene-Jules Marey's (1830-1904) experiments on chronophotography and Eadweard Muybridge's (1830-1904) experiments on animal locomotion and invention of the *Zoopraxiscope* (1879). These examples illustrate the repeated fragmentation of media sources into elements (film frames, tv lines, digital image's pixels) that cannot be perceived as such by the naked human eye. Referring to the invention of a device in television's pre-history, the Nipkow's disk, Kittler stated:

> Nipkow also knew about the inertia of the eye and its unconscious ability to filter out the image flicker either physiologically through the after-image effect already employed by film, or more generally or mathematically through the integration of individual pixels.[114]

The chemical basis of the photoreceptors responsible for the afterimages and the POV phenomena's effects makes the perception of movement essentially stroboscopic, a quality that attributes a necessarily temporal quality to vision. Therefore, an observer's sensations are necessarily dependent on a sequence of stimuli registered by the individual photoreceptors in the retinal receptive fields, which are, therefore, spatio-temporally linked with the neural networks of the brain.

From the perspective of the media spectator, as Rudolf Arnheim has shown, movement is the visual parameter that most attracts human attention. Considering the general specialization of retinal photoreceptors, rods, rather than cones, are more active agents in movement detection, as they have a higher concentration in the peripheral area of the retina. Recalling the functional sectors of the retina, it is the high concentration of cells in its central area that permits humans to focus and see details of objects in the central region of the sight field. The information received from the peripheral cells, on the other hand, is more related to rougher sort of visual information: *"Movement is seen, but it is impossible to identify the object, and there is no colour. When movement stops the object becomes invisible"*[115]. This instinctive feature is, however, enough for triggering a reflex movement, activating the eye muscles to turn the attention (the foveal region) towards the moving object. Looking ahead, one can perceive something moving, without being able to recognize precisely what kind of object it is. After its immediate detection, the decision about whether the object is stationary or moving is made in the brain. These kinds of choices depend on their hierarchical relationships, which are defined according to their frames, variability and intensity, as demonstrated by studies on human vi-

114 Kittler 2010: 209.
115 Ibid: 98.

sual perception, such as those conducted by the Gestalt researchers Karl Duncker (1903-1940) and Erika Oppenheimer (1910-2003).[116]

Given the inherent spatio-temporal quality of movement perception, one can consider the photosensitivity of human eyes as one of the key determinants of the concepts of time and memory in Western thinking. On the one hand, the eye's photosensitivity and ability to detect movements[117] imply the perception of time passing, which happens precisely at the very moment of perception due to its sequential nature. On the other hand, human perception of movement is a biological feature that continuously turns the external stimulus' sequential quality into a spatial quality, creating by extension the notion of memory. Since every perceived moment constantly modifies the previous ones, each perceived event finds its place in the spatial structure of memory. This is because brain and nervous system's material assimilation of electric pulses happens through spatial- rather than time-based patterns.[118]

The information provided thus far all points to understanding the eye not as a mere image-forming black box but, rather, as an important organ participating in the thinking process. Experiments such as those conducted by psychologist Celeste McCollough Howard (1927-) in the 1960s on vision scaling and adaptive abilities as biological strategies avoiding bodies own errors, demonstrate how the human eye-brain act enables us to make sense of the world. The power of eye-brain cooperation has become clearer through the efforts of technicians engaged in developing optical devices to take on intriguing problems concerning the differences between the eye's and camera's ways of seeing. These differences become even more intriguing when observing the perception of movement instead of colour perception. Questions such as *"Why the visual world does not swing round with eye movements, though it does when a cine camera is panned around a scene"*?[119] convey the highly accurate and still very mysterious work of the human brain.

Although optical engineers do their best to approximate human perception by simulating more and more 'realistic' effects, one can still easily distinguish the qualities of an eye's images from those of a camera. These differences lose their importance, however, when the image itself is not the final goal of the optical device. Such devices are frequently implemented in technical ensembles due to their operative functions rather than image quality. In their efforts to achieve more successful results, engineers working on machinic vision systems have also been exploring anatomical and physiological elements found in the vision systems of other animals. According to Gregory:

116 Arnheim 1980: 372-3.
117 Together with the auditory perceptual system.
118 Arnheim 1980: 368.
119 Gregory 1998: 114.

> A detailed model has been suggested for the compound eye of flies and is the basis for a system in aircraft that detects drift due to wind blowing them off course. This movement detector was developed by biological evolution millions of years ago, and has now been discovered by applying electronics, to be useful for technology. This is a nice example of backwards and forwards bio-engineering.[120]

A highlight of the technical tools for computer vision currently available is the library OpenCV (Open Source Computer Vision), a series of applications that implement different methods according to developers' needs. One of the motion tracking methods available at OpenCV library that is closely related to the fly's vision system is 'optical flow', a specific technique based on the recognition of apparent motion of objects, surfaces, and edges in a given image, calculated through relative changes in the frames over time. In the 1940s, psychologist James J. Gibson (1904-1979) promoted what he termed an ecological approach to vision[121] and introduced the concept of optical flow to describe the relationship between visual stimuli and animals moving through the world. In computer vision, optical flow encompasses techniques used in image processing and navigation control, such as motion detection, object segmentation, time-to-contact information, calculations of focus expansion, luminance, motion compensated encoding, and stereo disparity measurement.[122]

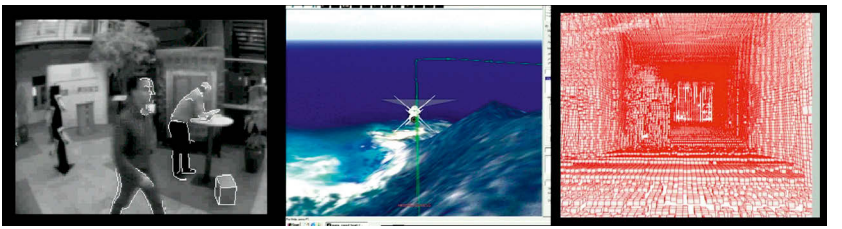
Another computational method often used to detect movements is blobs detection, which consists of identifying shapes in a digital image that can be distinguished by any property (colour, brightness, etc.) in relation to its surrounding pixels. The movement of the shape can be tracked by the constancy of those properties in a sequence of frames. This sort of algorithm and the equipment required to run it and its scanning features share much in common with the previously discussed control and surveillance issues. Preoccupations with these issues were materialized in the 1960s and 70s in video installations of different forms by artists like Bruce Nauman (1941-), Dan Graham (1942-), Michael Snow (1929-) and others, and have since been constantly revisited in the arts in relation to the contemporary technological context. This can be seen, for instance, in Harun Farocki's (1944-2014) trilogy *Eye Machine* (2001-2003) (Fig. 2.15: I, II and III), which explores the contemporary *modus operandi* of warfare by inserting military image-based technologies into everyday civilian life. His work inevitably touches on the political dimension of machine vision. Using images taken by technological devices ranging from the

120 Gregory 1997: 100-1.

121 Gibson's ecological theory of perception considered not only the individum's perceptual systems, but rather their relationship with its specific environments. According to Gregory, Gibson experimental work on depth and form, for instance, was based on modeling a dynamic 'optical array of light'. (Gregory 1998: 9)

122 Vijayarajan et al. Automatic detection of moving objects using Kalman algorithm. In: *International Journal of Pharmacy and Technology.* Vol.8 Issue 3, Sept 2016. pp. 18963-18970.

suicide cameras embedded in missiles in the Gulf War in 1991, to robots in the production line, less invasive surgery equipment and autonomous driving systems, the artist simultaneously invokes the benevolence and perversity of the operations behind such images, whose beauty, if existent, is merely the result of chance.



2.15: Frames extracted respectively from the video series *Eye, machine I* (2000), *Eye, machine II* (2002) and *Eye, machine III* (2003), by Harun Farocki. © Harun Farocki GbR.

Farocki's work shows how the ubiquitous and pervasive use of technological devices turned previously hierarchical control systems into self-regulating systems as well, as civilians also came to adopt these devices for their private security.

To date, there are plenty of artworks based on machine and computer-vision and the management of the visible that do not establish any kind of interrelationship with the human sense of sight. The relationship between computer vision and art has gone beyond seeing. The representational and symbolic qualities of the images produced play absolutely no role in the functional computer vision aesthetic systems, which serve as instruments for measuring, mapping and acting upon a situation. In other words, the values conveyed by an image change when imaging techniques and purposes change. In most current cases where computer vision has been implemented, what is represented in the captured images (or how they are composed) has been less relevant (if relevant at all) than if the system handling them is properly working. The medium is not necessarily the message.

Studies focused on the use of machine/computer vision in art have identified two main paradigms: (1) artworks based on the reconstitution of a concrete space and the localization of objects, followed by an action that is triggered if a predefined condition is met[123]; and (2) those based on pattern recognition in a vast amount of images and the connection of these images' formal characteristics with a

123 Just to mention a few, as listed by André Mintz: The pioneer *Video Place* (1969), by Myron Kruger; and more recent classics *Text Rain* (1999), Camille Utterback e Romi Achituv, *Tensión Superficial* (1998) de Rafael Lozano Hemmer, *Hand from above* (2009), by Chris O' Shea. Mintz, André. Máquinas que veem : visão computacional e agenciamentos do visível. In: Menotti, Gabriel; Bastos, Marcus; Moran, Patrícia (Orgs.) *Cinema apesar da imagem*. São Paulo: Intermeios, 2016. p. 162.

semantic network.[124] The serious issues of control and surveillance become playful features in exhibition spaces when artists use this technology to create augmented mirroring effects. In this sense, such technology is a double-edged sword. On the one hand, it can enable an audience to experiment and discover new body patterns; on the other, the programmed system of which it is a part can be so closed as to lead to a sort of domestication of bodies.

Media artist and engineer Golan Levin (1976-) states that the challenge facing computer vision is overcoming the informational opacity of images,[125] suggesting that this is only possible through such corporeal and material experiences themselves. In this sense, media artworks play an essential role to address the complexity of the problem. Understanding works like Harun Farocki's *Eye-machine* series also requires an awareness of machine and computer vision techniques. As media theoretician Geoff Cox (1960-) observed in his text *Ways of machine seeing* (2016):

> if algorithms can be understood as seeing, in what sense, and under what conditions? Algorithms are ideological only inasmuch as they are part of larger infrastructures and assemblages.
> But to ask whether machines can see or not is the wrong question to ask, rather we should discuss how machines have changed the nature of seeing and hence our knowledge of the world.[126]

Cox reminds us here that it is still human beings who build the seeing machines, thus it is still human beings, influenced by ideologies and values, who are ethically responsible for making the decisions embedded in the tracking algorithms and the outcomes of the machine's performance. An exemplary case of this is found in the contrasting uses of eye-tracking technology. On the one hand, eye tracking has been used as promising method for marketing. On the other hand, there are initiatives such as the *EyeWriter* (2009) project collaboratively[127] developed for the

124 This technique is often associated with machine learning systems. In the same article on computer vision and the management of the visible, Mintz hightlighs the artwork *I'm Google* (2011-) by Dina Kelberman. (Mintz 2016: 169)

125 Golan, Levin. Computer vision for artists and designers: pedagogic tools and techniques for novice programmers. In: *Journal for Artificial Intelligence and Society*. Vol. 20 n. 4, 2006. pp. 462-482.

126 Cox, Geoff. Machines of Seeing. In: *Unthinking Photography*. Nov, 2016. Available at <https://unthinking.photography/themes/machine-vision/ways-of-machine-seeing> Accessed February 25th 2017.

127 Conceived by Mick Ebeling and developed by artists and engineers from the Free Art & Technology Lab, Graffiti Research Lab and OpenFrameworks teams, including Zachary Lieberman, Evan Roth, James Powderly, Theo Watson and Chris Sugrue. The initiative has been awarded in several contexts. Further information available at <http://eyewriter.org/> Accessed October 2nd 2017.

graffiti activist Tempt1, who was diagnosed with a disease that has left him physically paralyzed, except for his eyes. Based on accessible cameras and open source computer vision software, the created eye-tracking device (Fig. 2.16) enabled the artist to paint using his eyes' movements.

2.16: Tempt1 wearing his eye-tracking device; Source: The EyeWriter Project.

2.1.3 Hybrid visions

Eye-tracking systems inevitably involve the physical coupling of organic and machinic ways of seeing. They are also an instructive example of the implementation of biofeedback loops in hybrid technical ensembles using photosensitive elements.

The *Eyewriter* project is an example of hybrid vision in which an eye-tracking system was implemented to achieve utilitarian ends. Yet the work is equally powerful on a symbolic level. Through the symbiotic relationship established between eye and camera, eye movements are tracked and translated into beams of light that can be controlled by the artist. It explores the eye, not as a controlled, passive or reactive organ, but rather as a creative and emancipatory one. In this sense, the project, like *Zerseher* mentioned earlier in this chapter, seems to reference the ancient 'emission theory' originally proposed by Empedocles.

Machinic structures are getting closer and closer to the human retina in more than just a metaphorical sense. While discussing the impact and effects of former optical mass media on the audience, Kittler observed: *"telepresence can thus be described as an invasion or conquest of the retina through an artificial paradise"*[128]. Due to

128 Kittler 2010: 223.

the strong eye-brain connection, by "conquest of the retina" Kittler meant also the conquest of the human cognitive faculty. More recently, in light of the fact that vision and touch are intimately connected,[129] the conquest of the audience's cognitive faculties has extended to the tactile sense through touch screens and other tangible interfaces. Even the whole body moving through the world is becoming involved through applications based on data from the Global Positioning System (GPS) available in any smartphone. Technology critics and enthusiasts alike have suggested that among the reasons for the failure of Google Glass is that is that it isolates the sense of sight.[130] Recently, Sony patented contact lenses that, if successful, will enable the user to record images by blinking their eyes. Except for use by those with corporeal disabilities, it is not difficult to imagine that it might suffer the same fate as Google Glass.

The complexity of the aforementioned cases and the impossibility of stopping techno-cultural development make it imperative to overcome an apocalyptic view of the relationships between media (and, by extension, machines) and people. People are the creators of media and can invert, subvert and reinvent media devices' purposes, operations and frequently dominating modes of interaction.[131]

Despite the huge advances in machine learning, distinctions between organic and machinic entities remain, and scientific efforts continue to be constantly and intensively applied to dissolve them. The machinic implementation of the knowledge gleaned from research on retinas – ranging from the light-sensitive colloids of films to the most up-to-date pixel-based image sensors – shows, however, that organs and man-made devices with similar purposes (image forming and processing) nevertheless present distinct forms of functioning:

> The nerve signals are in the form of electrical pulses (action potentials), which are the brain's only input and its only output. They depend on alteration in the ion permeability of the cell membrane (Figure 4.4). At rest, the inside of an axon is negative with respect to the surface; but when a disturbance occurs – for example when a retinal receptor is stimulated by light – the centre of the fibre becomes positive, initiating a flow of current which continues down the nerve as a wave. It travels much more slowly than electricity along a wire: in large fibres it travels at about 100 metres per second, and in the smallest fibres at less than one metre per second. The thick high-speed fibres have a special fatty coating – the myelin

129 Gregory 1998: 151-153.

130 More about this discussion at Harrasser, Karin. *Körper 2.0: Über die technische Erweitbarkeit des Menschen*. Bielefeld: transcript, 2013. pp. 78-80.

131 If something is against something this can be reduced to specific groups of people against other groups of people, ranging from work relationships to international warfare.

> sheath – which insulates the fibres from their neighbours and also serves to increase the rate of conduction of the action potentials.[132]

Since, as Gregory demonstrates, the differences are based on the materials through which electric current is transferred, the challenges for creating hybrid entities, and therefore hybrid forms of vision, center around minimizing the differences and finding symbiotic ways and contexts for the materials to cooperate beginning on the atomic scale.

While reflecting on the differences between the nature of machinic and human ways of handling memory, Simondon proposed that the coupling between human and machine can only occur if a common coding ground between both types of memories is found. Like Flusser's theory of the zero-dimensionality of electronic media, Simondon suggests that a synergy between systems can be consolidated through the establishment of a code convertibility in the informational exchange between them.[133] This paradigm both authors present defines the basic condition for the possibility of hybridizations between machinic and organic elements.

In addition to the aforementioned *EyeWriter* project, there are other artists working on devices interfacing organic and machinic vision. The 'eyeborgs' Rob Spence, Miikka Terho and Neil Harbisson, e.g., each deal with different types of visual impairment. Filmmaker Rob Spence[134] replaced his lost eye with a bionic eye composed of a wireless video camera that provides so-called subjective shots on demand. Terho[135], in turn, inherited retinitis pigmentosa, a disease that caused the photoreceptors in the retina to irreversibly to die out. After becoming severely blind at the age of 35, he volunteered to be implanted with an array of 1500-microphotodiodes in the macula, the most photosensitive part of the retina, in order to partially rescue his sense of sight, heavily relying on the plasticity of the remaining nervous system to which they were attached.[136]This sort of retinal implant is only available for cases of diseases that cause the loss of photoreceptors but do not destroy the functionality of retinal neural tissue. The implant consists of series of modules: an image sensor, an image processing and/or amplifying unit, and

132 Gregory 1998: 69.

133 Simondon 1958: 173.

134 Spence produced out of his experience the short film *Deus Ex The Eyeborg Documentary* (2011). (Harrasser 2013: 29) The documentary has been commissioned to promote the video game *Deus Ex: Human Revolution*, whose protagonist is also an eyeborg. More information about Spence experience available at <http://www.eyeborgproject.com/> Accessed July 15th 2018.

135 Finnish Miikka Terho has been a reference for Rob Spence while researching possibilities for developing his bionic eye.

136 Zrenner, Eberhart et al. Subretinal electronic chips allow blind patients to read letters and combine them to words. In: *Proceedings of The Royal Society B.* October 2010. Available at <http://rspb.royalsocietypublishing.org/content/early/2010/11/01/rspb.2010.1747.full> Accessed July 15th 2018.

an array of eletroctrodes, whose function is to artificially stimulate the remaining neural cells in order to bypass the degenerated photoreceptors.[137] This technical ensemble puts in question the very complex interface functionality of sensors, addressing the interdependence between the sensorial apparatus, the external world and the cognitive processes happening inside the brain.

Neil Harbisson[138] was born with achromatopsia, a congenital disease that causes people to see in black and white. Dealing creatively with his partial visual impairment and taking advantage of the artificially constructed common ground between a photosensitive device placed in front of his head and his own perceptual faculties, Harbisson incorporated a device that translates surrounding colours into sounds. According to the artist, the experience brought him a new sense of "hearing colours", a synesthetic experience that will be further discussed in the third chapter dedicated specifically to light-to-sound translations.

Scientists all over the world are currently working on obtaining patents on combinations of human eye and machine vision, whose possibilities have been greatly enhanced by the power of nanotechnology and the development of biomaterials.

In the 1990s, pioneering developers of image processors called artificial retinas[139] anticipated still current problems in the field, pointing out that the main challenges were mostly related to the separation between image sensing (executed by a camera) and image processing (executed by a computer). In contrast to the real-time reactivity of human retina, which simultaneously combine these activities, the performance of previous machinic vision devices was frequently limited due to low camera frame rate or transmission rate. Thus, instead of specific functional devices, such as silicon retinas, vision chips, focal plane processors or any other type of space and time filtering device, people then working in the field sought to merge their functions in a single technical ensemble with multiple features: image sensing, image processing and learning capabilities.

Neuroscientist Jakob Macke, head of the MackeLab at the Research Center Caesar in Bonn, Germany, although admitting that studies in Convolutional Neural Networks (CNNs) revolutionized computer vision and machine learning, believes

137 Hornig, R.; Velikay-Parel, M. Retina Implants. In: Inmann, Andreas; Hodgins, Diana (eds). *Implantable sensor systems for medical applications.* Oxford, Cambridge, Philadelphia New Delhi: Woodhead Publishing, 2013. pp. 469-496.

138 Harbisson is a cyborg activist currently involved in the Transpecies Society, in Barcelona. Although giving lectures on the pop science scene, a technical and scientific look at his proposal reveals many gaps in his sci-fi narrative of being the first eyeborg of the world. Simple practical details of his implant have not been clarified by the artist, neither in writing nor in an interview. His producer rejected a proposed interview in an e-mail.

139 Kyuma, Kazuo et al. Artificial retinas – Fast, versatile, image processors. In: *Nature*, Vol. 372 Nov 10th, 1994. pp. 197-8.

that despite surprising correlations, there are still more differences than similarities between organic and machinic ways of seeing. According to Macke, advances in neuroscience in recent decades were not based on the attempt to imitate the operations of the human cognitive system but rather on using advanced computational skills to process a huge amount of data and find patterns.[140]

Also because of enhancements in computer vision systems made since the 1990s, retinal implants have improved exponentially.[141] However, no prosthetic retina built and successfully implemented thus far has been able to provide image quality analogous to human vision, which entails the joint-collaborative work of no less than 130 million photoreceptors. In this sense, the technical fetish for high-resolution is found in the industry of retinal implants too, suggesting that the core endeavour is the human exigency to artificially attain its own observational ability.

2.17: Simulation of visual perception through a retina implant;
Source: Hornig & Velikay-Parel 2013: 473.

In the 2010s, advances in nanotechnology have contributed to the creation of hybrid bio-organic interfaces for neuronal photo-activation, for instance, as an alternative technology to bionic eyes that have been making progress as a means to compensate for full or partial blindness.[142] According to Ghezzi et al., the main challenge here is to create hybrid structures able to perform *"reliable transduction of*

140 Macke, Jakob. "Making sense of light: Processing visual information in Neural Systems" Lecture held at *Wo/man mind machine* - Interdisciplinary Conference organized by *Die Junge Akademie* & The Israel Young Academy. Berlin-Brandenburg Academy of Sciences and Humanities. June 14th 2016.

141 According to Hornig and Velikay-Parel, *"retina implant consists of an image sensor, a processing and/or ampliflying unit, and a set of electrodes"* and was firstly implemented in 1996. (Hornig and Velikay-Parel 2013: 469)

142 Rojahn, Susan Young. What it's like to see again with an Artificial Retina. In: MIT Technology Review. May 9th 2013. Available at <https://www.technologyreview.com/s/514081/can-artificial-retinas-restore-natural-sight/> Accessed November 10th 2017.

information carried by light into specific patterns of electrical activity in visual information processing networks".[143]

In relation to photosensitive biomaterials, the technically attractive molecular function of rhodopsin-like proteins is useful for developing photoreceptor devices and opto-electronic detectors. Their behavioural properties in relation to photovoltage, photocurrent, colour and refractive index are favourable for optical information storage and processing, the conversion of sunlight into chemical energy and light-driven proton translocation.[144] Naturally these innovations on the molecular level have a direct impact on the implementation in the macro structure of organs and other applications, which heightens the complexity, especially concerning vision. A counter example can also be seen in the successful 3D printing of the synthetic tissue of cardio cells, which when it was subsequently charged electrically caused a small piece of flesh to start beating.[145] Through the same biotechnological flow, bionic eyes and other kinds of prosthetic retinas are slowly becoming available on the market.[146] Nevertheless, in contrast to bio-printed cardiovascular tissue, which simulates the mechanical response of the muscular movements, the case of artificial retina involves a complex integrated cognitive activity, since seeing is not merely an optical phenomenon occurring inside the black box of the eye. According to ophthalmologist and biomedical engineer Mark Salaman Humayun, among the implants that use electrodes to interface with the body, such as a pacemaker or the cochlear, the most troublesome is the retinal prosthetic, which requi-

143 Ghezzi, Diego; Antognazza, Maria Rosa; Dal Maschio, Marco; Lanzarini, Benfenati, Fabio; Lanzani, Guglielmo. A hybrid bioorganic interface for neuronal photoactivation. In: *Nature Communications* 2:166 Macmillan Publishers. Jan 18, 2011.

144 Gualtieri 2001.

145 Dvir, Tal. *Nanodevices for Actuating and Monitoring Engineered Cardiac Tissues*. Lecture held at *Wo/Man Mind Machine* - Interdisciplinary Conference at the Einstensaal/Berlin-Brandenburg Academy of Sciences and Humanities on June 14th 2016. Event co-organized by *Die Junge Akademie* and The Israel Young Academy.

146 The first retinal prosthesis with European approval for clinical and commercial use dates from 2011. Graham-Rowe. A bionic eye comes to market. In: *MIT Technology Review*. Article available at <https://www.technologyreview.com/s/423216/a-bionic-eye-comes-to-market/> Accessed November 10th 2017. One example of artificial retina, depicted at MIT Technology Review: "Argus II, has three main parts: a glasses-mounted video camera; a portable computer; and a chip implanted near the retina. The video camera sends image data to the computer, which is worn on a belt. The processor converts the image data into electrical signals that are beamed to a chip implanted near the retina. The signals are then sent to an array of 60 electrodes that stimulate the retinal cells. These electrodes essentially do the work of the light-sensing cells that have degenerated. So far, the system can't help patients make out different colors, but it can provide them with enough visual sensation to sense the outlines of things nearby." Bourzac, Katherine. Rewriting life. Bionic Eye Implant Approved for U.S. Patents. In: *MIT Technology Review*. February 15th 2013. Available at <https://www.technologyreview.com/s/511356/bionic-eye-implant-approved-for-us-patients/> Accessed November 7th 2017.

res biocompatibility with a much higher number of connections, protection from overheating and adaptability to the eye's movements.[147] Facing these challenges, scientific communities are experimenting with biosynthetic materials as well. Recently, a young doctoral student named Vanessa Restrepo-Schild (1993-) at Oxford University's Department of Chemistry produced a synthetic, double-layered retina, made of hydrogel and biological cell membrane proteins. Mimicking the shape and function of the human retina, the bio-fabricated tissue is able to produce a grey scale image and is ostensibly more compatible with the human corporeal environment in addition to being biodegradable. Analogously to the trajectory of media history and development, the next steps of the research are to implement colour and shape detection and conduct implants in animals and humans.[148] This case clearly exemplifies human efforts to find common ground for the communication between natural and synthetic entities. In this sense, building machines seems to be an intermediate step on the way to understanding how organic elements work, confirming Kittler's position that humans knew nothing about their own senses before media provided the metaphors for modelling them.

Recent cross-disciplinary conferences such as *The eye and the chip* have brought together specialists from all over the world to discuss the improvements and challenges currently being faced at the intersection between nanoelectronics and neurobiology. However, it is still difficult to evaluate how much the promising hybrid-vision entities will impact the cultural aspects of everyday life. Parallel expressions in media art using such advanced hybrid-vision techniques are still unknown or have not been widely enough diffused

The success and efficiency of the many potential technical solutions for retinal prosthetic devices being developed for utilitarian purposes depends to a large degree on the kind of blindness the patient has, which, e.g., may not be caused by problems related to the retina. Despite the promising researches on eye and retinal engineering, it is impossible, as contemporary studies on the intersection between neuroscience and philosophy recognize, either to establish a clear division between cognition and the sense of sight or to isolate any of the senses. This, indeed, was already addressed by Merleau-Ponty as the basis of his phenomenology of perception in the mid-1940's. The eyes, metaphorically described as the "window of/to the soul"[149], continuously exchange information with the brain and the whole

147 Humayun et al. (Eds.) *Artificial sight: Basic Research, Biomedical Engineering and Clinical Advances.* New York: Springer, 2007.

148 Oxford student creates first synthetic retina In: University of Oxford Website. Available at <http://www.ox.ac.uk/news/2017-05-04-oxford-student-creates-first-synthetic-retina> Accessed November 7th 2017.

149 Reference to the Brazilian film *Sobre a janela da alma* (2001), by João Jardim and Walter Carvalho.

body. Indeed, herein lies the core of what 'being' might mean: the reciprocal and simultaneous activities of parts within a whole.

2.2 Photosensitivity beyond human subjectivity

In the arts, posthuman and new materialist perspectives[150] have been being actualized for decades under the label of bioart[151] and other derivative more or less connected to media art, depending on the background of the artists engaged with the issue. Photosensitivity, as a material phenomenon outside the human sensory apparatus, has been continually addressed in art through the use of bacteria, plants, animals, chimeras, cyborgs, and so forth.

2.2.1 Skotopoeisis: Plants as agents

As demonstrated in the case of the anthotypes discussed in the first chapter, the use of plants' photosensitivity in media history can be found much earlier than the recent use of their sensory apparatuses in real time audio-visual installations and performances.[152] Plants' photosensitivity, unlike that of the human eyes, is not based on image forming, but it is an essential characteristic of their existence. Besides their dependency on light for making photosynthesis, plants contain a series of versatile light-based self-organizing mechanisms, which are occasionally metaphorically understood as the 'sense of sight' of plants. Sensors placed at the tip of plant stems, for instance, allow them to notice the direction of light, triggering the growing process towards the light source – a mechanism called phototropism. Another feature of their 'sense of sight', called photoperiodism, takes place in the leaves and manages the flowering process according to the amount of red light or

150 Advocated by Geoff Cox, among others, who states: *"we should not try to oppose machine and human seeing but take them to be more thoroughly entangled—a more 'posthuman' or 'new materialist' position that challenges the onto-epistemological character of seeing—and produces new kinds of knowledge-power that both challenges as well as extends the anthropomorphism of vision and its attachment to dominant forms of rationality".* (Cox 2016)

151 Although adopted by specialists to refer to their field of actuation, the use of the term "bioart" is debatable. It is generally used to refer to artworks made by the hybrid profiles of 'researcher-scientist-artists", who stress the potentialities of diverse biotechnologies (or biological knowledge) for symbolic and aesthetic appropriation. For more details about the complexity of the topic, see the interview with the curator Jens Hauser available at <http://www.digicult.it/news/dialogues-on-bioart-1-a-conversation-with-jens-hauser/> Accessed March 29th 2017.

152 Weil, Florian. *Artistic human-plants interfaces.* Master thesis defended at the Universität für künstlerische und industrielle Gestaltung. Kunstuniversität Linz. 2014.

the length of darkness. Phytochromes[153] in plant leaves filter the red light spectrum and operate like a light activated switch. Depending on the kind of red light, the flowering process may be turned on or off.[154]

A contemporary artwork based on the photosensitive characteristics of plants that considers posthuman issues is the performance *Skotopoiesis*[155] (2015), by Špela Petrič (1980-), which was part of the series *Confronting Vegetal Otherness*. The artist stands in front of a strong beam of light and produces a shadow in a field of germinating cress. After nineteen hours of performance divided into twelve and seven hours over two days, the plants placed in the shaded region become pale yellow. This effect is produced by the action of the phytochromes, whose signalling can activate or deactivate the synthesis of chlorophyll, for example. Simultaneously, the decrease of light stimulus triggers the production of auxin, a plant hormone responsible for stem elongation, which is a survival response by the plant to search for light. While the elongation of the cress occurs, Petrič's spine is shortened by standing for so long, in "*'vegetalized' immobility*", as cleverly observed media art critic Régine Debatty.

Artworks involving biological matter raise complicated ethical issues, usually evaluated by an assigned ethical committee. According to the artist, choosing an uncomfortable position was an attempt to approach an ethical interaction with the plants, although the extreme dissimilarity between the human and the vegetal world provides no moral basis to assure a fair interaction. The logic adopted was that, since the cress faces difficulties under the imposed shadow, the artist, in turn, would self-imposition the difficulty of standing without moving. With a background in biology, Petrič explains that muscles are there to move, making movement an inherently animal characteristic. Thus, standing for so long is a situation that requires a form of resistance (inversely) similar to that required of the field of cress.

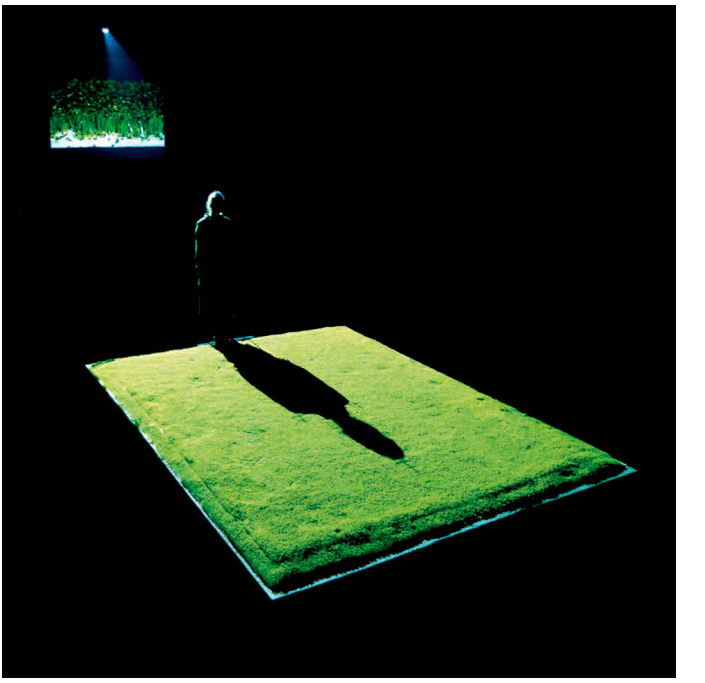
Petrič's performance is a plastic space-time framing of what the artist terms 'plant-human intercognition', *"a process during which the plant and the human exchange physico-chemical signals and hence perturb each other's state."*[156] It draws attention to the materiality of the relations, where physical movement or, rather, the interplay between mobility and immobility is indirectly used as a metaphor for what is alive and

153 Photoreceptors that detect light and regulate a variety of vegetal metabolic processes.

154 Weil 2014: 14-15.

155 The performance title is etymologically formed by the Proto-Indo-European/Greek terms: skótos (σκότος), which correspond to darkness, shadow and poiesis (ποιέω), which refer to making, creating, composing. Etymonline <https://www.etymonline.com/word/*skoto-> and <https://www.etymonline.com/word/poesy> Accessed July 15th 2018.

156 Petrič, Špela. Website of the artist. Available at <http://www.spelapetric.org/> Accessed October 22th 2017.



2.18: Slovenian artist Špela Petrič performing *Confronting vegetal otherness: Skotopoeisis* (2015) at the Click Festival in Helsingor, Denmark, 2017. Photo: Miha Turšič. Courtesy of the artist.

in communication or common-action. However, as the artist herself puts it, the experiment on hybridity cannot be seen only through the lenses of functionality as it comprises "*a conceptual enslavement of particular capacities of plants and humans with the purpose of recognizing the limits of compatibility, empathy and post-anthropocentrism*".[157]

2.2.2 Phototropy: light-sensitive artificial life

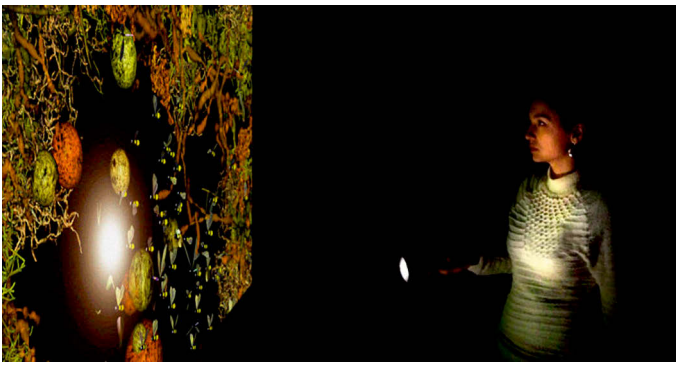
Photosensitive principles ruling organisms' lives have also been addressed in artworks by the pioneers in using plants as interfaces[158] Christa Sommerer (1964-) and Laurent Mignonneau (1967-) in the 1990s, when they frequently explore various biological concepts via three-dimensional computer graphics. In one of their classic interactive installations, *Phototropy* (1995), the artists use the biological process for which the artwork is named to discuss light as a metaphor for life and death. The

157 Ibid.

158 The worldwide known installation *Interactive Plant Growing* dates from 1992.

ability of the artists to create metaphors and an interactive design using biological and computational knowledge is a result of their fruitful collaboration. Sommerer is graduated in biology and botany, whereas Laurent Mignonneau holds a PhD in engineering. They have managed to transform their artistic processes and creations into a material and embodied philosophy.

The interactive computer installation is based on the interaction between audience and virtual insect-like organisms, whose lives were influenced by the flashlight held and moved by the participants. The virtual organisms search for the central focus of light in order to get support and energy. The pre-conditions for interaction are set.



2.19: Participant in the installation *Phototropy* (1994-1995) in Moscow.
© Christa Sommerer & Laurent Mignonneau. Courtesy of the artists.

Although this initial description might lead to the impression of a simple reactive artwork, its complexity becomes clearer when its *modus operandi* is revealed and one sees how the metaphors emerge from the experience.

Virtual cocoon-insects' life-cycles are dependent on the concrete light beam provided by the participant and are controlled by algorithms that establish the role of light as simultaneously live-enabling and dangerous. The photosensitive apparatus of the virtual characters is enacted by an artificial system, namely a camera and computer, running computer vision software. The electronic basis of a camera allows uses far beyond what is encompassed by the metaphor of an eye as image forming entity. The artists had the freedom to create the rules of the system, inventing how the photosensitive feature of the ensemble screen/camera/image would lead to a meaningful experience. According to Sommerer and Mignonneau's own description:

> When reaching a certain quantity of light intensity, the insect-like artificial creatures will be able to reproduce, by exchanging their genetic information. Two crea-

tures will then produce an offspring, that carries the genetic code of the parents. The child insect will follow the light source as well.[159]

Thanks to its familiar quotidian form and function, the flashlight is an effective and intuitive interface that easily invites the audience into the game's dynamics. By adjusting the speed that they move the flashlight, the visitors discover different reactions. The creatures need some time under the light beam to be able to reproduce. On the one hand, if the flashlight is turned off, the virtual organisms die and instantly fade away; when it remains so, the system enters an autonomous mode, developing the self-generated growth of new cocoons, ready to be 'awakened' by the next visitors. Here light gains another layer of meaning: it determines the life cycle, represented by the time that the interaction between visitor and system has lasted.[160]

At this point it is worth recalling Rudolf Arnheim's contention that human perceptual differentiation between organic and inorganic forms occurs relatively late in a person's development. According to him, children and those the author called 'primitives' do not distinguish between dead and living things. The same applies to artists, the arts and spontaneous perception.[161] This spontaneous perceptual quality is rescued by the playful atmosphere of media artworks like *Phototropy.* Using dynamic systems that conceptually center around the animation of originally non-living objects, it explores the principles of life on both conceptual and material levels, as if actualizing the 'breath of life' through the management of energy. It is interesting to note that when the opposite happens – transforming life into things – ethical objections are raised against the outrageous objectification of life.[162]

The interaction dynamics between visitors' flashlights and the installation's system in *Phototropy* make light simultaneously the technical engine and the symbolic

159 Sommerer, Christa; Mignonneau, Laurent. Documentation of the installation on the website of the artists. Phototropy. 1995. Available at <http://www.interface.ufg.ac.at/christa-laurent/WORKS/CONCEPTS/PhotoConcept.html> Accessed November 12th 2017.

160 According to the words of the artists: "*Life is not only seen as a temporary appearance, it is considered to be an involving mechanisms, that links the artificial life of the insects to the real life of the visitors*". (Sommerer and Mignonneau, 1995)

161 For Arnheim scientific and objective criteria to discriminate animate and inanimate, as intelligent and non-intelligent forms are not valid to spontaneous perception. He offers an interesting example of how amazed an occidental being of the 20th century can be by the behavioural similarities between a simple phototropic robot ant and a living being. He concludes that probably the behavior patterns of observed forces is perceived as more complex when it involves a reciprocal exchange between object and its environment. (Arnheim 1980: 391-393)

162 A rich example is the critique by Chun on the ur-text of modern genetics, which suggests reading Erwin Schrödinger's "*What's life?*" (1944) as "*What's software?*". (Chun 2011: 103)

vehicle of life, growth, reproduction, evolution and movement. The artists managed to coincide the abstraction of meanings with the concreteness of the physical world. When insects reach the epicentre of the light beam and stay there for too long (possible if the visitor does not move it), the light becomes dangerous, burning the virtual insects to death. The analogy of danger is not entirely accurate, however, since the participant clearly distinguishes the virtual otherness of the artificial creatures and their ability to be reanimated at anytime by turning the flashlight on. Nevertheless, in the fictional pact between audience and artwork, "*the visitor has to be careful with his/her lamp.*"[163] While interacting, the visitor learns quickly how the system works and becomes more aware of her responsibility for keeping the interaction with the artificial system alive.

Phototropy's system is programmed so that participants are constantly required to search for an equilibrium or an optimized way of interacting. One needs to adapt by means of improvising with the artificial creatures to keep the interaction going. In this sense, the artwork is also an expressive sample from the 1990s wave of Artificial Intelligence (AI) and generative algorithm applications that incited discussions of hybridity through the concept of artificial life. In *Phototropy,* AI algorithms are the means through which visitors can inhabit an artificial biosphere. Since the meanings evolve from experience, the concept of 'emergence', borrowed from the field of biology and the theory of complexity[164], became a key component of the interpretive lexicon for media artworks based on AI techniques.

Through the careful articulation of concepts, materials and techniques, the artists managed to create an artwork whose hybridity is essentially enabled by the role of photosensitivity in bridging the communication processes between human and non-human actors.[165]

2.2.3 Pulsu(m) Plantae: hacking photosensitivity

Living organisms are often referred to as the most complex "machines" we know, with complex adaptive, regenerative and reproductive properties that are still physically unrealizable in man-made machines. On the software level, however, this becomes more easily feasible, as exemplified by *Phototropy*.

Attempts to implement machinic features with living entities triggered the creation of wetware, a term currently used in computer science, biology and the

163 Sommerer and Mignonneau 1995.

164 Érdi, Péter. *Complexity explained.* Berlin/Heidelberg, Springer: 2008.

165 These terms are direct references to Bruno Latour's Actor-Netwerk Theory (ANT), its material-semiotic method and the so-called symmetry principle. Latour, Bruno. *On actor-network theory. A few clarifications plus more than a few complications.* In: *Soziale Welt*, Vol. 47, 1996, pp. 369-381.

arts to refer to devices that blur the borders between organic and machinic elements. In computer science, wetware refers to organic computers built from living neurons, also known as artificial organic brains or neurocomputers. In biology, it refers to the protocols and molecular devices used in the fields of molecular and synthetic biology. In the arts, an elucidative recent example of this technique is the cybernetic neural synthesizer *CellF* (2017), a wetware-based autonomous instrument made of networked biological matter that evolves, created by artist Guy Ben-Ary (1967-).[166]

The popularization of synthetic biology and organic machines fostered the emergence of biotinkering and biohacking communities, in which artists are often members. Given the increasing accessibility of techniques for manipulating biological matter, one now encounters exhibits featuring artworks based on fungi, algae and bacteria more and more frequently.[167] The metabolic activities of living beings are being abstracted into measurements of variations in electric resistance by means of electronic and digital instruments. Although the potential of light sensitive organisms to be used in the context of wetware has been considerably enhanced, the most established examples of the artistic use of photosensitivity are based on hacking organisms' photosensitivity rather than creating new photosensitive wetware and letting the organisms evolve on their own.

Pulsu(m) Plantae (2010)[168], by Leslie Garcia, is a project that emerged within the biohacking context. Its purpose was to empirically analyse the various sensitive mechanisms of plants and discern how their metabolic processes constitute means of communication even though they are imperceptible to the human senses. Technically, *Pulsu(m) Plantae* consisted of different electronic set-ups based on the transduction of plants' metabolic activities into sounds, which Garcia termed sound prostheses.

In scientific research, the effect that light has on plants is usually understood as either a signal or an energy source. This, too, is probably a model of understanding based on the functions of man-made devices: photovoltaic cells simply absorb energy, while CCDs generate data. However, in the wetware context, this traditional

166 More information about the project at <http://cdm.link/2017/05/cybernetic-synth-contains-brain-grown-inventors-cells/> Accessed May 9th 2017.

167 To mention few contemporary examples I can there are Pierre Huygue's (1962-) *After ALife Ahead*, at *Skulptur Projekte* 2017 in Münster, Germany; and Philippe Parreno's (1964-) untitled exhibition at Martin Gropius Bau, Berlin, between May and August 2018, in the context of the program *Immersion - Exhibition 4*. Both artworks included bio-reactors as actants in their aesthetic proposals. Furthermore, the Art Laboratory Berlin has focused their programs in non-human subjectivities, which ends to be a trendy topic in the Anthropocene.

168 More information about the project is available at <http://lessnullvoid.cc/pulsum/> Accessed September 6th 2017.

distinction used in media theory loses its significance. Whether using the energetic or the signalling properties of light and light-sensitive matter, what propels the increasing hybridization of media artworks is the common denominator of electric current. Exploring this possibility, Garcia built a series of prototypes that were progressively enhanced during the course of several international workshops and art exhibitions.

2.20: One of the set-ups for *Pulsu(m) Plantae* (2010), by Leslie Garcia: Sonifying the photosensitivity of a suculenta. Courtesy of the artist.

Pulsu(m) Plantae is based on both the implementation of biofeedback principles between plant, machine, artist, and (eventually) visitors, and on the concept of chaosmosis, developed by philosopher Félix Guattari (1930 – 1992) in a book with the same name. By questioning traditional subjectivity's foundations, Guattari's ethico-aesthetic paradigm envisions acknowledging other forms of subjectivity, which involves the redefinition of machines and their influence on subjectivity's composition. His paradigm also includes the hybridization of "*semiologies that produce significations, the common currency of social groups*" with "*a-signifying semiotics, which regardless of the quantities of significations they can convey, handle figures of expression that might be qualified as 'non-human'*.[169]

In this sense, hybridizations present in artworks like *Pulsu(m) Plantae* evince the materiality of communication[170] and demonstrate that every materiality is dis-

169 Guattari, Félix. *Chaosmosis: an ethico-aesthetic paradigm.* Translated by Paul Bain and Julian Pefanis. Bloomington and Indianapolis: Indiana University Press: 1995. p. 36.

170 Gumbrecht 2004: 8.

cursive.[171] Furthermore, as media artist and theoretician Guto Nóbrega precisely formulates:

> More than interactive response to human behaviour these organisms ask for dialogues, requiring a sort of investigation into their own nature in order to unfold the network of meaning to which they belong. If nature is a concept, never achieved objectively, but only subjectively, and if art is one of the most powerful tools to modulate subjectivity, ultimately our consciousness, the hybrid of plants and artificial systems may bring new insights about the world we live in and its ongoing metamorphosis.[172]

Together with Guatarri and Nóbrega's theoretical reflections, Garcia's practice provides the ground for a genuine discussion[173] of otherness and non-human subjectivities.

While Guattari criticizes the attempt of structuralism to put everything related to the psyche under the control of linguistic signifiers as a mistake[174], it also probable that artworks consisting of such hermetic concepts and technologies might not communicate anything to people who do not share a similar vocabulary and skillset. The nature of these media artworks poses artists with a challenging task: How can one communicate the extraordinary experience of discovery they had in the creative process that at the same time enables an intelligible and welcoming means for external observers to join the aesthetic system? How can one keep the system open to further conversation[175] and create the conditions for meaning to emerge through experience for every single participant? Concepts, like materials, can be understood and handled as abstract machines that demand to be articulated to enable a richer process of exchange in any aesthetic system.

2.3 Hybrid matters

As shown throughout the chapter, photosensitivity has been explored in media artwork thorough a variety of forms and approaches using organic and machinic elements. An overview of structural and operational similarities and differences bet-

171 Barad, Karen. *Agentieller Realismus: Über die Bedeutung materiell-diskursiver Praktiken*. Berlin: Suhrkamp, 2012.

172 Nóbrega, Guto. *Equilibrium*. Website of the artist, available at <http://www.gutonobrega.co.uk/Equilibrium> Accessed August 9th 2017.

173 Especially due to the care Garcia has demonstrated by offering an ongoing series of workshops and providing rich documentation on her personal website.

174 Guattari 1995: 5.

175 Eco, Umberto. *Obra aberta: Forma e indeterminação nas poéticas contemporâneas.* São Paulo: Editora Perspectiva, 1991.

ween the photosensitive parts of a human eye and a digital camera enables one to observe how organic and machinic entities are mutually influenced by one another and amenable to hybridization processes. The following sections, in addition to briefly contextualizing the conceptual and historical framework of such processes, discusses the implications of hybridization for the way in which (media) art is conceived and realized.

2.3.1 A brief conceptual-historical contextualization

The hybridization of biological and man-made sensorial apparatuses is hardly new. Although multiple perspectives on the interdependence between nature and culture have been established for quite some time, what such perspectives demonstrate is that this relationship has not always been symbiotic. At the beginning of the industrialization period, for instance, natural and machinic entities were often seen as oppositionally and violently connected.[176] The legacy of this industrial heritage remains, and its deconstruction has been an arduous challenge. Systems theory, bionics, cybernetics and new materialism are just a few of the countless theoretical frameworks that have contributed to the dissolution of the nature-culture dichotomy.

Biologist Ludwig von Bertalanffy (1901-1972), founder of the general system theory during the early twentieth century, was one of the early proponents of an organismic and integrative approach.[177] Bertalanffy was a strong critic of the mechanistic view of man (and its origins in Newtonian physics) inherent to industrial society, holding it responsible for the focus on a hierarchical notion of mankind exercising control over matter. Organicism, as the historian of science Debora Hammond (1951-) has written, was essentially rooted in the search for analogies between living and non-living systems.[178]

While it is true that "*the complex biophysical and biochemical processes underpinning sensors and sensing in living organisms are governed by the same fundamental physical-chemical principles and laws that describe artificial sensors*"[179], it is also true, as shown by organismic models rejecting the atomist and reductionist approaches frequently used in physics and chemistry, that "*the distinction between the organic and the inorganic is not a question of substance but of organization.*"[180] The organismic perspective attempts to clarify why, despite continuous efforts to merge biological and human-

176 Fohler 2003: 124-5.

177 Hammond, Debora. *The Science of Synthesis: Exploring the social implications of General Systems Theory.* Boulde, Colorado: University Press of Colorado, 2003. p. 32.

178 Ibid.

179 Barth, Friedrich G; Humphrey, Joseph A.C.; Secomb, Timothy W. (eds.) *Sensors and sensing in biology and engineering*. Wien/New York: Springer, 2003. p. V.

180 Hammond 2003: 32.

made entities, one today still encounters approaches based on the culturally constructed organic-machinic dichotomy.

One place where the opposition between what has 'naturally evolved' and human artefacts is still frequently found is in partial appropriations of the Darwinian notion of evolution. Contemporary statements such as "*even the living world makes use of certain 'technologies'*"[181] or "*a stunning wealth in the inventions made by millions of years of evolutionary history*"[182] suggest that nature has planned, projected and implemented "solutions". However, the reason that it is difficult to talk about "design" in nature is that, as evolutionary principles demonstrate, movements towards changes in living beings are not based on practical efficiency, but on stability and survival. If efficiency were to be defined through cybernetic principles, namely as better adaptation to circumstantial conditions, the comparison could work. In practice, however, engineering and management circles comprehend it essentially in terms of profit.

There are still other reasons why technical definitions of sensors likewise reflect the distinction between nature and culture. In the *Handbook of Modern Sensors* (2004), the inventor Jacob Fraden distinguished natural from man-made sensors. On the one hand, "*the natural sensors, like those found in living organisms, usually respond with signals, having an electro-chemical character; that is, their physical nature is based on ion transport, like in the nerve fibers*"[183]. On the other hand, "*in man-made devices, information is also transmitted and processed in electrical form – however, through the transport of electrons*"[184]. Aware of this basic difference, scientists pioneering the dissolution of the borders between biological and machinic entities, have taken on the challenge of minimizing it, or at least, learning from it empirically. That was the central move, for instance, behind the emergence of fields such as bionics, which was established at the end of the 1950's and defined as "*a general catchword that covered attempts to analyse biological processes, to formalize them and to implement them on computers*"[185].

The research conducted at the Biological Computer Laboratory (BCL), founded and headed by cyberneticist Heinz von Foerster (1911-2002), also unfolded in the same context. Among the collaborators were Humberto Maturana, Warren McCullough (1898-1969), Ranulph Glanville (1946-2014), Paul Pangaro, and Stuart Umpleby (1944-). They and other collaborators were mainly concerned with topics like the

181 Meixner 2003: 27.

182 Barth et al 2003: 11.

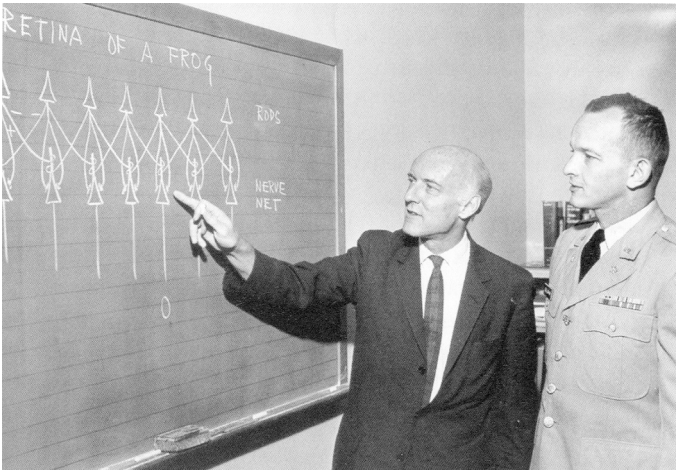
183 Fraden, Jacob. *Handbook of Modern Sensors: Physics, Designs and Applications.* New York, Berlin, Heidelberg: Springer-Verlag, 2004, p. 01.

184 Fraden 2004: 01-02.

185 Müller, Albert. A brief history of the BCL. Heinz von Foerster and the Biological Computer Laboratory. In: Müller, Albert.; Müller, Karl H. *An unfinished revolution? Heinz von Foerster and the Biological Computer Laboratory | BCL 1958-1976.* Vol.3 of the Series: Complexity | Design | Society. Wien: Echoraum, 2007. p. 286.

synthesis and operationality of neurons, the simulation of genetic pre-organization, and the adaptability of the machines to the surroundings. One can consider the aforementioned BCL experiment *Numarete* as an indirect result of the acknowledgement of the closeness between human vision and cognitive faculties; using a common available photosensitive element of the epoch to simulate mathematically the counting phenomenon in machinical terms.

The theoretical framework discussed at that time at the BCL is still relevant today, albeit in a radically different technological context. Moreover, as far as can be gathered from the published documentation, the results of the experiments there did not have a greater impact than that of other laboratories or artists in the same period, or even earlier. The novelty and power was more substantially related to the cross-disciplinary methodology[186] implemented by von Foerster and his collaborators.



2.21: Heinz von Foerster explains the McCullogh-Pitt neuron model using the example of a frog's retina at BCL. Courtesy of the Heinz von Foerster Archive, Institute of Contemporary History, University of Vienna.

Hybrid entities are now much easier to implement, and represent an alternative to the organic-machinic dichotomy, being essentially enabled either by biofeedback principles and/or through the computational assisted synthesis of bio-

186 Foerster, Heinz von. *Cybernetics of Cybernetics: The control of the control and the communication of the communication.* Minneapolis: Minnesota, Future Systems, Inc. 1995. For a more specific perspective on the topic see also: Müller, Karl, H. A period of High-Trans-disciplinarity, 1948-1958. (Müller and Müller 2007: 225-251)

materials, biosensors[187] and biomachines. Subsequent fields of investigation, such as bionics, bioinformatics and bioengineering, are also dedicated to the development of biosensors and other man-made biological machines. According to sensor engineer Hans Meixner, the creation of biosensors is based on the exploration of "*the capability of biological materials (...) to find certain substances, so-called analytes*[188], *among a multitude of other materials, in accordance with the lock-and-key principle of molecular biology and to react with them*"[189]. While chemically reacting, biological material and analytes are conducive to changes in physical parameters, such as the electric potential, mass, fluorescence or temperature. Here Flusser's theory of the zero-dimensionality of electronic and digital media meets the MIT Media Lab founder Nicholas Negroponte's (1943-) statement that "*bio is the new digital*"[190]: the physical changes from the chemical reaction are converted into measurable signals, to be amplified[191] and made available for use in another desired (or needed?) context.

In the context of visual media history, at least since the advent of photography and the manipulation of silver salts in combination with other organic components, light-sensitive materials have been dealt with fundamentally on the nanoscale. However, the currently available instruments and promising science fiction-like properties of wetware are driving research sponsors to massively invest in cross-disciplinary research in order to identify the molecular components of living systems and to understand the process of their synthesis.[192] In a sort of return to the atomist epistemological credo that "*each molecule or macromolecule is or can be functionalized in order to perform a specific performance*" and in which "*enzymes and proteins are redefined as biological machines*"[193], nanotechnology, according to the historian of chemistry Bernadette Bensaude-Vincent (1949-), has received special attention in the last two decades. In fact, one can approach the development of nano-machines as a sort of scale translation, since nanotechnology scientists are mainly occupied in transferring the operations of machines and devices developed in the twentieth century to the molecular scale. Nanotechnology has triggered epistemic

187 "From combining certain biological building blocks used by organisms to perceiving signals with components of mensuration and analysis engineering, a number of interesting applications are arising. Biosensors can be regarded as a bridge between biology and engineering (especially electrical engineering and electronics)". (Meixner, Hans, 2003: 27)

188 Analyte (or analito) is technical word that refers to a chemical substance that is the subject of chemical analysis.

189 Meixner 2003: 27.

190 Lecture "Why Bio is the New Digital" by Joichi Ito from the MIT Media Lab. Available at <https://www.youtube.com/watch?v=pnHD8gvccpI> Accessed October 13th 2017.

191 Meixner 2003: 27.

192 Bensaude-Vincent, Bernadette. *Materials as machines.* Unpublished manuscript of the lecture held at the opening conference of the research group Science in the Context of Application" in October 2016. p. 7.

193 Ibid.

changes and reintroduced the extensive use of the machine metaphor, which had been temporarily abandoned in favor of metaphors from information theory and technology. Interestingly, the historian of science Lily E. Kay (1947-2000) has described how the opposite happened within the field of molecular biology in the 1950s[194], when the rhetoric of 'biological specificity', highly influenced by mechanical lock-and-key analogies, was largely abandoned in favour of an information-thinking paradigm. Now, it seems that contemporary hybridization processes are being based on the mergence of both.

For Bensaude-Vincent, the convergence of AI (Artificial Intelligence) and MSE (Material Science Engineering) has been a new Renaissance along the lines envisioned by computer scientist Hiroshi Ishii in his "radical atomsäpproach. The use of nanotechnological tools has also been taken up in the arts under the name of Nano Art, whose manifestations are still grounded in a pictorial understanding of the arts, or on the previously known physical scale, even revisiting Guttenberg's era, as demonstrated by the case of the smallest book ever printed: *Teeny Ted from Turnip Town* (2007)[195], by the artist Robert Chaplin (1968-). The potential to program zero-dimensional matter towards self-regulating operations is still more dream than reality. More artworks dealing with the manipulation of materials to achieve hybridity can be found under the umbrella of bio art, which frequently involves forms of reprogramming biological matter through genetic modifications. To this date, the author is unaware of any expressive symbolic and aesthetic use of photosensitive nano hybrid machines, able to coincide material, technical and semantic layers.

In addition to providing a very small overview of the variety of approaches to the hybridization of organisms and machines, recounting the history and aesthetic appropriations of photosensitive elements has elucidated how the emphasis in organic-machinic relationships on differences or similarities, respectively, are influenced by cultural factors that have changed over time.

2.3.2 Hybrid artworks: What is at stake?

Observing the technical and aesthetic appropriations of photosensitive elements calls attention to the intrinsic correlations between discoveries about the human sense of sight and the way optical media, specifically digital cameras, operate. Reducing vision to photosensitivity and its electrical properties leads to three con-

194 Chun 2011:104 apud Kay 2000: xv.

195 The book has been produced in partnership with the Nano Imaging Facility of Simon Fraser University and measures 0.07 x 0.1mm using a focused-gallium-ion beam and electron microscopes; the book consists of 20 microtablets carved on a polished single piece of crystalline silicon. More information at Nanowerk, an electronic magazine for Nanotechnology: Nanotechnology lab produces world's smallest book. Available at <https://www.nanowerk.com/news/newsid=1773.php> Accessed July 15th 2018.

current benefits: (1) it improves our knowledge of a material-based phenomenon and acknowledges its specificities in their respective contexts; (2) it permits the transposition of the photosensitive qualities of the retina (or of an image sensor or other organic element) to other objects and contexts; and (3) it enhances the possibilities of coupling these new objects with other objects with distinct characteristics. These coexisting tendencies have already been analysed by the sociologist and philosopher Bruno Latour (1947-) in his work on the proliferation of hybrids and the confusions in the cultural movement of modernity, which he considers to be based on practices of purification and translation.[196] In Latour's own words:

> the word 'modern' designates two sets of entirely different practices which must remain distinct if they are to remain effective, but have recently begun to be confused. The first set of practices, by 'translation', creates mixtures between entirely new types of beings, hybrids of nature and culture. The second, by 'purification', creates two entirely distinct ontological zones: that of human beings on the one hand; that of nonhumans on the other.[197]

Latour's observation explains the foundation of dichotomous thinking while reconciling its role with existing initiatives to overcome it. The coexistence of purifications (process n.1 above) and translations (processes n. 2 and 3 above) on the material level of media artwork is, therefore, a concretization of Latour's philosophical statement.

As observed in the examples discussed above, media artworks are at liberty to go beyond an anthropocentric perspective and overcome the pre-established opposition between mechanistic and vitalist paradigms,[198] and they demonstrate how hybridization can occur on different levels and to various degrees of intensity. Considering the example of hybrid vision, the prosthetic sight developed in *EyeWriter* resulted from a deepening understanding of eye-brain collaboration through computer vision technology. The new understanding and its material implementation led to the transposition of the ability lost in the artist's hands to his still functioning eyes, and it was achieved by means of a complex physical translation from eye movements into light beam variations.

The hybridizations found in *Skotopoiesis* and *Pulsu(m) Plantae* touch on lesser known terrain, aesthetically speculating on the operational modes of vegetal otherness. In the first case, the artist took for granted that plant behaviour is already known and predictable; whereas in the latter, the artist traces paths for investigation, favouring the deepening of knowledge precisely through the physical translati-

196 Latour, Bruno. *We have never been modern*. Cambridge, MA: Harvard University Press: 1993, p. 10-12.

197 Ibid.

198 Hammond 2003: 32.

on processes, from light (and other types of stimulus) to sound. The hybrid quality of both these examples, however, is still less intense than in scientific attempts to synthetize an organic tissue, such as the 3D printing of photosensitive proteins in the aforementioned organic/artificial retina. Hacking plants and bacteria or any other living body, as Leslie Garcia does in *Pulsu(m) Plantae*, is different from fabricating biomaterials with similar photosensitive properties to those of living beings via computer assisted design. In such cases, purification and translation procedures coincide at the very origin of the creative process, amplifying the confusion that Latour has depicted.

That the implementation of prosthetic elements, biotinkering and bio-synthesis in the arts necessitates intertwining organic materials and machines is clear. However, the main ongoing development has been the convergence of sensing (as input) and actuating (as output) in the same body. The clear and well-defined input-output paradigm long followed by information engineers is being broken. In addition, and for the same reason, the cybernetic appraisal for circularity has never been so explored. The level of hybridity in media artworks is directly related to both the intensity and quality of feedback processes between the parts of the system, as well as the degree to which they push the whole towards self-regulatory and self-organizing situations. In this sense, the creative possibilities of hybrids range from 'design from nature' to 'design with nature'; in other words, from bio-mimicry to bio-synthesis. The first comprehends the transposition of biological mechanisms in terms of other materialities; whereas the second already takes the biological materialities as its point of departure and is, therefore, closer to the possibility of generating self-organizing systems.

These practices suggest that the material turn in the arts is now about fictionalizing[199] directly with matter, and no longer only with its mere representational possibilities. Media artworks are made by recombining the material building blocks of physicochemical phenomena that science has made accessible through processes of abstraction and fragmentation. In this sense, one may also understand the coupling of science and art in media art as a way to implement and merge the purification and translation processes of knowledge construction. This is the context in which the imaginative acts of media artists aim to "*increase the number of choices*"[200] with the goal of realizing "*all possible abstract machines*".[201]

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199 Experimenting in the arts has always been directly with matter. The paradigm change implicit with this term refers to the current possibility of using the imagination to create new materials, non-trivial and non-existing combinations. It suggests approaching the idea of invention, creation of new functions and narratives.

200 von Foerster, Heinz. Ethics and second-order cybernetics. In: *SEHR*, Vol. 4, Issue 2: Constructions of the Mind. Updated June 4th 1995. p. 9.

201 A direct reference to William Ross Ashby's (1903-1972) definition of Cybernetics *"as the study of all possible abstract machines"*. (EMCSR 2012)

In addition to the technical knowledge needed to execute an artistic conception, media artists need sensitivity and awareness to deal with the limits and potentialities of communication between all kinds of materials. Every living entity and every material and technological object presents its own ongoing historicity and agency, which partake of the stabilising-destabilising dynamics of the world.[202]

Thinking of media art as a field for creating hybrid machines[203] entails approaching contemporary artworks as relational entities and demands constant changes of perspective from all involved agents. This approach requires ignoring the separation between art and science, since both are integrated within a single interlaced field of knowledge and action; it also requires neglecting excesses of objectivity or subjectivity in order to exercise a more empathic post-human paradigm. On the contrary of what many may think, post-human attitudes do not devalue human beings but rather facilitate and create conditions for resituating humans in a less arrogant, less destructive and more balanced position within the planet's dynamics.

Biological diversity and the diversity of media devices enhance the possibilities of recombination in an even broader variety of contexts, where the task of media artists becomes investigating and designing the exchanges of electric and electrochemical signals through the senses and sensitive materials, directing the flux of signals between both carbon- and silicon-based structures. This extreme freedom of matter manipulation is also why ethical committees are needed at art exhibitions featuring biomaterials. These committees face the challenge of constantly having to revisit what the cyberneticist von Foerster formalized as the principle of undecidable questions: *"Only those questions that are in principle undecidable, we can decide*".[204]

In media art and in the creation of hybrid systems, knowledge emerges both from the empirical experience with the materials and the articulation of scientific, logical, symbolic and other abstract mental models potentially corresponding to a certain reality. Intertwined with sensuous and aesthetic layers, the scientific knowledge involved in media art can neither be too hidden nor too emphasized. The task of media artists is far from familarizing the audience with scientific principles that one could get by consulting reference works. Rather, if there is a general challenge, it is to investigate modes of sensitising the audience to perceive and reflect on the complexity of relationships and modes of existence in the world, especially in ways that other traditional art forms are not able to address. In addition, it is important when dealing with hybrid technical ensembles to constantly nurture a critical approach towards scientific methods, expanding the dialogue with the

202 Barad 2003.

203 In this process, manifold personalised methods can evolve. A methodological starting point can be, for instance, to imagine improbable (or less probable) hybrid combinations through 'what if' questions, either speculating about a better future for humankind and the planet, or reflecting on the past, as is done by media-archaeological artists.

204 von Foerster 1995: 7.

audience. These observations lead to the conclusion that the hybridity of media artworks is a characteristic that radicalizes both the procedural and the contextual aesthetic basis of contemporary art to an even greater degree.

Photosensitive elements have been used here to make the complex relations and conflicts behind organic and machinic entities explicit, as well as to show how contemporary artworks are addressing their own hybridization. We have learned that, rather than assuming a position between conflicting absolute viewpoints, it is more important to observe that the oscillating movement between purifying and translating any sort of materiality in media artworks turns simple matter into symbolic entities, whose meanings are open and moveable, with enough power to trigger reflection and, perhaps, changes in society. While this chapter has mostly looked at media art in relation to purification processes more aligned with objectivist scientific thinking, the following chapter will focus on media devices and artworks based on the translation of materialities, namely between light and sound.

Chapter 3
Light-to-sound translations

"Anything said is said **to** an observer"
Heinz von Foerster. [1]

The previous chapters surveyed a selection of the enormous variety of photosensitive elements and their uses in media history and media art. Here the discussion is expanded to the subject of attaching light sensitive matter to more complex technical ensembles within media devices and artworks, with particular attention devoted to the many ways of converting light into sound.

The lowest common denominator of the organic and man-made elements in contemporary media devices and artworks is electric current. The zero-dimensionality of electronic and digital media and their software[2] permits the manipulation of matter at the atomic level. This, in turn, enables the creation of new materials, the enhancement of existing ones, and boosts the possibilities of combination and recombination among technical ensembles.[3]

Adressing more concretely how Flusser's idea of the 'zero-dimensionality' of electricity and its modulations enable what is here called the translation of materialities, this chapter discusses examples of media devices and artworks based on translations from light to sound. In the previous chapter nano technology was briefly described as a sort of scale translation, with the operations of machines and devices developed in the twentieth century now being transposed to the molecular scale. Considering the rational and abstractive human action upon the concrete material world (objects, environment, other living entities), one can approach nano technology as a further enhancement of human translating possibilities. In this

1 von Foerster, Heinz. At each and every moment, I can decide who I am. In: Poerksen, Bernhard. *The certainty of uncertainty.* Charlottesville, VA USA: Imprint Academic, 2004. p. 12.

2 Flusser 2008: 16-19.

3 Technically, these technical ensembles may be embedded with an immense variety of sensors and actuators. As observed in the previous chapter dedicated to the discussion of hybrid systems, when organic matter comes into play, such as in wetware, the input quality of sensors and output quality of actuators tend to merge, just as they do on our skin: one touches and is touched, simultaneously.

sense, the making of art and the narratives with which it is associated is also a process of translation involving the translation of sensations, ideas, needs, and other abstract issues into specially organised concrete materials – projected, designed, *gestaltet* and so forth.

A more direct concept used by Flusser to support how human translating activity is manifested within media development is his concept of *Mediumsprünge*: the act of jumping from one medium to another, from the logic of one system to another.[4] He expressed and implemented this concept in at least four different contexts within his media theory: changes of media; comparisons between media; media as an instance of translation; and media development.[5] The present focus on different translation processes from light to sound involves a combination of the two latter instances.

In this chapter, selected historical and contemporary media devices and aesthetic experiments are highlighted. The media devices here discussed use inventions based on applications of photocells in the early history of sound-film and telecommunication, such as the *Photophone* (1880), the *Fotoliptófono* (1930) and even assistive technologies like the *Optophone* (1912). The media artworks, in turn, range from Dada to contemporary aesthetic experiments, including a device and performance developed by the author during the research process as a methodological tool – *Self-portrait of an absence* (2016). Besides representing an instance of cybernetic second-order observation[6], the inclusion of my own work in the analysis challenges the opposition between theory and practice traditionally found in the academic context. Comparable examples are additionally incorporated to enrich the discussion. The study cases were selected based on their historical and technical relevance in relation to the development and applications of photosensitive materials and devices, with the aim of establishing an analytical approach that can assist media artists, researchers and critics to reflect upon the process of meaning attribution through the organization and recombination of materials and techniques in their specific contexts.

The analysis of the examples shows that, although Flusser's perspective is a good starting point for this discussion, it does not encompass the intertwoven aspects between the abstractions and the materialities handled in media art production. To avoid priviledging either the abstract or the material aspects of media art to focus on the complexity of the in-between space where media art's cultural relevance lies, the discussion aims to balance Flusser with authors with more technical

4 Guldin 2010: 165.

5 Guldin 2010: 166.

6 Among other differences, Heinz von Forster distinguishes second-order cybernetics from Wiener's first-order cybernetics, essentially by considering the role of the observer in the observing process. (von Foerster 1995: 2-4)

and material analytical viewpoints, such as Gilbert Simondon, Friedrich Kittler, and others.

Through a sort of "trancedental empiricism"[7], media art is here envisioned as an open field for the invention and re-signification of technical ensembles (with machines and organisms) that are potentially able to generate meaningful situations and experiences. The analysis in the following sections unpacks the cultural relevance of media objects by delineating the knowledge embedded within them and inquiring into symbolic aspects embedded in both how they are built and how they operate in their specific *milieux*.

3.1 On the search for correspondences

3.1.1 Bell and Tainter's Photophone: In-between continuous and intermittent signals

"*– Mr. Bell, if you hear what I say, come to the window and wave your hat.*"[8] These were the words uttered by the engineer and inventor Charles Sumner Tainter (1854-1940) to his boss, the scientist and inventor Alexander Graham Bell (1847-1922), while testing a successful version of the photophone – an apparatus for the production, transmission and reproduction of sound by means of light.

A summary of the series of experiments they developed[9] was published in a paper by Bell in Science Journal in 1880, in which the author also acknowledged the importance of previous researches into the photosensitive properties of the chemical element selenium, discovered in 1817 by scientist Jöns Jakob Berzelius (1779-1848). Bell and Tainter were not the only ones experimenting with the new possibilities opened by the discovery of the new material. In the same paper Bell mentioned a considerable number of researchers whose experiments had informed his research process. In 1907, for instance, the scientist Arthur Korn (1891-1978) built a pioneering and ambitious machine to transmit images likewise based on the light-sensitive properties of selenium in association with a telegraph, which is nowadays recognized as a crucial step in the development of telefax. Another precursor of the telefax was developed by inventor Claude Joseph Édouard Belin (1876-1963), who between 1907 and 1921 coupled a photocell with a telephone and, later, radio technology in order to transmit images. Around 1920, Bell too was occupied with

7 Hui, Yuk. Induction, deduction and transduction: On the aesthetics and logic of digital objects. In: *Networking Knowldege.* Vol. 8 Issue 3. Standard Issue June 2015.

8 Bell, Alexander Graham. *The Photophone.* In: *Science* os-1 (12), September 11, 1880. p. 133.

9 Concerning other experiments with selenium in combination with other metals, e.g. brass, the scientists have devised 50 different apparatuses to study the possibilities of controlling sunlight beams (Bell 1880).

the transmission of images and developed a similar invention, the wirephoto system[10].

Bell's observations of a series of experiments led him to hypothesize that there might be a "*class of substances sensitive to light-vibrations*"[11]. Selenium, Bell reported, was additionally responsive to invisible energy radiation[12] (today's ultraviolet and infrared spectra), emphasizing, however, that the "*ordinary beam of light* (that) *contains the rays which are operative*"[13]. Adding to the previously existent knowledge on selenium, Bell noticed that "*when a vibratory beam of light falls upon these substances they emit sounds*", and "*the pitch depends upon the frequency of the vibratory change in the light*"[14]. Tainter's and Bell's research showed that every material contains a sonority that can be revealed by hitting it with a strong beam of light, thereby consolidating the preliminary empirical documentation of the so-called photoacoustic effect – the phenomena through which a strong light source can be converted into sound due to absorption and thermal excitation. Today it is known that when pulses of light are rapidly projected onto a sample of matter, they are often absorbed and irradiated as heat, whose pressure variations generate sound waves.

Following these observations, further experiments were carried out to find ways to directly influence the sound by better controlling the form and character of the light source. The project also embraced Bell's discoveries pertaining to telephone technology and merged the technique for converting light into sound with voice transmission technology. The photophone, as shown in the illustration below, functioned on the basis of a transmitter and a receiver.

The transmitting apparatus consisted of

> a plain mirror of flexible material – such as silvered mica or microscopic glass. Against the back of this mirror the speaker's voice is directed. The light reflected from this mirror is thus thrown into vibration corresponding to those of the diaphragm itself (…) the curve produced that would graphically represent the

10 Cubitt, Sean. *The practice of light: a genealogy of visual technologies from Prints to Pixels.* Cambridge, Massachussetts/London, England: MIT Press 2014. p. 90.

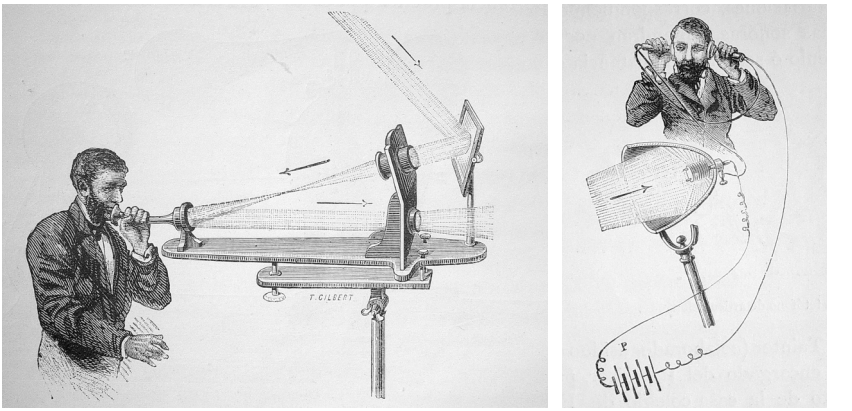
11 Bell wrote: "*We have found this property in gold, silver, platinum, iron, steel, brass, cooper, zinc, lead, antimony, German silver, Jenkin's metal, Babbit's metal, ivory, celluloid, gutta percha, hard rubber, soft vulcanized rubber, paper, parchment, wood, mica and silvered glass; and the only substances from which we have not obtained results are carbon and thin microscopic glass*". (Bell 1880: 130)

12 Mr. May (assistant of Mr. Willoughby Smith) realized that sensitiveness of Selenium was rather upon light, not upon temperature. According to Bell, this fact has been later also verified by Sale, Draper and Moss. Lord Rosse conducted experiments with non-visible radiation. Werner Siemens did further experiments investigating the resistance by analyzing the combination between temperature and light (Bell 1880: 132).

13 Ibid: 133.

14 Ibid: 130.

changes of light would be similar in shape to that representing the movement of the air.[15]



3.1: Photophone transmitter (left) and receiver (right); Source: Guillemin, Amédée 1882.[16]

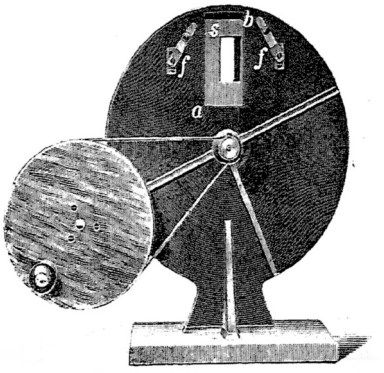
The sound waves of the voices were therefore modulated through the light beam and materially transported to the other side through the air. The modulation of the light source in the photophone was inspired by the application of Morse code[17] in telegraphy and was physically enabled by a disc placed at the bottom of the transmitter, as shown in figure 3.2.

The receiver, in turn, consisted of a parabolic mirror with a light-sensitive selenium cell placed at its focal point, which was connected to a local circuit, which, accompanied by a battery and a telephone, reconverted the modulated light beam

15 Bell 1880: 133.

16 Guillemin, Amédée. *El mundo físico: gravedad, gravitación, luz, calor, electricidad, magnetismo, etc.* Barcelona: Montaner y Simón, 1882.

17 Morse code as it is known today was developed collaboratively in the mid-1830s and standardized in 1865 at the International Telegraph Conference in Paris. Its name refers to Samuel Finley Breese Morse (1791-1872), who first built a working electronmagnetic telegraph using a primitive version of the code in 1833. (Finley, D. Morse Code: Breaking the Barrier. Starkville, MS: MFJ Publishing Company, 1997) Morse code is comprised of a signal set for the transmission of letters, numbers and other characters. It consists basically of three symbols: short signal, long signal and pause. It can be transmitted through different material means, most commonly as sound signals, radio signals, electrical pulses, as well as mechanically or optically (such as through blinking light). Now considered obsolete in scientific, technological and military contexts, it is still used in specific cases ranging from amateur radio to assistive technologies to media artworks.



3.2: Sample of intermittent light disc from the mid-1920's; Source: Fournier D'Albe 1924: 67.

into sound. Enthusiastic about wireless possibilities, Bell envisioned the photophone as a substitute for the telephone, and, indeed, media historians consider the photophone as a precursor of both fiberoptic and wireless technologies.[18]

In Bell's own description of the photophone's working principle, the transmitted speech was produced by means of "*an undulatory beam of light, in contradistinction to a merely intermittent one*"[19]. What is intriguing in this statement is the apparent contradiction to how they previously described the procedure of modulating the light beam using an intermittent light disc. It is possible that Bell was referring to a specific part of the working system. Nevertheless, if one consideres the whole, it seems that the photophone is a media-archaeological artefact that challenges the current opposition between analog (continuos, undulatory) and digital (limited, discrete) signals.

What is essential to notice here is that Bell's and Tainter's experiments led to the conclusion that "*sounds can be produced by the action of a variable light from substances of all kinds, when in the form of thin diaphragms*"[20]. Following this work, the photoacoustic effect was largely ignored for more than a century, until Rosenwaig and Gersho[21] investigated and systematized its theoretical basis. What they found was that the photoacoustic effect is the result of an "*intermittent thermal heating of*

18 The experiments around the photophone happened 19 years before the first known voice radio transmission. Carson, Mary Kay. *Alexander Graham Bell: Giving Voice To The World*. New York: Sterling Publishing, 2007. p. 77.

19 Bell 1880: 132.

20 Ibid: 133.

21 Rosenwaig, A.; Gersho, A. Theory of photoacoustic effect with solids. In: *Journal of applied Physics*. Vol. 47 Issue 1, 1976. pp. 64-69.

a medium that absorbes the energy of intensity modulated light. This causes an intermittent expansion of the absorbing medium. As a result, the medium launches an acoustic wave into its surroundings".[22]

The manner in which Bell and Tainter were able to manipulate this phenomenon is, again, evidence of the efficacy of the fragmentation and discretization of materialities by means of abstract models and rational knowledge. This trend was also observed in scientific investigations related to organic matter, as in the fragmentation and discretization of the human body's sensorial mechanisms and the emergence of physiology as a field of study in the same period.[23] Curiously, in a further development of physiology and attempts to understand the still mysterious and unknown aspects of human nature, contemporary neuroscientific studies, although recognizing brain modules for each of the senses, are also continuously searching for correspondences and associations between the brain's visual and auditory components. According to Gregory, neurology can now even identify regions of the brain for processing different visual dimensions, for instance "*separate 'channels' for the fine detail and broadbrush strokes of a scene. Visual scientists speak of 'spatial frequencies' by analogy with temporal frequencies of sound*".[24] However it is still unknown how the abundance of information comes together to form perception.

This analogy can also be considered the basis for understanding how audiovisual perception works as a key element in human space-time perception, providing an idea of reality as a continuous entity. However, as already discussed in the context of the physiology of vision in the previous chapter, the space-time continuity of the world constructed by human perception and cognitive systems is also based on discretising surrounding stimuli, which are filtered on the molecular level through the physic-chemical activity of sensing cells. Biological strategies found in movement perception through vision, for instance, are similar to those used to distinguish musical tones[25], as musicologist Victor Zuckerkandl[26] and subsequent studies in psychoacoustics[27] on the stroboscopic effect behind movement perception demonstrated. Fournier D'Albe already speculated in the 1920's that the discrete

22 Roozen, N. Bert; Glorieux, Christ; Liu, Liwang; Rychtáriková, Monika; Van der Donck, Tom; Jacobs, Aernoudt. Converting sunlight into audible sound by means of the photoacoustic effect: The Heliophone. In: *Journal of the Acoustical Society of America*. Vol. 140 Issue 3, 2016. p. 1697.

23 Crary 1990.

24 Gregory 1998: 71.

25 Arnheim 2004: 384.

26 Zuckerkland, Victor. *Sound and Symbol – Music and the external world*. New York: Princeton University Press, 1956.

27 Similarly to the visual system, auditory perception is based on significant signal processing in both the inner ear and brain, by means of the conversion from sound waveforms into neural stimuli. The material constraint of the cells' activities entails that certain differences between waveforms may be imperceptible. More introductory information on the topic can be found

quality of human audio-visual perception could resemble the biological adaptation to the minimum portions of energy (quantum/photons).[28]

3.1.2 Hausmann's optophone

In Bell's article on the photophone, he expressed his amazement at the richness of the scientific knowledge groundind the experiment and the variety of disciplines it involved – optics, electromagnetism, spectrophotometry, etc. – and wondered why selenium had not been used in the arts until that moment, instead remaining merely a "*chemical curiosity*".[29] Nevertheless, some decades later, at the beginning of the 1920s, dadaist Raoul Hausmann (1886- 1971) became enchanted with the technical and aesthetic possibilities of selenium cells and envisioned developing and patenting an *Optophone,*[30] or general electrotechnical apparatus intended to combine the vibrations of light and sound in a synaesthetic manner. By migrating from poster-poetry to so-called optophonetics, Hausmann centered his aesthetic statement around the motif of destruction and creation[31], fragmenting the initial language (verbal or visual) and liberating its elements to be configured in new arragements. In his sound-based artworks, speech and words were suspended, with individual letters freed from any meaning standing side by side as raw elements to become a new statement or even a new language. This method was similar to that of his photomontages, which served to communicate non-trivial associations in contrast to pre-established correspondences, in order to query the status quo of certain realities. His idea of building an optophone followed the same logic, by means of executing translations from light into sound.

On the one hand, Hausmann's artworks were in consonance with Dadasophy, as defended by the major dadaist figure Johannes Baader (1875-1955), which asserted that "*the use of nonsense is to develop the sense that is in the world*".[32] This perspective draws attention to the role of human nature in meaning attribution (*Sinngebung*)

in Plack, Christopher J. *The Sense of Hearing*. London/New York: Psychology Press, Lawrence Erlbaum Associates, 2014.

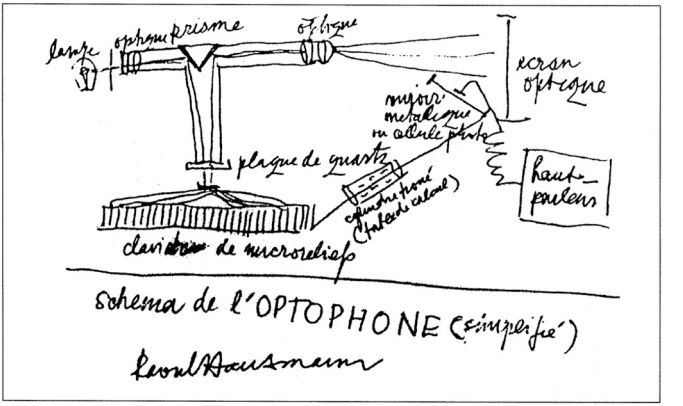
28 Fournier D'Albe 1924: 90.

29 Bell 1880: 132.

30 Donguy, Jacques. Machine Head: Raoul Hausmann and the Optophone. In: *Leonardo – Synesthesia and intersenses.* Vol.34 (3), 2001.p. 217

31 Essentially inspired by the psychoanalytical and philosophical concept of *Selbstzerstörung als Schöpfungsakt* (Self-destruction as creative act), possibly developed by philospher and writer Salomo Friedländer (1871-1946).

32 From the original excerpt in German *"die Benutzung des Unsinns sei, um den Sinn, der in der Welt steckt, zu entwickeln*" Züchner, Eva (Ed.) *Scharfrichter der bürgerlicher Seele: Raoul Hausmann in Berlin 1900-1933*. München/Berlin: Berlinische Galerie/Verlag Gerd Hatje, 1998. pp. 15-16.



3.3: Illustration by Raoul Hausmann with his idea for an optophone. Elements translated by Jacques Donguy: "lamp, lens, prism, sheet of quartz, set of micro-reliefs, slitted cylinder (calculating table), metal mirror or photo cell, speakers, optical screen."; Source: Donguy 2001: 218.

processes, which play out differently relative to the profile of the individual.[33] On the other hand, Hausmann constantly tried to align his artistic production with the scientific discourses of his epoch.[34] He used a similar strategy to substantiate his *optophonetische Weltanschauung* (literally 'optophonetic worldview'). He was convinced that light, electricity and sound vibrate in a basic shared substance called ether, and therefore able to be translated into one another. Less known for his attempts to legitimate his ideas scientifically than for his photomontages and phonetic- and poster poetry,[35] Hausmann's curious multifaceted scientific-artistic legacy encompasses a collection of old-fashioned scientific theories that he articulated to confirm or justify his assumptions. Inspired also by Ernst Marcus's theory on ëccentric

33 Flusser, Vilém. 5….CxB? In: *O Estado de São Paulo.* Published on May 23rd 1964. Available at Vilém Flusser Archive.

34 According to Arndt Niebisch, the ground for Hausmann's physiology, aesthetic, scientific and technological thinking was supported mainly by Hanns Hörbiger's (1860-1931) Welteislehre (literally "world ice theory", also known as glacial cosmogony); Ernst Marcus' (1856-1928) Theorie der exzentrischen Empfindung (theory of the eccentric sensation); Karl Kölsch's Wellentheorie (waves theory); Johannes Zacharias and Arthur Patschke's Ätherdrucklehre (literally "ether pressure theory"); as well as technical media of his time (film, x-ray, radio, etc.). Niebisch, Arndt. Einleitung. In: Hausmann, Raoul. *Dada-Wissenschaft: Wissenschaftliche und technische Schriften*. Hamburg: Philo Fine Arts/Berlinische Galerie, 2013. p. 21.

35 Ibid.

sensations"[36] as a special way to achieve synaesthesia[37], Hausmann's proposals[38] for an optophonetic aesthetics were also related to his belief that the visual arts were already saturated.[39] Moreover, among his aims was harmonising the cosmologic processes, modern media technologies and human life[40] in an attempt to push the boundaries of scientific and technological discourses to a symbolic, aesthetic and existential level. Besides deepening his knowledge of optics and acoustics[41], he worked through the idea that the mergence of the senses and technology was a sort of "spiritual formation of matter" towards a "creative fluid".[42] In his *PRÉ-sentismus Manifest* (1921), Hausmann pleaded for the conquest of all human senses, affirming that "*sensory perceptions are not bound to the limits of the body, but can expand into the outside world, indeed into space*"[43] and that "*every sensation, be it hearing, sight, taste, smell, is added to the sense of touch*"[44]. He invented the "law of universal functionality", reflecting "*that all human organ abilities are unfinished states that carry the germ of self-creative expansion*"[45].

Despite his lack of success at scientifically explaining his aesthetic research, as revealed in his imprecise scientific writings and his attempts to patent inventions, Hausmann's artistic experiments with the concepts, materials and techniques of his time were very fruitful. Still, the objectivism of the scientific community remained sceptical of his ideas and, indeed, rejected his patent applications.[46] Professor of aesthetics Peter Bexte, in a letter addressed to Ralf Burmeister, director of

36 Marcus, Ernst. *Das Problem der exzentrischen Empfindung und seine Lösung*. Verlag der Sturm, 1917.

37 A special Leonardo issue on Synesthesia defines it as "*the phenomenon in which the stimulation of one sense modality gives rise to a sensation in another sense modality, for example some synesthetes see colors when they hear music*". (Donguy 2001: 217)

38 From the original excerpt in German "*Jeder Sinnesempfindung, sei es Hören, Sehen, Schmecken, Riechen, ist der Tastsinn beigegeben*". (Züchner 1998 : 17)

39 Lhot, Patrick. *L'indifférence créatice de Raoul Hausmann – aux source du dadaïsme.* Aix-en-provance : Presses Univ. de Provence, 2013 and Donguy 2001 : 217.

40 Niebsch 2013 : 19.

41 Donguy 2001: 2017.

42 From the original excerpt in German: "*geistigen Formation der Materie*" and "*schöpferischen Fluidum*" respectively. (Züchner 1998: 18, translated by the author, the same for the next excerpts)

43 From the except in German "*die Eroberung aller unserer Sinne*" "*Sinneswahrnehmungen nicht an die Grenzen des Körpers gebunden sind, sondern sich in die Außenwelt, ja bis ins All ausdehnen können*" (Züchner 1998: 17)

44 "*Jeder Sinnesempfindung, sei es Hören, Sehen, Schmecken, Riechen, ist der Tastsinn beigegeben*". (Züchner 1998: 17. Translated by the author)

45 From the original excerpt in German: "*Gesetz der Universalen Funktionalität*" "*…dass alle menschlichen Organfähigkeiten unfertig Zustände seien, die den Keim einer eigenschöpferischen Erweiterung in sich tragen*". (Züchner 1998:18, translated by the author)

46 The Berlin patents office refused his application, stating that his invention was technically feasible but presented no useful application. Hausmann indeed never built a prototype, claiming that he never had the money to afford it. (Donguy 2001: 217)

the *Berlinische Galerie*'s artist archive, states that much of Hausmann's texts on the 'optophonetic worldview' were also "*composed with scissors*", alleging that *"a scientist would be unmasked with such an observation - Hausmann, on the other hand, turns out to be what he is: Dadaist"*[47].

3.1.3 Derivations: the photo-acoustic principle as creative matter

As contemporary media artworks frequently enter into substantial dialogues with media history, it was not difficult to find contemporary artists who are aesthetically appropriating the photo-acoustic principle as seen in Bell's photophone, Hausmann's optophone and similar devices. Produced in radically different contexts and formats, through distinct technical and aesthetic choices, one may also call these expressions, which range from sound installations (with and without participation) to performative artworks, 'optical synthesis'. Some of the countless examples that have been selected for discussion here are: Peter Keene's (1953-) series of optophones (1999-2004); Aernoudt Jacobs' (1968-) *Photophon* (2013) and *Heliophone* (2016); Klaus Filip (1963-) and Arnold Haberl's (noid) (1970-) *Photophon* (2010); Kathrin Stumreich's (1976-) *Stofftonband* (2013); and Arcángel Constantini's (1970-) *Phonotube* (2013).

The artist Peter Keene attempted to reconstruct an *Optophone* consulting the remaining documentation of Hausmann's sketches and writings, completing an initial version in 1999, a second in 2000 and a third in 2004.[48]

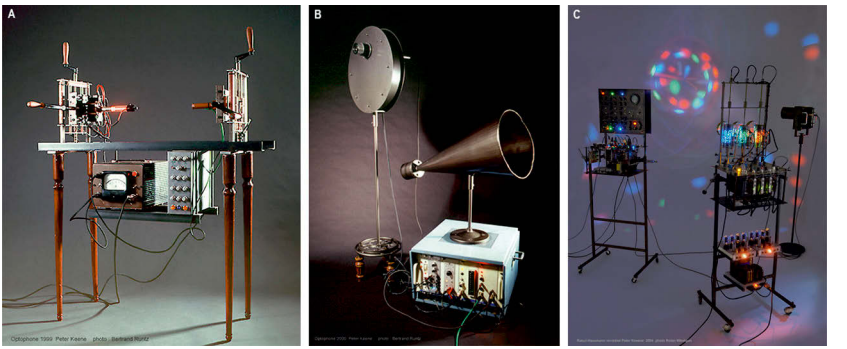
Since the specifications in Hausmann's documents about his idea of an optophone were relatively open and dependent on the materials and techniques of his time, the series developed by Peter Keene constitutes free transpositions, resulting in different actualizations from a common conceptual ground. The main challenge consisted of putting light and sound in correspondence, as well as painting and music, starting with the premise of an existing continuum between the electromagnetic waves of light and the vibrational waves of the air that generate sound.

According to the artist, the *Optophone* built in January 1999 was based on the documents from Raoul Hausmann's patent application for an optical calculating machine, a second version of an optophone that Hausmann submitted in collaboration with engineer Daniel Broid after his patent application for the first idea of an optophone had been refused.[49] Following its logic, Keene's apparatus consisted

47 From the original excerpt in German: *"Ein Wissenschaftler würde mit solcherart Beobachtung zwar entlarvt – Hausmann hingegen entpuppt sich darin eben als das, was er ist: Dadaist"*. (Burmeister 2013:14, translated by the author)

48 Keene, Peter. *Optophones*. 1999, 2000 and 2004. Available at <http://www.peter-keene.com/Optophones.html> Accessed March 23rd, 2017.

49 Donguy 2001.



3.4: Versions of the *Optophones* created by Peter Keene: 1999(A), 2000(B), 2004(C). Mixed media. Photos: Bertrand Runtz (A and B) and Roaln Ménégon (C). Courtesy of the artist.

of a sound matrix activated during the coincidental encounter between a photosensitive sensor and a laser beam on two axes x and y by means of the crank's movements (Fig. 3.4a). For the version exhibited at *Donjon de Vez* in 2000 (fig. 3.4b), in turn, Keene was inspired by John Logie Baird's (1888-1946) mechanical television, associating the previous simple light-to-sound with a more complex technical ensamble based on image-to-sound conversion, a process carried out through a Baird's camera coupled to a Theremin. Keene's machine also could make the inverse correspondence, sound-to-image conversion, by means of a microphone and a television from the same time period.[50]

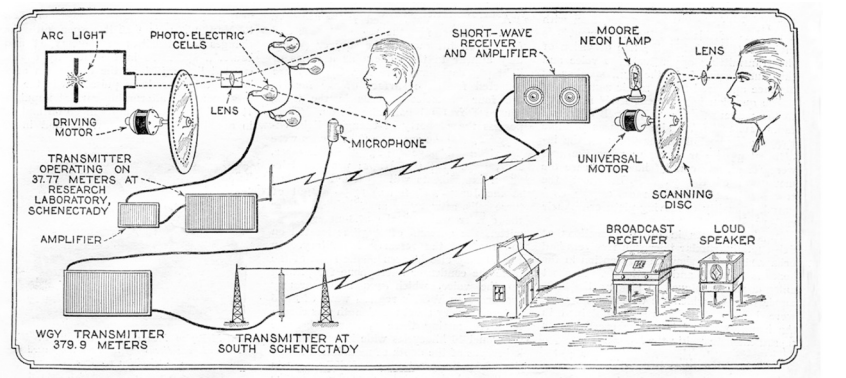
Keene's initiative reveals an interest in technology that bridges the early experiments with selenium cells and its applications in image formation and transmission, a path also suggested by Fournier D'Albe in his book *The Moon Element: an introduction to the wonders of selenium* (1924). The early mechanical television system,[51] on the capture side, was equipped with a mechanical scanning device embedded with a selenium cell and a spinning disk with holes[52] to scan the scene and gene-

50 According to the artist, the second version of his optophone was driven by the idea to use technologies available in the early to mid-1920s, the period in which Raoul Hausmann was elaborating the concept of the optophone. Images formed on a 30-lines television are synthetised from the sounds picked up by the microphone, and the sounds produced by the theremin were controlled by images from a 30-lines camera.

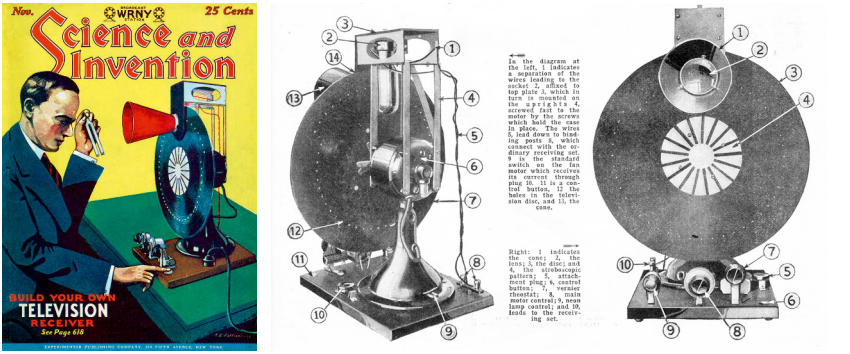
51 In contrast to the television technologies that followed, in which the creation and display of the picture are based on electronic scanning methods, for example the electron beams in cathode ray tube (CRT) televisions or liquid-crystal displays (LCD).

52 The Nipkow disc, invented by the young inventor Paul Julius Gottlieb Nipkow (1860-1940), was fundamental for the development of the early experimental mechanical televisions. Media archaeologist and artist Gebhard Sengmüller has been working on *Big Paul*, an enlar-

rate the image signal; on the receiver side, a similar mechanical device displayed the picture. Figures 3.5 and 3.6 below clairify:



3.5: Early mechanical-scan television system: Image transmission principle using Nipkow's disc and selenium cells; Source: Rowe, C. G. B. 1928.[53]



3.6: US-American magazine presenting a DIY mechanical television receiver in late 1920's; Source: Science and Invention 1928: Cover page and schematics cropped from p. 619.[54]

ged version of Nipkow's disk. More information available at the website of the artist: <http://www.gebseng.com/11_big_paul/> Accessed March 5th 2018.

53 Article titled "Television Comes to the Home" at *Radio News* Magazine, published by Experimenter Publishing, New York, NY, Vol. 9, n. 10, April 1928, p. 1098.

54 Gernsback, Hugo (Ed.) How to build the S&I Television Receiver In: *Science and Invention*, Vol. 16 n. 7, New York, NY. Experimenter Publishing. November 1928. pp. 618-20.

In the version Peter Keene developed in 2004, titled *Raoul Hausmann revisited*, the artist implemented a more complex technical ensemble based on the feedback principle, using a sound source, analog synthesizers, a projection apparatus, photomultiplier sensors, and loudspeakers. According to information available on the artist's own webpage, the initial input sound is transformed by the action of the cylinders into spatialized colored light animation, i.e. a constantly moving image, which is in turn captured and retransmitted to become synthesized sounds. The sequence of feedbacks results in a floating image constantly moved by sound enriched by spontaneously emerging overlays. The colours arising from these overlays themselves generate new frequencies, new sounds. The system is continuosly reinformed with new input sources to create a self-regulating situation.

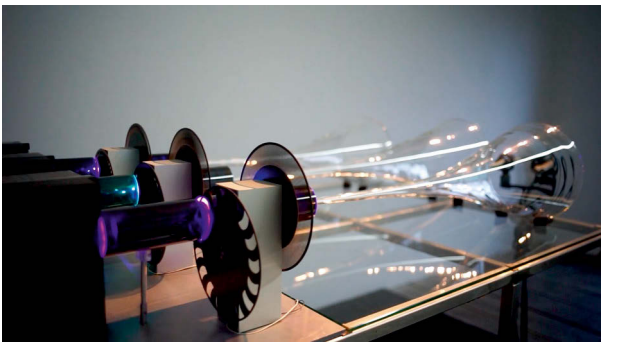
The *Photophon* (2013) by Aernoudt Jacobs, likewise built in a variety of versions, is an installation in direct dialogue with the thermo and photoacoustic principle of Bell's homonimous experimental device. Produced in collaboration with the Laboratory of Acoustics and Thermal Physics from the *Katholieke Universiteit Leuven* in Belgium, the artwork premiered in Maastricht as part of *Resonance*, the European Sound Art Network.

Technically, Jacob's *Photophon* consists of three almost identical photophonic objects, each of them playing a variable tone. Independent strong laser beams generate the sounds simultaneously, each of them coupled with a rotating disc, which chops the light beam into small fragments. The general tonality of the installation constantly shifts over time and provides a changing vibrating micro-tonal structure. The technical ensemble is organised to provide a certain kind of musicality, produced by the form of an installation rather than that of a musical instrument.

Jacobs had direct contact with Bell and Tainter's patent documentation and, contrary to the original device, the artist did not aim to establish remote communication. Jacob's installation reanimates a technical principle of a historical media device in a new version built with contemporary materials and technology, without the pretense of reconstructing an exact copy of the original. In this case, the value of the creative process lies less in the applied technical principle than in the discoveries and knowledge gained during the process of constructing the installation. In an interview with the artist,[55] he pointed out that laser colour intensity was associated with sound amplitude, whereas the amount (frequency) and shape of the perforations on the paper disc influenced the speed and pitch of the sound waves.

Keene's and Jacobs' cases demonstrate how arbitrary and intuitive relationships stand behind every aesthetic choice made concerning the elements used, both in terms of objective and subjective parameters. In fact, the aesthetic handling of technical objects dissolves the objective-subjective polarity normally emphasized in scientific contexts.

55 Conversation with the artist was held via skype on July 9th 2017.



3.7: *Photophon* (2013), by Aernoudt Jacobs. Details of the photoacoustic cell and the intermittent light disc of the installation assembled at the exhibition 'Cause and Nature of Sound' at Le Bon Acceuil in Rennes, France. © Aernoudt Jacobs. Courtesy of the artist.

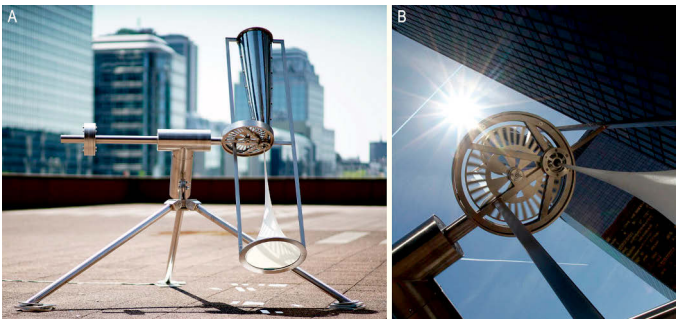
On the one hand, Jacobs' poetics can be better grasped by considering the underlying motivations for his artworks. According to the artist, he was interested in "*achieving a sonic event from pure ephemeral phenomena*" (...) "*I am mesmerized by the idea that sounds around us can be created with light.*"[56]. As a 'sound hunter'[57], he has been producing a series of machines and installations to access new sorts of sonorities, from amplifying ice formation (*SIKUVALLIAJUQ – ice is forming*, 2012 and *Permafrost*, 2015) to experiments with electroactive polymers and other metamaterials, as is the case on *Color of noise* (ongoing research since 2014). On the other hand, Jacobs' experiments with audible non-trivial sounds that emerge from simultaneously simple and complex interactions of matter are inseparable from the strong visual appeal found in his artworks. They are highly conducive to the perception of audiovisual stimulus as a space-time continuum despite the fact that one cannot immediately grasp what exactly is happening on the physical stratum, which may account for why the sculptures and installations attract such attention.

In a further development of his research on light-to-sound translations, Jacobs also created the *Heliophone* (2015), a sort of kinetic sculpture that turns sunlight into sound. The device acts autonomously by following, absorbing, focusing and fragmenting the sunlight. The artist's intention was to create a sound sculpture

56 Jacobs 2013. *Photophon*. Available at <http://www.aernoudtjacobs.info/photophon.html> Accessed February 15th 2018.

57 Exploring different techniques and materials, Jacobs' poetics is strongly based on discovering sound in, and generating sound from, unusual sources, as well as the potentialities for the reception of these sounds in spatialized and visually attractive forms.

for the sun whose tonality changes constantly according to the intensity of light available, which also varies widely according to geographical position.



3.8: A: Setup of the *Heliophone* (2015), by Aernoudt Jacobs, at the roof of WTC Tower I, Brussels, Belgium; B: Detail of sunlight and the optical chopper. © Aernoudt Jacobs. Courtesy of the artist.

By making the atomical changes within the material that constitutes the light-to-sound transducing membrane perceivable, Jacobs' piece involves aesthetic research on the origin of sound and 'environmental sounds'. On his amazement about the physical photoacoustic principle, Jacobs states:

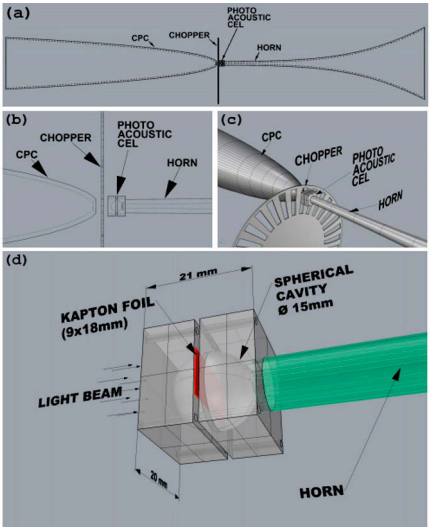
> We know that every material has a resonant frequency but also every material can be 'activated' with light to 'sound' and this sound has a direct correlation to its resonant frequencies. Of course, the shape of materials will also have a big impact, but this remains a side effect. For me this is quite an important revelation because it touches the world of sounds in its very essence. The sun radiates enough energy to produce sounds. You don't need to create a sound with a direct or physical contact. Sound can happen by itself without any direct physical contact. The utmost ephemeral aspects of sounds around us can be revealed with light. Also, the fact that one can build a photo-acoustic cell from basic materials like copper and glass is a fascinating aspect for me. [58]

From a more exacting scientific perspective, the assertion that that sound can be created with "no physical contact" may lead to a misconception of the light-matter interaction.[59] To unveil the very physical "magic" behind the technical apparatuses being used in light-to-sound translations, it is necessary to look more carefully at the mechanisms enabling it.

58 Jacobs 2013.

59 This is a similar misunderstanding to Edmond Couchot's aforementioned statement reducing electronic images to their immaterial nature.

Similarly to his *Photophon*, the technical ensemble responsible for the translation of light into sound consists of a CPC (Compound Parabolic Collimator), a piece through which the light is focused on a photoacoustic cell; a chopper, a sequencially perfurated disc placed in between these two pieces; and a horn, through which amplifies the sound. The material basis of the photoacoustic cell is a patented Kapton®foil (see Fig. 3.10, session d), which is "*coated with copper and blackened with carbon soot from a candle flame*"[60] in order to enhance both light and heat absorption. The rotating disk (chopper) is responsible for the fragmentation and modulation of the light beam before its absorption. The distance between every overture on the disc in combination with its rotational speed forms the intermittent signal, whose audible frequencies are immediately amplified by the parametrically designed horn. The sequence of pictures below shows how the technical elements are organized in the *Heliophone*:



3.9: Detail of photo-acoustic cell used by Aernoudt Jacobs at *Photophone* and *Heliophone;* Source: Roozen et. al 2016: 1697.

Unboxing the technical and aesthetic layers of *Heliophone* reveals the epochal differences between scientific papers addressing similar issues. While in the late 19th century Bell and Tainter needed to test more than fifty different shapes for

60 Tests on how to optimize the relationship between the light intensity and the increase of temperature have also been made in order to find the Kapton Foil's maximum level of efficiency. For more technical details consult Roozen et. al 2016: 1697-8.

their device,[61] the scientists working with Jacobs on the *Heliophone* adopted computer-assisted simulations to develop an optimized and effective design model, which greatly facilitated finding the functional material specifications of both the photoacoustic cell and horn.

Another version of a contemporary art installation departing technically and aesthetically from the photoacoustic principle is the *Photophon* (2010), developed by Klaus Filip and Arnold Haberl (noid). According to Filip[62], the project emerged in an informal conversation with his collaborator and was influenced by an exhibition organised and curated by the Institute of Media Archaeology (IMA) called *Magical Sound Machines*. [63] Reporting that the creative process was intertwined with his experience teaching a media studies course, Filip directly refers to Bell and Tainter's *Photophone*, and the homonious sound installation features "*a direct translation from sound into light and vice versa*"[64]. The artists provided modified headphones able to transform the light signals into sound, and since every light bulb in the room transmits a different frequency to the earphones, the audience can both see what they hear and hear what they see.

3.10: *Photophon* (2010), by Klaus Filip and Noid. © Klaus Filip and Noid. Courtesy of the artists.

Technically, Filip's and noid's artwork is based on a very simple circuit that uses LEDs as the source light and a self-made light-to-sound converter that uses

61 Bell 1880:133.

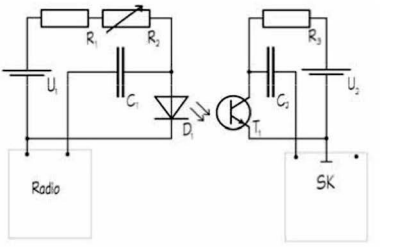
62 Interview with Klaus Filip was conducted by Skype in March 28th 2018.

63 Brief documentation of the exihbition available at <https://ima.or.at/en/sound-machines/> Accessed March 13th 2018.

64 Website of the artist available at <http://filipino.klingt.org/photophon/> Accessed March 13th 2018.

phototransistors. LEDs were chosen due to the ease with which their brightness can be modulated, resulting in the generation of a variety of sound frequencies.

- 2 Batterien (9V): U_1, U_2
- 2 Kondensatoren (2200 F): C_1, C_2
- helle LED (grün, glasklar): D_1
- Fototransistor BPX 25: T_1
- Widerstand (100 Ω): R_1
- Potentiometer (10 kΩ): R_2
- Widerstand (10 kΩ): R_3
- Sinusgenerator (Soundkarte, verstärkt durch Stereoanlage)/ Radio mit Kopfhöreraus-gang



3.11: Radio transmitter circuit that served as the basis for the customization of headphones in the Filip and Noid's Photophon; Source: Klaus Filip's personal archive.[65] Courtesy of the artist.

In addition to its explicit reference to the work of Bell and Tainter, envisioning a synaesthesic experience for the audience by means of artificially merging the senses of hearing and sight brings Filip and Noid's installation conceptually close to Raoul Hausmann's *optophonetische Weltanschauung*. Nonetheless, the artists overcome the merely technical aspects of the device, enticing the audience to participate and to create a very personal soundtrack by moving around the room and potentially playing with the light sources. Beyond the "participatory hells"[66] critized by Claire Bishop (1971-), this set up provides an open listening experience and enables the visitor to take an exploratory approach to easily and intuitively engage with the composition and shape a sonorous narrative that gives sense to their own sensorial experience.

It is curious that in the case of each of these derivative contemporary photophones the artists retained the name given to their forerunner even though they did not aim to rebuild a replica of it. In this sense, the conceptual-material link emphasises the historical and technical aspects of the technical ensemble as a guideline for the artistic research process, without however explicitly commenting on

65 File exchanged during interview with the artist.

66 Bishop, Claire. *Artificial hells: Participatory art and the politics of spectatorship.* London/New York: Verso, 2012.

the nature of the reinvention. This is not the case with the already mentioned *Heliophone*, by Aernoudt Jacobs, or with the *Stofftonband* (2013) by Katrin Stumreich, which will be introduced in the following pages. Are artists who focus more on the material level of their propositions more prone to undervalue the conceptual side of their artworks? Each conceptual-material relationship must be considered within its context.

Aernoudt Jacobs' version of the *Optophone* based on three optophonetic pieces forms a luminous sound sculpture, with a simple minimalist sound composition triggererd by preset machinery, that explores the overlap of changing frequencies. Jacobs' sound poetics is not based on the final artistic product but, rather, on the investigative path the artist chose for finding sounds from non-trivial sources. Nevertheless, when facing non-trivial machines such as Jacobs' *Photopone,* one way that interested audiences frequently query how they work is by investigating if they themselves can somehow influence what is happening. If the machine reacts to any sort of bodily movement around the piece, the next step might be to observe the connections among the given elements, trying to notice any kind of difference and/or repetition in its audio-visual effects. These very first steps can be decisive for grabbing the audience's attention since the human capacity for learning is activated by comparison and pattern recognition operations. It seems that the more one is able to learn with such systems the more attractive and engaging the artwork is, as suggested by Mihaly Csikszentmihalyi's (1934-) remarks on the state of flow.[67] Unlike a musical composition designed simply to be played, the acoustic appreciation of this kind of installation cannot be considered the main aesthetic element of the artwork since the orchestration is concentrated on the articulation of all the constructive elements of the piece.

Both *Photophon* and *Heliophone* are organized technical ensembles that reveal the activity of matter to the human senses. In this sense, such aesthetic experiments recall what Peter Weibel (1944-) called "the world as interface"[68], a term defining a media art creation and its interfaces as a sort of management of the dynamics of the world, by means of addressing endophysics, which, like second-order cybernetics, highlights the role of the observer in the observing act.[69] In this sense, and in a subtler way than real-time reactive installations, the sound machines are

67 Csikszentmihalyi, Mihaly. *Flow: The psychology of optimal experience.* New York: Harper and Row Publisher, 1990. p. 74.

68 Weibel, Peter. The world as interface: Towards the contruction of context-controlled-events-worlds. In: Druckrey, Timothy (Ed.) *Electronic Culture.* New York: Aperture, 1996. pp. 338-343.

69 According to Weibel: "*The description of the world in terms of interface and the acknowledgement of the non-objective, observer-objective nature of objects are corollaries of the endophysical theorem. The world interpreted as observer relative and as interface is the doctrine of electronics interpreted as endophysics. The world changes as our interfaces do. The boundaries of the world are the boundaries of our interface. We do not interact with the world – only with the interface to the world. Electronic*

frames for reality-revealing poetic matter that the human senses in natura cannot perceive. In the case of the autonomous mechanism *Heliophone*, Jacobs framed a piece of physical reality to be perceived beyond the range of the human senses. At the same time as he created another instance of sensing, he set up a situation that stimulates a posthuman perspective. Moreover, the artpiece guides the audience to perceive the given surrounding enviroment as something distinct from the routine nature of everyday life. By creating a sort of poetics of sunlight, this non-trivial machine goes beyond functionality: it expresses the sonorous dimension of an ignored, or less perceived, physical phenomena surrounding humankind by making one aware of the activity of matter, that is constantly at work without our being aware of it.

Filip and Noid's version of the *Photophon* seems to be more structured in terms of the real-time experience it renders. The appearance of the objects used in the assemblage does not play an essential role in comparison to the condition of free spatial mobility that they enable for the audience. Through the earphones and moving light sources that allow the audience to compose their own unpredictable sound experience, Filip and noid's *Photophon* suggests a listening experience similar to that of a labyrinth, to borrow the metaphor used by the composer and music critic Leonardo Androvandi[70] to describe the possible delights of musical appreciation. An uncertain soundscape co-produced by artist and visitor emerges from the programmed set of chances. Like the experience inside a labirynth, the most important aspect of listening fruition is not to solve its riddle but to engage in the game of exertion and wandering.

Arcángel Constantini's work has also been inspired by photoacoustic devices, resulting in the development of a series of experimental instruments that he uses for live audio-visual performances. His *Phonotube,* for instance, was constructed with rotating luminous tubes covered with printed sound sequencers. In constrast to the previous examples, Constantini uses the suffix "-tube" to name his instruments, highlighting the subjective nature of his formal choices and his contribution to the aesthetic and cultural understanding of photoacoustic phenomena. The light tubes are capped with offset negative's containing sound waves/patterns that can spin at variable speeds, according to the artist's wishes. In Constantini's own words:

> The oscillation from the light emitted by these patterns is transduced to sound, processed by light excitation, a variety of electronic circuits as pre-amps with photo-cells and phototransitors, voltage control oscillators, relays, filters, 1bit

art should help us to better understand the nature of electronic culture and the foundations of our electronic world". (Weibel 1996: 343)

70 Aldrovandi, Leonardo. Escuta e labirinto. In: *O sonoro e o imaginável: Ensaios sobre escuta, composição e olhar*. São Bernardo do Campo: Lamparina Luminosa, 2014. pp. 11-34.

attiny85 micro controller. The technological principle is based on the photophone, patented by Graham Bell and inspired by audio-visual experimenters as Norman Mclaren, that used the optical sound technology of film.[71]

3.12: *Phonotube* (2011), by Arcángel Constantini. © Arcángel Constantini. Courtesy of the artist.

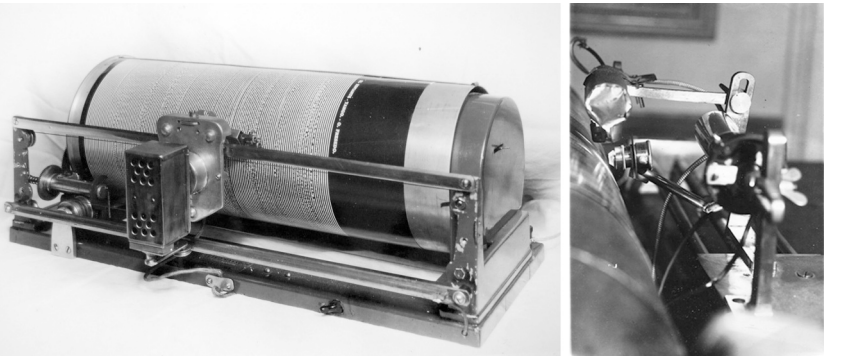
Observing Arcángel Constatini's references more closely, one sees that the artist implemented a remix aesthetic[72] by sampling not only audiovisual contents but also audiovisual machinery. Among his sources was another important and lesser known device called the *Fotoliptófono*, an audio recorder and player invented by Fernando Crudo (1906-1972) in the late 1920s and patented in 1934 in Argentina. Crudo's intention was to create the means for an efficient mass distribution of sound contents using common paper as the medium in which sound waves were printed. Sound reproduction, in turn, required sensors that detected the light level reflected by the printed paper.[73]

According to audio researcher Ianina Canalis, in contrast to the *Phonograph* (1877) invented by Thomas Alva Edison (1847-1931), but analogously to the *Gramopho-*

71 Constantini, Arcangel. *Phonotube.* Available at <http://www.arc-data.net/phonotube/> Accessed September 10th 2017.

72 Navas, Eduardo. *Remix Theory: the aesthetics of sampling*. Wien/New York: Springer, 2012.

73 Canalis, Ianina. El fotoliptófono y sus páginas sonoras. Un reproductor de sonido en la Argentina de los años '30. In : Espinosa, Susana (Ed.) *Escritos sobre Audiovision. Lenguajes, Tecnologías, Producciones.* Remedios de Escalada : EdUNLa, 2010. pp. 151-166.



3.13: Fotoliptófono (left) and detail of the pick-up (right); Source: Canalis 2010.

ne (1887) invented by Emil Belriner (1851-1929), Crudo's *Fotoliptófono* required distinct devices for recording and reproducing audio signals.

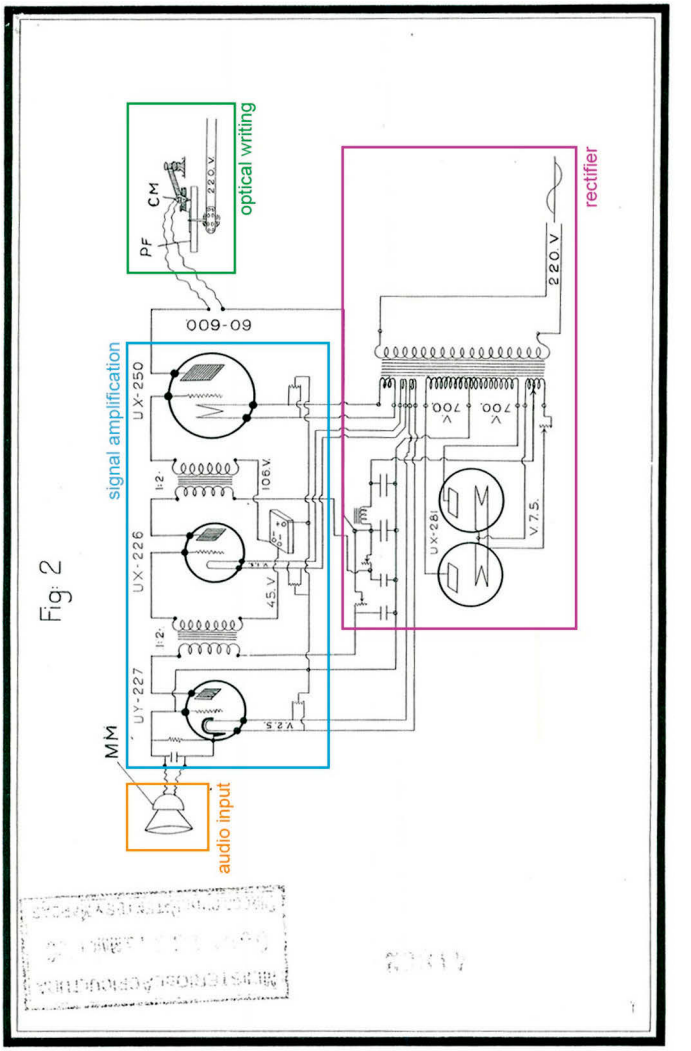
Crudo worked on two different prototypes with distinct techniques for inscribing audio information. One was based on variable grayscale intensity[74], recorded onto a circular disc; the other on the wave inscription through variable width[75], recorded onto a rectangular page. The recording machine needed to be placed in a dark room, since the media in which the signal was written was photosensitive film, similar to that used in still photography and cinema, however, of the format and size required for the posteriorly printed sound pages. Attached to the rotating cylinder was a small lamp that slid along a fixed axis, which emitted the light to mark the film in a helical form.

The audio input was identical in both cases, being captured through a microphone sensitive to variations in the air's pressure and speed, which transduced this mechanical energy into voltage variations. Once the recording process was finished, the 'burned' film was developed, resulting in a sheet full of parallel graphic

74 As reported by Canalis, in order to achieve the grayscale version of the audio information, the microphone signal was amplified to reach a bent glass tube containing rarefied neon gas that, according to the current passing through it, emitted an actinic light proportional to the current that passed through it, which was reflected by a polished metal reflector, which concentrated the light on the target. The emitted light burned the audio information on the light-sensitive film. (Canalis 2010)

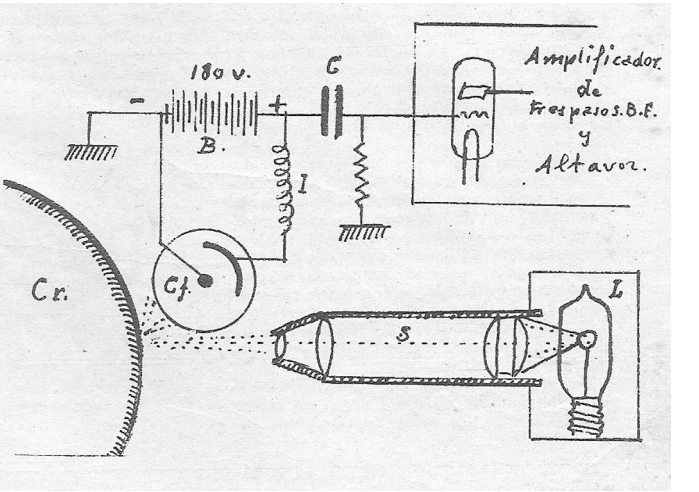
75 In order to record the audio by varying the width of the wave image, Crudo had a fixed beam of light fall on a very thin mirror welded onto a wire involved in a magnetic field and connected to a mechanism immersed in pure paraffin oil, which is capable of oscillating from left to right according to the polarity of the electrical current that reaches its terminals. This current is supplied by the amplifier coupling transformer of the electrical impulses coming from the microphone. (Canalis 2010)

waves: sound pages that could be made of either lithographic or zinc matrices. By observing the device's circuits (Figs. 3.14 and 3.15) it is possible to visualize the various layers of the conversion of the audio input into optical writing on photosensitive film.



3.14: Circuit from the Fotoliptófono for recording circular pages, by Fernando Crudo; Source: Modified from Canalis 2010.

The coloured rectangles drawn over the historic image represent the operating functions of the circuit: the audio input (orange), a microphone in this case; the required sequence of signal amplification (blue) needed to adequately transfer the audio signal to the end point; the mechanical arm with the light source (green); and a part dedicated to voltage rectification that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction.



3.15: Circuit from the Fotoliptófono for reading waves from the rotating cylinder, by Fernando Crudo; Source: Suplemento Blanco y Negro, ABC de Madrid, July 2nd 1933.[76]

The circuit for reading and reproducing the printed sound information, in turn, used reflected light from the paper absorbed by a photosensitive cell, which translated the variation of light into resistance/current/voltage[77] variation that formed a signal variation later amplified and made audible through the vibrations of the loudspeakers' membranes pushing and pulling the air.

A media archaeological approach enables one to realize the rhizomatic character of media genealogy. *Fotoliptófono* represents a summation of the technical principles of photography, phonography and lithography. If one looks back to the

76 Canalis, Ianina; Petrosino, Jorge. ¿Cuánta música cabe en una página de periódico? Sonido impreso en papel a principios del siglo XX. In: *Question*. Vol.1 n.42. Abril-Junio 2014. p. 266. Available at <http://perio.unlp.edu.ar/ojs/index.php/question/article/view/2138> Accessed March 10th 2018.

77 U = r * i (U for Voltage; r for Resistance; i for current).

not-so-distant past, these media archaeological artifacts comprise a combination of techniques that intertwine principles later implemented in Compact Disc (CD) technology – a media already considered obsolete after the popularization of the internet, the compacting .mp3 audio format, and the availability of online storage and streaming solutions under conditions of even faster internet access. In fact, the CD-ROM media, together with the popularization of personal computers, triggered great excitement among artists in the 1990s, many of whom explored the facilitated multimedia aspect of digital technology.[78]

Another example of the implementation of light-to-sound conversion using non-trivial materials in the context of art is *Stofftonband* (2013) by Katrin Stumreich. Her performative sound machine is based on rotative fabric bands, whose different weaving patterns result in different sounds. The fabric tracks play a role similar to that of the rotating chopper, intermittent discs and paper bobbins in the aforementioned projects.

Stumreich provides clear documentation of the piece that explicitly clarifies how she created the correspondences between the fabric design and the sound parameters manipulated during her performance:

> The tone pitch is created by the quality of the fabric, weaving tecnique, basically this is the amount of threads interrupting the light per second. Breaks and rhythm are due to the seam, and the length of each sort of fabric. The arrangement of the fabrics in aspects of length, quality and the connecting seams are additive parameters for composing a rhythm or a flowing change of the tone pitch.[79]

Beyond the photoacoustic principle, Sturmreich's artwork can also be conceptually associated to the first codes written by mathematician and writer Ada Lovelace (1815-1852)[80] at the advent of English textile industry,[81] and thereby be used as a powerful example to make the interweaving of codes and materialities explicit. In fact, one could endlessly enumerate media devices and artworks acting on finding and exploring light-to-sound correspondences.[82] While observing media artworks

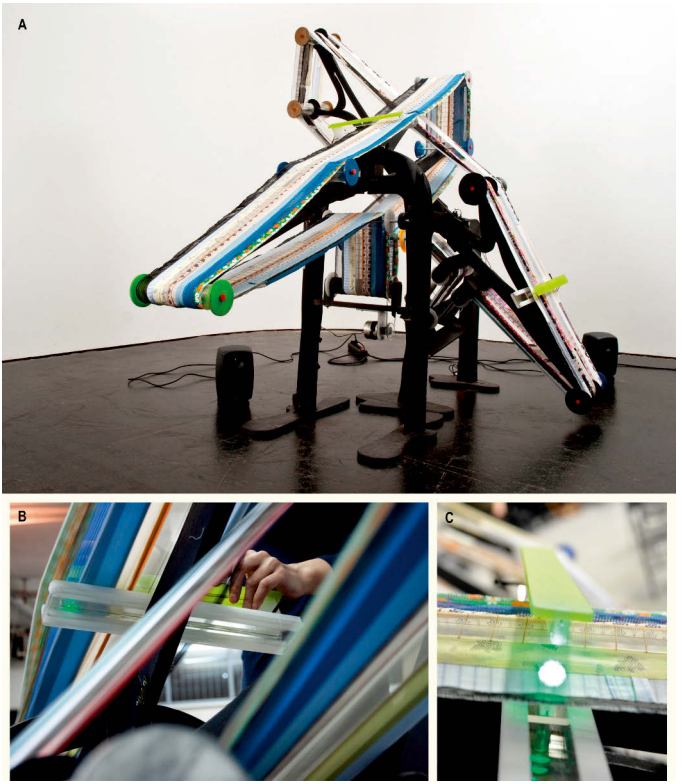
78 The trendy jargon that has always accompained technological media culture adopted the term 'multimedia' in the first half of 1990s, which, in turn, was later replaced by terms like "interactive" due to the advent of the internet and tangible interfaces. Unfruitful choices regarding the characterization and reception of media specificities included prefixes like 'new' or 'post', as seen in "new media" and, more recently, "post-digital" and "post-internet".

79 Artist's website available at <http://www.kathrinstumreich.com/stofftonband/> Accessed February 14th 2018.

80 Fuegi, J.; Francis, A. J. (October–December 2003), "Lovelace & Babbage and the creation of the 1843 'notes'" In: *Annals of the History of Computing*, IEEE, Vol. 25, Issue 4: pp. 16–26.

81 Francis, A.J.; Carr, T.H. Electricity in the wool-textiel industry. In: *Proceedings of the IEEE - Part II: Power Engineering*. Vol. 101, Issue 81, June 1954. pp. 291-307.

82 Just to mention a few examples: the classic *Very Nervous System* (1982-1991), by David Rokeby; more recently the already mentioned Leslie Garcia's *Pulsu(m) Plantae* (2010-2013), Yiannis



3.16: *Stofftonband* (2013), by Kathrin Stumreich. A: Overview of the machine; B and C: Detail of the optical reading system. Photo (C): Ben Keyserling. © Kathrin Stumreich. Courtesy of the artist.

in rhizomatic dialogue with historical devices, one realizes how artists end up using similar techniques, despite working with completely distinct materials, concepts and contexts. The few selected examples demonstrate the diversity of how different aesthetic choices can emerge from the same technical standpoint, and vice versa.

A common element seen in the collection of devices and artworks here presented is that their search for light-to-sound correspondences involves taking advantage of 'techno-magical' conversion in order to spark amazement and the effect of presence. Nevertheless, there is no formula or method certain to be more effective

Kranidiotis' *Pentatono* (2015) and his series of soundscaped based on classic paintings, such as the *Ichographs MdelP* (2015); sound artwork *Vibrant Disturbance III* (2014) by Christian Skødt's and many others.

or successful. Since every artwork emerges from different contexts and has different conditions for coming to fruition, they are in principle incomparable objects. However, the examples have also given precious hints about how aesthetic choices depend on the complex interdependence of several factors, ranging from the artist's subjectivity, background and repertoire, to the material, technical, and other (un)available resources, as well as their possibilities and limitations. The interweaving of technical and aesthetic choices, expressed through the material organization and its subsequent spatial conditions, narratives, metaphors, patterns and/or symbols, is the core issue addressed by the creative processes of media art. The friction and cohesion among these elements are valuable for creating more significant media artworks.

The few aforementioned examples also indicate that when working with photosensitive materials media artists must continually choose one or several of their countless possible operationalites. In this sense, working creatively with light and sound at the atomical level (electrically, electronically, digitally) entrusts media artists with both the freedom and the responsibility of a translator. This role requires being able to articulate different levels of abstraction in order to mobilize, signify and/or resignify matter and materials, be it light, sound, moisture, movement, etc. The abstractive thinking of translational experiments requires the acknowledgment of subjectivity and reveals the limitations of the technological and scientific objectivity necessary for developing media devices. The issue becomes even further intensified when one considers aesthetic experiments. Here, the material-immaterial interplay of light-sound translations addresses another dichotomous dynamic, that between objectivity and subjectivity.

The analysis of the examples gives rise to some difficult questions: Why are artists getting involved with these kinds of translations? Why does one spend time, energy and resources producing such objects and the experiences they render possible? What is at stake? On the one hand, they are based in humankind's urge to express, as can be observed throughout our cultural heritage. On the other hand, in a biological and evolutionary sense, creativity inherently implies the search for novelty and variability, which also emerge from repetition. Both hypotheses refer to an existential level, whose attribution of meaning emerges from and within action itself. The next section examines further examples of the genealogy of photosentive elements and their operationality in light-to-sound translations to explore approaches through which technical features are expanded to symbolic, expressive and existential dimensions.

3.2 Absence as creative matter

A topic that deserves special attention in light-to-sound (and other) conversions is the role played by the notion of absence. The most direct level of absence observed in this machinery is the gap between the energy or signal transfer from one physical system (e.g., light) to another (e.g., sound). Yet, the absence that characterizes this transitional space can be extended to other media contexts and investigated as a promising starting point for creativity. In this sense, this section comments on some of the various dimensions of absence in media history and media art history, ranging from the void found between one system and another, through the birth and development of media in correspondence to the limitations of the human sensory apparatus, to this void's empowering existential and symbolic force.

3.2.1 Selected cases in history of media and media art

To begin with a curios anecdote, it is said that Alexander Graham Bell's interest in hearing, seeing and speech was partially based on the fact that his mother Eliza Bell was hard of hearing (and became, in spite of this, an accomplished pianist), which together with his father's business, encouraged his engagement with the deaf community.[83] Bell's story fits Kittler's argument that "*we knew nothing about our senses until media provided models and metaphors*"[84], elucidating not only how absence triggers investigation, but also how affection plays an important role in knowledge expansion.

A more popular example of the creative potential of absence in media history is connected to the human endeavours towards verisimilitude that culminated in the development of sound-film. Media historians analysing the role of sound in cinema have pointed to an image-ocular centricity in the dominant narrative of cinema history, even though "*as long as cinema has existed, sound has been part of it – both in its presence and in its absence*."[85] The projection of the first so-called silent films were from the beginning accompanied by music performed by solo musicians or orchestras, who also created live sound effects that were later enhanced by the ability to use pre-recorded ones. However, the insertion of sound in the material film itself revolutionized the cinematographic industry and language, due to its economic and aesthetic implications. The absence of diegetic sound in cinema annoyed

83 Benito, Shandra. Alexander Graham Bell and the Deaf community: A troubled history. In *Rooted in Rights*. January 29th 2014. Available at <http://www.rootedinrights.org/alexander-graham-bell-and-the-deaf-community-a-troubled-history/> Accessed February 27th 2017.

84 Kittler 2010: 34.

85 Beck, Jay. The evolution of sound in cinema. In: Guynn, William (Ed.) *The Routledge Companion to Film History*. London/New York: 2011. p. 64.

those who sought to us cinematographic language as a means to achieve complete audience immersion, i.e. a 'real' experience closer to how the human sensorial apparatus perceives and shapes the surrounding physical world. If immersion is undertood as the full capture of the spectator's senses, the film experience was considered as an incomplete media, even if a live musician or orchestra accompanied the film exhibition. Taking theater as its reference, the absence of the human voice was seen as diminishing film's verisimilitude. Hence, sound-film is also called 'speaking-film'. Scientists and technologists all over the globe have worked on the solution to that 'problem', a process that was initiated with investigations around the design of devices based on selenium's photosensitivity.

In the United States of America the development of sound film involved an attempt to attain synchronous reproduction of sound and image, also reflected in inventions such as Thomas Edison's *Kinetophone*, (1895 and 1913); Léon Gaumont's (1864-1946) *Chronophone* (1902), Oskar Messters' (1866-1943) *Kosmograph* (1903), E.E. Norton's *Cameraphone* (1908)[86] and later Lee De Forest's (1873-1961) *Phonofilm* (1922), AT&T Bell Laboratories' *Vitaphone* (1925), Radio Corporation of America's *Photophone* and Radio-Keith-Orpheum *Photofilme* (1927), and so forth.[87]

Apart from the issue of image-sound synchronization, experiments on the optical inscription of sound on film began being conducted at the very beginning of the 20th century when Ernst Walter Rühmer (1878-1931) developed the *Photographophone* around 1900. Rühmer's technique was based on photographing the fluctuating light proceeding from a 'speaking arc', while the reproduction was executed by using the dynamic photosensitivity of selenium to control a telephonic current actuated by variable illumination. This principle is introduced in the explanation of the *Photophone* and clearly visible in the aforementioned *Phonotube* by Arcángel Constantin and *Fotoliptófono* by Fernando Crudo.

In the scientific imaginary and literature of the 1920s a mergence between the *Photophone* and film technique was suggested as a possible solution to the problem of image-sound synchronization in cinema. A brief article published in *Science Journal* titled "Film photophone"[88] described a precursor of what would be a new industrially and commercially successful technical ensemble: sound-film. The author envisioned the 'speaking films' as based on photo-telephony technology and acknowledged the parallel work being done in different countries, without, however, going into the details of how the sychrononization should be executed.

86 Beck 2011: 66. Curiosly, there is little information about the inventor or his device, which coincided with the early versions of smartphones, which overtook the attention of media historians.

87 Ibid: 67-68.

88 The film photophone. In: *Science* 54 (October 21, 1921)Science 54 (1399), p. 373.

A decade later, in a publication responding to the increasing demand for consolidation in the industry, the technical engineers Fischer and Lichte elaborated all the details of sound-film.[89] Observing illustration b in the figure 3.18 below, one notices the miniaturization of the mechanical principle present in Bell and Tainter's *Photophone.* Since the light variation incident onto the selenium cell produced a variable resistence, which was drained off through the anode to the amplifier, the inscription of intermittent light was in this case implemented by means of electric current.

The sequence of illustrations above demonstrates that the elements operate in a similar way to the optical writing process of the *Fotoliptófono*, an invention that was indeed partially inspired by the emerging sound-film technology. Focusing on the technical working systems of the series of examples discussed above, enables one to see the photocell[90] as a leading element in both writing and reading the soundwaves on and from the film surface. Like the *Fotoliptófono*, the signal of the waves inscribed or read from the medium needed to be amplified (*Verstärker* = amplifier).

Selenium cells also played an important role in the development of optophones, prior to Hausmann's awe at his optophonetic perception and failed patent applications. As an enthusiast of the wonders of selenium and fascinated by the possibilities for converting light into sound and vice versa, the engineer Edmund Edward Fournier D'Albe (1868-1933) developed a version of an *Optophone* in 1912 as a means to facilitate the lives of visually impaired people by helping them to orient themselves in their surroundings and be able to read.[91] Therefore, the device belongs today to the technological heritage of visual impairement, which encompasses a variety of attempts to assist people whose bodies are not aligned to the standard media of the epoch, which constantly and emphatically promoted the supremacy of vision.[92]

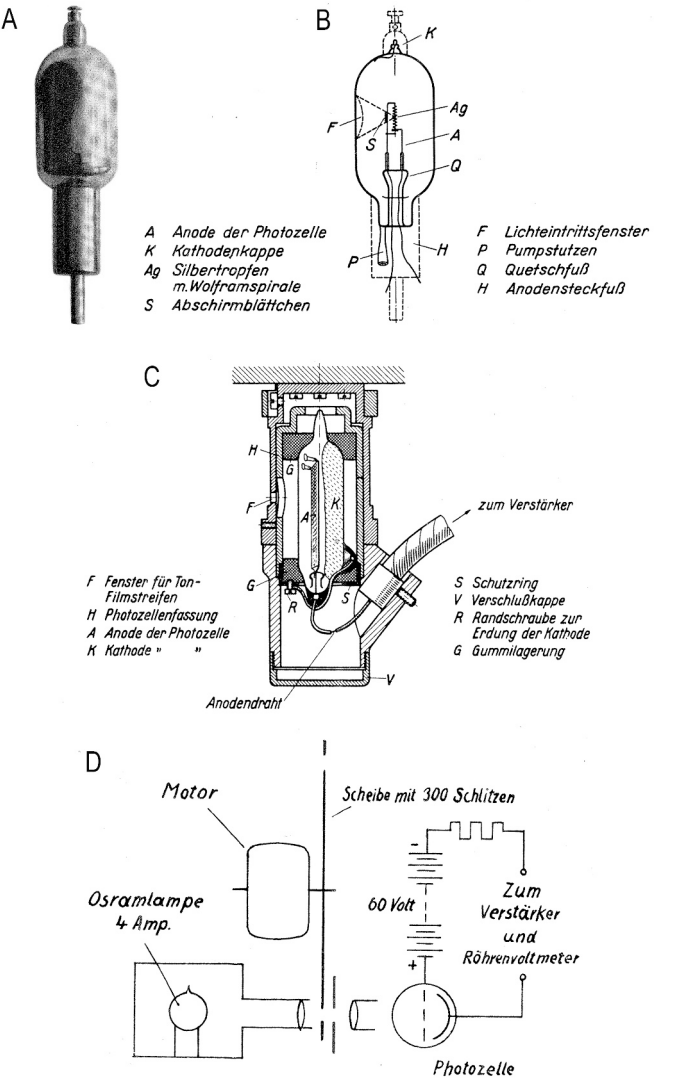
Indeed, the development of media devices is simultaneously based on the limits of the human sensory apparatus and endeavours to extend, assist, enhance, and/or adjust them. Despite the predominance of normative perspectives, there

89 Fischer, F.; Lichte, H. *Tonfilm: Aufnahmen und Wiedergabe nach dem Klangfilm-Verfahren.* (System Klangfilm-Tobis). Leipzig, Verlag von S.Hirzel, 1931.

90 At that time made of the element selenium (indicated by letter S in illustration B).

91 Fournier D'Albe 1924: 32 and Niebsch, Arndt. Einleintug/Optophonethik und die Photozelle In: *Raoul Hausmann. Dada-Wissenschaft. Wissenschaftliche und technische Schrifften.* Hamburg: Philo Fine Arts, 2013. p. 57.

92 In *Techniques of the observer* (1990) Jonathan Crary deeply analysed how optical media since the 19th century have contributed to the abstraction of vision and the formation of visual-based consumers. In contrast, the *Eyewriter* project discussed in chapter two (the optical device that assisted the graffitti artist, despite his absential body movements, to make graffitti again) is a case in which one observes a technological effort that takes advantage of the power and supremacy of vision. It was precisely the contiguity of human vision and cognitive processes that enabled the developers of the project to minimize the body conflict experienced by artist.



3.17: Photocell implemented in recording and reproducing sound-film. A: Photography of a photocell; B: Schematic lateral view with details of each composing element; C: Photocell attached to the structure where the optical inscription is made; D: Circuit of a technical ensemble in which the photocell reproduces audio information. *Source:* Fischer and Lichte, 1931. pp. 58 (A and B) and 66 (C and D).

3.18: Miss Jameson at the optophone; Source: Fournier D'Albe 1924: 132.

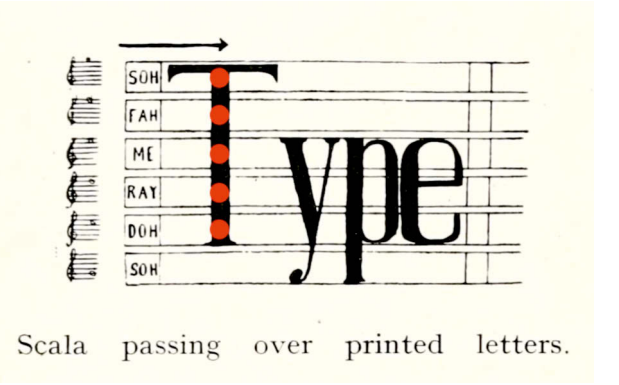
are also appropriations of assistive technologies that regard deviation as a means toward innovation. The idea behind optophones still remains today an inspiring source for creative media technologists and touches upon other levels of absence beyond physiological disability. The aforemetioned case of Peter Keene's apparatuses based on Hausmann's *Optophone*, for instance, also depended on the absence of detailed technical information about the original apparatus leading the artist to create his own relationships between light and sound. The innumerable possibilities for light-to-sound conversion have led to dialogues with media history, especially Keene's endeavour to use devices available on the market in Hausmann's epoch in the second version of his optophone, which has turned his artistic research into a continual process of knowledge construction.

Media archaeologists have been analysing the functional principles of former optophone models, as depicted in figure 3.20. Fournier D'Albe's reading machine resembles a primitive scanning technology, in which an object, as a framed field, is swept by light against a photosensitive surface, thereby detecting the presence (or absence) of elements shaping the letters through light contrast.[93]

On a Cartesian plane, axis x represents the path of the light source while axis y represents the acoustic notes. For each point detected in the scanned column, the corresponding notes that formed that letter were played. Although Fournier D'Albe claimed that through his invention the "*reading problem of the blind was completely solved by means of selenium*"[94], the resulting combination of musical notes as

93 A media archaeological approach requires recognizing this device as part of the history of computer vision; it also has similarities to the technique later used in the *Numarete,* which is presented briefly in chapter 2 as well.

94 Fournier D'Albe 1924: 94.



3.19: Schema of the sound output of an optophone; Source: Tiffany Chan / Maker Lab. July 4th 2016.

feedback can still make it hard to properly distinguish each character, which probably contributed to the short commercial lifespan of the device. The fragmented acoustic feedback of Fournier D'Albe's optophone also bears a resemblance to Morse code, since both suggest a connection between sounds and alphabetic letters. Interestingly, Morse code, as an even earlier technique for coding messages, has been employed as an assistive technology until today, enabling people with a variety of disabilities to communicate as long as they possess a minimal sensory-motor skill to perceive or express the binary combinations of long and short signs.

Contemporary attempts to use light-to-sound translations to develop assistive technological devices search for useful correspondences between visual and auditory stimuli that are more intuitive for users. Finding and establishing these correspondences is called in the scientific context image-visual to audio-auditory mapping[95], which necessarily presupposes an image encoder and software implementing methods to detect and distinguish objects from the background of the visual scene. In a case of mapping reported by Matta et al.[96], for instance, the images are transformed into a multiplexed auditory representation in which every frame is sampled, digitized and stored as a pixel matrix. Rows and columns of

95 In neuroscience one also speaks about mapping retinal images in the context of the immediate relationships between vision and cognitive process within the brain. (Damasio 2010: 63-70)

96 Matta, Suresh; Rudolph, Heiko; Kumar, Dinesh. Auditory eyes: representing visual information in sound and tactile cues. In *IEEE Xplore*. 13th European Signal Processing Conference. Sept 4-8th 2005. Antalya, Turkey. Available at <https://ieeexplore.ieee.org/document/7078395/> Accessed August 1st 2018.

each matrix are individually averaged, and the mapping translates the vertical position into frequency and the horizontal position into time delay, while brightness is translated into amplitude. The mapping method suggested by Matta et al., however, also uses image depth, and therefore becomes slightly more complex: Motion is translated into frequency shift (simulating the doppler effect); brightness into pitch; space into amplitude, reverberation, azimuth and elevation; and edge into duration. Although scientific efforts have aimed to find solutions that users could effortlessly adopt, scientists have been forthright in acknowledging the arbitrariness behind their inventions and have made it clear that the systems they develop require extensive training by the users, who have their own perceptual and learning idiosyncrasies.

Recalling Hausmann's ideal of an *optophonetiche Weltanschauung* and corresponding idea for the construction of an optophone leads to another dimension of absence that is both mirrored in his creative method and observable in his photomontages: destruction is the artificial construction of an absence. Hausmann's theory aimed to harmonise cosmologic processes, modern media technologies and human life,[97] and his propositions were clearly attempts to push the limits of the scientific and technological discourses to a symbolic and aesthetic level beyond the former utilitarian uses imagined, for instance, for the *Optophone*. Convinced that the visual arts were saturated, Hausmann adopted destruction and recreation as his artistic method, artificially creating the absence of meaning and form that opened a terrain for him to let novelty emerge.

The method also implied the absence of meaning aimed at in the Dadaist Manifesto against bourgeois values, a strong statement in the political context of the time. Considering himself a pioneer and martyr for the birth of the new man,[98] Hausmann saw in psychoanalysis the foundations for working towards this ideal: the revolution should begin with one's own 'self'. As a result of these ideas, he appropriated the principle of self-destruction as an act of creation to an aesthetic level, turning it into one of the main tenets of his dadasophy and Dada Berlin.[99] This polar creative impulse between destruction and creation is presumably also the origin of, and therefore the guideline to contextualize the closeness between, his poster poems and his optophonetics.

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97 Niebsch 2013: 19.

98 Züchner 1998: 15

99 Hausmann was also influenced by Salomo Friedlaender's (1871-1946) "creative indifference". For Friedlaender one can only perceive what is different. The difference that makes something a perceptible phenomenon is the "difference." The difference gives rise to a polar structure, and the opposites are related to each other. Friedlaender was interested in the middle between the differentiated poles. Friedlander, Salomo (Mynona). Schöpferische Indifferenz. In: Thiel, Detlef; Geerken, Hartmut (Ed.) *Gesammelte Schriften*. Band 10. Herrsching: Waitawhile, 2009 (1918).

Moreover, in light of the process of fragmentation in his photomontages and the suggestion of synaesthesia (a topic of interest to him following World War II), Hausmann's artworks make the operationalities of the human perceptual apparatus explicit, similarly to the foundations of Op and Kinectic Art. In the Dadaist movement, however, the interrelationship between human sensory and cognitive apparatuses is far more provocative, taking place precisely in the space between sensing and making sense.

A similar contemporary approach to that of Hausmann's *optophonetische Weltanschauung* and the enhancement of the human senses can be found in the artistic statement of eyeborg Neil Harbisson briefely introduced at chapter two in the context of hybrid vision. Inspired by his congenital disease achromatopsia[100], Harbisson has worked on the embodiment of a device that creates sounds according to the colours captured by a photosensitive sensor placed in front of his head.[101] He reports that since the last update of the device his perception of sound occurs through a direct connection with his skull, which has given him the new sense of 'hearing colours', a synthetic synesthetic experience.

As already depicted in the previous chapters, the existence of colours in human vision is the result of light-matter interaction conditioned by the triadic material composition of the cones, which are photoreceptors that form the retina together with the rods.[102] This basic physiological principle of human vision harks back to Isaac Newton's experiments in the 17th century showing that white sunlight is not a single entity but a spectrum of infinite colours. Hausmann's ideas, expressed in his texts on the *optophonetische Weltansachuung*, also address different theories of colours[103] and reveal an attempt to merge the objective and the subjective aspects present in the dominant discourses of his period. "*The eye connects space and brain through a subjective-optical creation toward the temporal world-view, to an intuition of light, called optics. We do not see any light, we see colours*" [104]. Today, considered in terms of

100 Achromatopsia is a medical syndrome also known as total colour blindness, causing people to see only black, white and shades of gray.

101 In collaboration with Adam Montadon, Peter Kese and Matias Lazano. Harbisson, Neil. Human Antenna, March 2014. Manuscripts shared by Harbisson's producer Mariana Viada per email via hiperlink: <https://docs.wixstatic.com/ugd/bbd83c_6e51180105-65401094005275d17b62ad.pdf> Accessed August 8th 2017.

102 Guyton and Hall 1996: 577-589.

103 The predominant influences were Newton's, Helmholz's and Goethe's theories of colours.

104 From the original in German: "*Raum und Gehirn verbidet das Auge durch eine subjektiv-optische Schöpfung zum Zeitlichen Weltbild, zu einer Anschauung vom Licht, Optik gennant. Wir sehen kein Licht, wir sehen Farben.*" (Translated by the author) (Hausmann, Raoul. Versuch einer komischen Ontographie/Optophonetische Weltanschauung. I. Teil. Notizbuch VIII, 1922-1923. In: Hausmann, Raoul. *Dada-Wissenschaft: Wissenschaftliche und technische Schriften*. FUNDUS Band 193. Hamburg: Philo Fine Arts/Berlinische Galerie - Landesmuseum für Moderne Kunt, Fotografie und Architektur, 2013. p. 76.

an electromagnetic radiation with wave-particle properties, the light-colour relationship is the basis of the measuring parameters commonly used both in scientific and aesthetic investigations. When isolated, the energy of a monochromatic beam of radiation is related to its wavelength and frequency. The subjective perception of colour, however, is not evidence of its supposed immaterial condition[105], as some theorists contend. Looking closely at sensitivity to light and the molecular structure of pigments, one finds a material condition enabling colours to be seen or not seen.[106] The absence of specific material conditions within Harbisson's retina is the reason for his achromatopsia.

According to the artist, he was used to ignoring or avoiding colours in his everyday life until the moment he discovered studies relating colour frequencies to sound frequencies and felt motivated to investigate how he could perceive them. Ever since, his previous neglect of this absence has been transformed into a series of creative projects.

Although Harbisson does not provide information on how he developed his own 'sonochromatic scale', it basically consists of correspondences between a colour hue and a musical note, ranging from invisible ultraviolet to infrared spectra. General methods for the sonochromatic music scale consist of microtonal and logarithmic scales with 360 notes in an octave and each note corresponding to a specific degree of a colour wheel ranging from the pure colour to white, the maximum brightness. In contrast, Harbisson's sonochromatic scale is a non-logarithmic scale that includes infrared and ultraviolet, discards colour as being part of a colour wheel and ignores conventions on musical perception in order to overstep the limits of human perception.[107]

The search for correspondences between colour and sound has been an inspiring field of exploration for artists, as exemplified by such works as the *Projet de clavier ultrachromatique* (1943) by the composer Ivan Wyschnegradsky[108] and the

105 Pedrosa 1977.

106 Guyton and Hall 1997: 577-589.

107 To exemplifiy the correspondences that Harbisson is using some of the hues and notes are: Red (to a 363.797Hz) frequency is attributed the note F; Orange (440.195 Hz) is F#, Yellow (462.023Hz) is G; Chartreuse (unspecified frequency) is G#; Green (478.394Hz) is A; Spring (unspecified frequency) is A#; Cyan (551.154Hz) is B; Azure (unspecified frequency) is C; Blue (573.891Hz) is C#; Violet (607.542Hz) is D; Magenta (unspecified frequency) is D#, Rose (unspecified frequency) is E. An audiovisual reference on Harbisson's sonochromatic scale is available at the Youtube channel of the artist at <https://www.youtube.com/watch?v=UawXwCpwDjo> Accessed January 6th 2018.

108 Images and brief description available at <http://www.documenta14.de/en/artists/22761/ivan-wyschnegradsky> Accessed January 5th 2018.

cybernetic *Musicolour* machine (1953-1957) by Gordon Pask (1928-1996) and Robin McKinnon-Wood (1931-1995).[109]

A casual look at the way artists and scientists create their light-to-sound translations induces one to perceive them as natural transpositions, as if the correspondences have always been there, and to ignore the human agency required to bridge the gap between one system and another. The arbitrariness of the established correspondences is necessarily bound to the subjectivities of those who have created them. As philosopher Ludwig Josef Johann Wittgenstein (1889-1951) noticed about Goethe's colour theory[110], such colour-to-sound associations are due more to the psychological traits than physiological ones. Fournier D'Albe addressed a similar issue by calling light-to-sound conversions symbolic rather than actual in the context of revealing the problem of the great physical disproportion between the range of frequencies of light and sound waves:

> Light-waves are from forty thousand to seventy thousand to the inch, according to their colour. In duration they are even further apart. If we could slow down an average light-wave until it took one second to pass us, and could slow down an average sound-wave in the same ratio, it would take no less than two hundred million years to pass by! [111]

In a pragmatic sense, light- or colour-to-sound translations are the product of a mathematical method for scaling and establishing proportions. From an epistemological and biological perspective, one can also remark that the considerable difference between light and sound waves the physical parameter in evolution that has shaped the different types of cells to compose visual and auditory perceptual systems. Moreover, within Fournier D'Albe's attempt to objectively consider the problem one must also notice that his idea of an 'average wave' can only be stated in relation to a specific frequency range, namely, the spectrum that humans can perceive. Such pseudo-objective positions reflect the constant attempt to define a 'standard human being' and the notion of normality, which is frequently not compatible with the specificity of each being.

Since light-to-sound translations have been technically and aesthetically explored in a variety of forms, what is the novelty or potency of Harbisson's work? On the one hand, it lies in the technical audacity to implement with/in his own body a hybrid version of what the classic references have proposed. The automatic

109 *Musicolour* was in fact based on the translation from sound into light projection and movement (Rosen 2008: 131).

110 Wittgenstein, Ludwig. Anscombe, Gertrude Elizabeth Margaret (Ed.) *Remarks on Colour*. University of California Press, 1977. (Original as *Bemerkungen über die Farben* written in Vienna in 1950).

111 Fournier D'Albe 1924: 90.

response of the machinic system embedded in Harbisson's body to translate luminous stimuli into vibrations has led to a self-organizing situation. Self-organizing principles were already very present in almost all Pask's artworks, but according to Harbisson's statements, in his case, biological and machinic systems are merged in the artist's own flesh[112], enabling the mergence of sensorial and cognitive abilities as well. Harbisson has been advancing the idea that he is technology, since a cultural object and its abstractions (encoded knowledge) were symbiotically attached to his body, forcing it on to a new stage of organization. On the other hand, what has substantially empowered his narrative about his corporeal experiment and its derivative artistic propositions is his drive to deal with the absence creatively. He approached his colour blindness in an innovative manner, opening a space for disability aesthetics[113] to flourish.

3.2.2 Self-portrait of an absence

Conceptualization: An artistic experiment as a research tool

The performance *Self-portrait of an absence* (2016)[114] has been created as methodological tool for investigating what is at stake when implementing photosensitive elements in the artistic context and analysing the relevant issues for an academic audience. The project started by considering the materiality and behaviour of photosensors, evolved to encompass the confrontation of eye and camera – organic and machinic samples of photosensitivity, and ended by incorporating and taking advantage of the author's monocularity.[115]

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112 The author did not have access to any technical details of the implanted hardware nor to how the implant has been conducted. According to essays written by Harbisson and provided by his secretary producer Mariana Viada, the implant surgery has been done illegally by an anonimized doctor.

113 Siebers, Tobin. Disability aesthetics. In: *Journal for Cultural and Religious Theory.* Vol. 7 n. 2, 2006. p. 63-73.

114 A video-documentation of the performance recorded at the Gleisdreieck Park in Berlin is available at <http://grazielelautenschlaeger.com/portfolio/self-portrait-of-an-absence/> Accessed August 7th 2018. A more detailed information about the project can be consulted at paper "Self-portraying of an absence" published Candy, Linda; Fabrizio Poltronieri, Ernest Edmonds (Eds). *Explorations in art and technology*. London: Springer Verlag, 2018.

115 The experience of being monocular implies having a more limited sight field (25% shorter), perhaps a slower reflect to some circumstances of spatial perception, and the impossibility of using stereoscopic optical devices. According to Crary sudies on stereoscopy remounts to the first half of the 19th century, unfolded from researches on subjective vision, physiology of the eyes, and debates about the perception of space. Charles Wheatstone (1802-1866) and David Brewster (1781-1868), who worked on optical illusions, colour theory, afterimages and other visual phenomena, were among the main characters behind the first sprouts of stereoscopic optical devices. They are the result of investigations started around the 1820's, when physiologists were looking for anatomical evidences in the optical chiasma, where the ner-

Appealing to an imaginative 'what if question', the artistic research was driven by the curiosity to know more about an unknown part of my own body, my right blind eye. As I already know what it is like to see and have no interest in implanting an artificial retina or anything to 'correct' my partial blindness, I was intrigued by the possibility to aesthetically explore this particular absence. What can an eye that cannot form images do? By reducing the eye and camera's photosensitivity to its operationality in the zero-dimension of electric changes, I was able to address the partial absence of vision by means of challenging the historical dichotomy between the form and function of an eye. Following this logic, on a technical level the project consisted of an eye-tracking system programmed to generate and process sounds according to data generated from the asynchronous eye movements.[116] Wearing a costume in which the necessary electronic devices[117] were embedded I have been performing in public and semi-public spaces, inviting people to share in an observing-listening exercise under a huge umbrella.[118]

Alterations of the material's resistance resulting from the light-matter interaction[119] in the camera's image sensor are the zero-dimensional matter (or data, as some might prefer to call it) that enables light input to be directed and transformed into another physicochemical stimulus, sound in this case. It could have been any other kind of conceptual-material translation. Nevertheless, inevitably the context shaped the choices made during the creative process.

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ve fibers leading from the retina to the brain cross each other, transferring electrochemical pulses from each retina to each side of the brain. (Crary 1990:118-19)

116 Due to its blindness, my right eye behaves differently than the left one, sometimes synchronizing sometimes floating – assuming a resting position when not focused on something relatively close. The regularity of this behaviour was realized only over time, when using and testing the eye-tracking system I developed.

117 Raspberry pi 3 board with camera module, push-buttons, cables, rechargeable usb power bank, software in Python and SuperCollider, costume made of cotton fabric, accessories of brass, steel and rubber.

118 By visually evoking strangeness through the unusual costume and technical accessories, a sort of character framing is established: The audience understands that the character is an invitation to engage in interaction. Moreover, visual contact with passers-by is used as strategy, and if they demonstrate any interest, they are englobed under the umbrella, followed by the introductory pre-recorded voice.

119 In Peter Sloterdijk's essay on light and resistance one can find similitudes between his and Flusser's perspective in relation to the interplay between material and immaterial layers of cultural objects, especially in their shared use of the metaphor of a knife: "*Der Mensch ist ein Tier, das schneiden kann*" / "*The human being is an animal that can cut*." (Sloterdijk 2015: 40, translated by the author)

3.20: Performing *Self-portrait of an absence* at Praça Mauá/MAR - Museu de Arte do Rio, in the context of Soma Rumor - Encontro Latino-americano de Arte Sonora. June, 29th 2019. Photo: Rafael Wallace; Source: Author's personal archive.

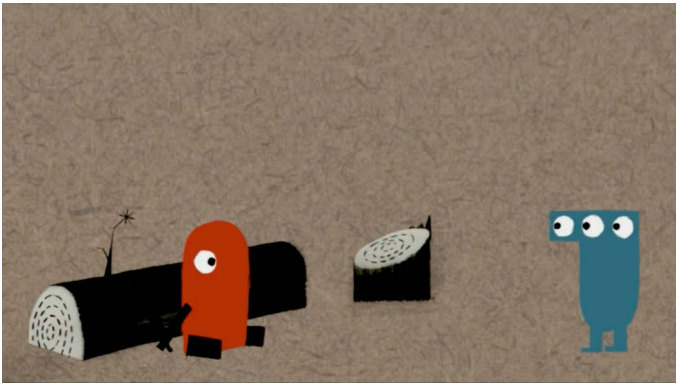
Implementing: A light-to-sound translation for presencing the absence

The choice to translate light into sound was, however, mainly made due to two factors: First, human auditory perception is also structured in terms of spatial qualities like the sense of sight, and therefore an analogy between seeing and listening was envisioned in relation to the reduced field of vision. Second, it was feasible in terms of the knowledge, resources and time available.

Nonetheless, as the artwork developed I realized that what is called translation is a deliberate and creatively arbitrary process. For the light entering the eye and the camera to be translated into sound in the vibrating membranes of the loudspeakers in the specific context of the performance, a sequence of meaning attributions was required for running the technical ensemble and shaping the aesthetic experience.

Unfolding the various suggested metaphors for the experience, absence is on the very first level expressed by the empty space offered to prospective participants under the performer's umbrella. The blind spot in my reduced visual field is turned into available space for the participant to join the performer-umbrella unit, which besides functioning as an acoustic shell suggests complementarity and the possibility of sharing an intimate space. This technical-aesthetical choice is a direct reference to the animation *An eye for Annai* (2005) by Jonathan Klassen and Dani-

el Rodrigues, in which the character Annai is also monocular and is looking for a suitable eye in the world, which is finally found in a partner who has three.



3.21: Frame of the video *An eye for Annai* (2005), by Jonathan Klassen and Daniel Rodrigues. Courtesy of the artists.

The option of building or purchasing eye-tracking glasses was consciously rejected due to its strong symbolic association to corrections of what is considered "imperfect" vision. The solution was to build a simple metallic structure that rests on the head and holds the camera module that tracks the eyes' movements.[120] In this way *Self-portrait of an absence* was spontaneously joined to disability aesthetics, which entails a refusal of "*harmony, integrity, and beauty – as the sole determination of the aesthetic*"[121]. The endeavour thus became an exploration of the absence by stretching the notions of normality and deviation. How can an absence be communicated and shared?

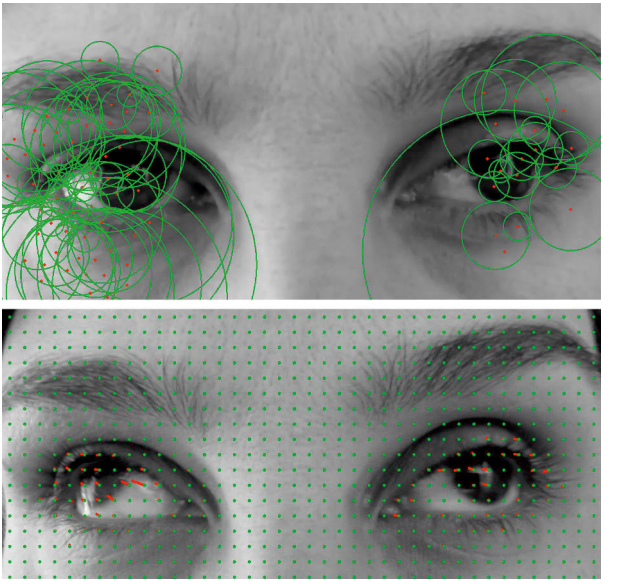
This question was more strongly addressed in the composition of the different sound modes activated during the promenade, which also guide the observing-listening exercise. The more desynchronized or deviated (D) the eyes behaved, the stronger the effects applied to the sounds being rendered were.[122] Absence has been translated into the notion of deviation. Absence has been given presence.

120 The confrontation is set: The eye, as organic photosensitive element, meets the camera, the man-made photosensitive element. This confrontation is the starting point for the theoretical questions that formed chapter two of this work.

121 Siebers 2006: 64.

122 In summary, the sound modes are: (1) Pre-recorded voice greeting the participant and introducing the project's idea; (2) percussive sound whose rhythm loses its periodicity according to D; (3) over pre-recorded audio samples are applied bit-crushing and downsampling effects, more or less intense according to D; (4) tones synthesis, including vibrato and panning effects according to D; and (5) pre-recorded voice thanking the participant and concluding

To put these ideas into practice and bridge the absent space between light input and sound output, software in Python and SuperCollider have been developed.[123] The eye tracking system was built using the library Open CV (Open Source Computer Vision) with a specific technique called optical flow, which is based on the recognition of the apparent motion of objects, surfaces, and edges in a given image, calculated by the relative changes within the frames over time. Another tested technique was blobs detection. However, it proved to be unnecessarily demanding and complicated given the required purpose. Getting absolute values from the blobs positions would require much more power from the hardware and provide unnecessarily more precise data. With the optical flow technique one can extract relational data obtained from the comparison between both matrices of pixels (left and right eyes), and the values are generated only when and where there is movement in the captured image. Further calculations to obtain information on the angle of the difference was obtained by the cosine of the vectors generated.

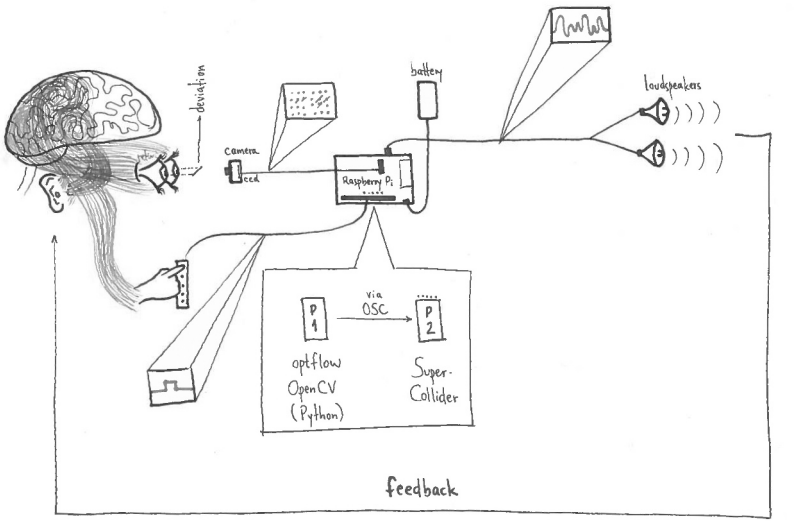


3.22: Frames extracted using the computer vision techniques of blob detection and optical flow; Source: Author's personal archive.

the intervention. They emerged from a soundscape simulating an intervention in an urban space, using the surrounding sounds as inspiration.

123 Special thanks are due to Edgar Zanella Alvarenga, Radamés Ajna da Silva and Dominik Hildebrand Marques Lopes, who asssited in formalizing the ideas in codes.

In addition to movement detection and angle calculation, the software written in Python (P1 at fig. 3.23) also sends the processed data via OSC protocol to SuperCollider (P2 at fig. 3.23), a programming language for real-time audio synthesis and algorithmic composition, where the five sound modes of the performance were written.[124] The illustration below shows the signal flow of the performance system that makes all the connections clearer:



3.23: Signal flow in abstract and concrete levels of *Self-portrait of an absence;* Source: Author's personal archive.

Opening the technical black-boxes of *Self-portrait of an absence*, one can observe the several layers of fragmentation and abstraction between light input and sound output. The technical and aesthetic solutions for executing the light-to-sound translation were much closer to the notion of invention than to finding pre-exisiting correspondences. In contrast to the majority of the other media devices and artworks based on light-to-sound translations presented throughout the chapter, *Self-portrait of an absence* required digital devices and programming for its technical implementation. This decision made the translation process simultaneously freer and more complex. Although technically less complex in relation to what computer scientists and engineers have been developing in the field of computer

124 All codes and audio files developed in the course of the project are documented at Github platform on the link <https://github.com/aivuk/self_portrait_of_an_absence> Accessed August 1st 2017.

vision, unboxing part of the technical details of this artwork is a way to demonstrate how data coding multiplies the possibilities engendered by the abstract in-between layers of translations from light into sound.

The coincidence that Vilém Flusser was also monocular has encouraged me to creatively explore my partial absence of vision regarding issues present in his work, particularly the notions of self-translation and *Mediumsprünge*[125]. As an exercise in playing between the abstract and concrete worlds of codes and materialities, *Self-portrait of an absence* became an unpretensious poetic experiment on the search for possible paths between sensing an making sense of an absence, by means of organic and machinic light-sensitive elements.

Facing the abyss between one system (light input) and another (sound output), Harbisson's case and *Self-portrait of an absence* were free to create completely novel correlations. The interstitial zone of the absence is, in this sense, a fertile field of indeterminacy in which artists can attribute and manage meanings created out of a void. Experiments like these challenge the classic form-function-content relationships that are characterized by friction between meanings and materialities, and they are greatly facilitated by the zero-dimensionality of electronic and digital media.

Translating and hybridizing

Although the creative process has been split here into conceptualizing and implementing, one notices that each aspect is hardly discussed in isolation. Concepts have directly material implications and the use of materials demands conceptualizations. Conceptualizing, building and performing *Self-portrait of an absence* has been an intense learning experience that recursively involved moments of asking, networking, constructing, understanding and reflecting on manifold levels. Nevertheless, regarding the thesis' frame, in addition to the light-to-sound translation itself, it is relevant here to share and comment upon some findings in relation to the biofeedback process established between my body and the constructed technical ensemble. Biofeedbacking has been the core principle enabling the hybrid character of the project.

125 Due to his immigration background, Flusser's philosophical method was strongly based on translations and retranslations. It is possible to draw relations between Flusser's translation theory of the 1960s and his media theory from the 1980s, as suggested by Rainer Guldin in *Pensar entre línguas: a teoria da tradução de Vilém Flusser* (2010). His reflections on media philosophy were intimately related to the concept of *Mediumsprünge,* the act of jumping from one medium to another, from the logic of one system another. This concept was articulated by Flusser in at least four different situations: discussions on the change of media, on the comparison between media, on media as circumstance of translation and on media-historical development. (Guldin 2010: 166)

The audio information produced by my eyes' movements taught me that their synchronization is related to the ability of my seeing-eye to focus, testifying to traces of a symmetry-based body. Based on this understanding, while training and performing with the apparatus I learned the muscular patterns of movement to control my blind eye's position, in a simpler, but similar, procedure to that which led Harbisson to be able to listen to colours. In this way, the aesthetic system was conceptually enriched as the circular interaction between being and machine also revealed a previously unconscious absence of bodily awareness.

The learned muscular control associated with research on optical devices and visual perception has driven me back to the issue of monocularity and its relations to spatial perception – which was set aside in the image-to-sound translation. The findings on the practice date back to studies on stereoscopy in the 19th century, when Wheatstone measured the binocular parallax,[126] contributing to the understanding of the correspondences between eyes' movements and how the physical proximity of objects *"brings binocular vision into play as an operation of reconciling disparity, of making two distinct views appear as one"*[127].

> When an object is viewed at so great distance that the optic axes of both eyes are sensibly parallel when directed towards it, the perspective projections of it, seen by each eye separately, and the appearance to the two eyes is precisely the same as when the object is seen by one eye only (...) When the object is placed so near the eyes that to view it the optic axes must converge... a different perspective projection of it is seen by each eye, and these perspectives are more dissimilar as the convergence of the optic axes becomes greater.[128]

This point recalls that the absence addressed was in the end not one of vision as such, but rather the absence of the stereoscopic nature of human visual perception as well as its related spatial qualities. Using this experiment to escape from the concrete limitations that transform this specific absence into an abnormal condition is an element that demands critical self-reflection. Being monocular gives me a bodily awareness that is skewed to one side of the body, a sort of a 'weight sensation', for lack of a better term, and a clearer perception of the dominant role vision plays in the way one perceives the world. The technical and aesthetic choices made during the experiment did not include sharing this specific way of seeing and perceiving the environment and the body itself. And perhaps that would only be possible to achieve if one could hack the participants' sensory and cognitive apparatuses – a proposition that is still fictional. Therefore, I cannot say that the sensation and the

126 Parallax corresponds to the degree to which the angle of the axis of each eye differ when focused on the same point.

127 Crary 1990:120.

128 Brewster and Wheatstone 1983: 65 apud Crary 1990: 120.

feeling of the absence were, as intended, entirely shared. However, the proposition at least enabled an aesthetic experience that has driven the participants' attention towards a broad and relativized concept of absence.

Furthermore, using biofeedback in an aesthetic proposiotion and one's own body and disability to inquire into the notion of normality is a second-order cybernetic approach that allows the coincidence of both types of absences: one physiological and another existential. Absence can become a presence that provokes reinvention. At stake is the fact that the body organizes the world in order to organize itself. The continuous stimulus exchange between physical entities may lead to new relevant information. In this process, absence becomes the engine for the creation and recreation of meanings, which evolve from empirical situations. Artworks, as well as lives, are experiences in which meanings are produced during the experience itself with its inherent material and spatio-temporal qualities.

The translation of materialities can be an explicit means of betrayal and loss of information[129], but it is also a precious way to visualize the gaps and create the open space for the emergence of novelty. Minding the gap is the first step towards the invention of interesting new bridges.

3.3 Translation of materialities

The media devices and artworks featured in this chapter showed different possibilities for manipulating physical elements to execute light-to-sound translations. The samples discussed were purposefully related to antecedents of digital media in order to elucidate how the process of fragmentation has been continuously enhanced in media history and has also served as the basis of scientific, historical and cultural developments more generally.

Digital media is associated with the possibility of gathering all materialities together in terms of an abstract lowest common denominator of voltage changes or digits, and, in a second step, transforming them into other possible materialities. This locates the current practice of media art literally in the interplay between abstraction and concreteness. In other words, this aspect of digital media leads to translation issues, since it theoretically allows the translation from any material phenomenon into another. In this sense, processes of the translation of materialities refer to this special possibility of programming and editing matter by transforming one type of physical or chemical stimulus into another, and therefore creating situations in which meaning emerges from the experiences that the combined technical ensembles can render.

129 Simondon 1958:143.

Since it is theoretically possible to establish correspondences between any physical or chemical phenomena, How have these correspondences been made in media artworks? And, How are they related to the meanings they potentially convey? Regarding the field of contemporary art, What is so necessary to express that it justifies the current investments of time, energy and resources in translating matter A to matter B?

Considering that any translation, regardless of how literal or free it is, always constitutes an interpretative act executed by a subject, the question remains if artists are aware of their arbitrary choices and the multiple nature – technical, aesthetic, symbolic, etc. – of the materials and methods they have been using. In shedding light on the notion of the "translation of materialities" this section has offered conceptual strategies to deal with the paradoxical material-immaterial challenges arising in the creative processes of media artworks.

3.3.1 Merging conceptual and material approaches to media creativity

Light-to-sound translation is just one example of countless forms of translation that have been accomplished during the current material turn, in part due to an exponentially increasing diversity of materials.[130] Already in the 1980s, a substantial number of issues relevant to the notion of the translation of materialities in artwork was discussed under the concept of intersemiotic translations.[131] Based on Roman Ossipowitsch Jakobson's (1896-1982) writings, artist and art critic Julio Plaza (1938-2003) defined intersemiotic translations,[132] which he also called transmutations, as "*consisting in the interpretation of verbal signs through non-verbal sign systems*"[133]. Despite acknowledging the material basis of any semiotic element[134], however, the necessary crossing over through verbal systems seems to be unsuitable for the increasingly hybrid kinds of media artworks, and other theoretical and practical paradigms have developed since Plaza published his book. This shortcoming is especially notable concerning the siginificant changes brought about by electronic and digital media. Plaza does not grasp electronic and digital media specificities,

130 Yeo, Jingjie; Jung, Gang Seob; Martín-Martínez, Francisco J.; Ling, Shengjie; Gu, Grace X; Qin, Zhao; Buehler, Markus J. Materials-by-design: computation, synthesis, and characterization from atoms to structures. In: *Physica Scripta*, Vol. 93, n. 5, April 2018.

131 Plaza, Julio. *Tradução intersemiótica*. São Paulo: Perspectiva, 2003.

132 The term is contrasted with intrasemiotic translation, in which a text is translated into another text using purely verbal means. The mutual transformative influence from one system to another remains in the verbal domain. Deeper discussion of the difference can be found at Dusi, Nicola. Intersemiotic translation: Theories, problems, analysis. In: *Semiotica*.Vol. 2015, Issue 206. pp. 181-205.

133 Plaza 2003: III.

134 Plaza 2003: 67.

largely due to the lack of attention given to programmability and the creation of potentially self-organizing systems. Mainly emphazising media transpositions from originally concrete poetry printed on paper to video, Plaza theorized about, and put into practice, the Flusserian notion of *Mediumsprünge*. He was thus aware of both the integrated role of sensorial and cognitive process in meaning attribution[135] and the increasing hibridization possibilities of translations.[136] However, in his artistic practice of intersemiotic translation he did not explore either the plasticity of the zero-dimensionality of electronic images, or absent space as creative matter, instead remaining attached to the concept-driven creative paradigms of literary and visual art.[137]

Since favouring the supremacy of meaning has never been the intention of this thesis, a semiotic approach has been seen from the beginning as an incompatible framework to work with regarding the translation of materialities, even in its more contemporary formulations.[138] An additional difficulty is that semiotic approaches disregard (even if inadvertently) the very material basis and implications of the creative use of media, and thus the hermetic terminology and conceptual tools of semiology seem to lack bridiging elements to the current new materialist and media-archaeological approaches of cultural studies. In the translation of materialities a creative process emerges through the activation and embodiment of different media by the artist/translator. Rather than consider meaning as a preexisiting entity, the investigative impetus may be a priori free of meaning(s), which is/are only later attached when framed and experienced in a specific context. This inversion in relation to of a semiotic perspective is a sort of acknowledgement of an initial meaninglessness, the core absence through which creative power emerges. This paradigm enables associations between different cultures and media to be created through movement across systems, in which the artist as translator mediates experiential processes that allow both artist and audience to make the sense(s) for themselves through the translational process. As demonstrated in the examples provided, this approach emcompasses the role of (photo)sensitive materialities as

135 Plaza 2003: 62-63.

136 Plaza 2003: 64-66.

137 In order to clarify how Plaza's video animations do not explore the specificities of electronic media, one can point out that the essence of his intersemiotic translations would remain if they were substituted or reacreated by photographic stop motion, for instance. This criticism does not disregard the historical and aethetic relevance of his experiments. However, they do not explore the technical specificity of the medium. To draw an analogy to the history of cinema, they would correspond to the very primitive experiments that films were short clips of filmed theater, without the further development of their own expressive language.

138 Brier, Søren. Cybersemiotics: A New Foundation for Transdisciplinary Theory of Information, Cognition, Meaningful Communication and the Interaction Between Nature and Culture. In *Integral Review*. Vol. 9, n. 2 June 2013.

protagonists in enhancing the transitional, relative and contextual quality of meanings among different media.

In the description and analysis of the media devices and artworks a variety of terms, such as conversion, translation, and transduction have emerged. Fournier D'Albe, for instance, in his book about the properties and applications of the element selenium, favoured the word 'conversion' to describe light-to-sound experiments based on selenium cells.[139] In contemporary compendiums from the field of electrical engineering, such as the *Handbook of modern sensors: Physics, designs, and application* (1996), inventor Jacob Fraden is technically and terminologically more accurate, distinguishing sensor from transducer. Considering a sensor as "*a translator of a generally nonelectrical value into an electrical value*", Fraden also emphasises the distinction by pointing out that a sensor may contain several transducers.[140] Following this definition one can deduce that the emergence of the term 'sensor' in the English language in 1947, deriving from the adjective 'sensory'[141], is related to the birth of digital technology and its imperative to transform all physical stimuli into a common denominator – electric current.

An etymological analysis of the term also corresponds with what is observed in media art practice. Since the practice involves the manipulation of material and symbolic elements, drawing comparisons between terms such as 'conversion', 'transduction' and 'translation' is challenging, especially because photosensitive matter involves the role of light as both energy (materiality) and signal (symbolic) source. Hence, a careful reflection on the light-matter interaction in the context of art, reinforced by an etymological examination, has led to the acknowledgement of the greater importance of the prefix 'trans-' as a metonymic option that encompasses the countless transferring and transgressing possibilities on which media artworks are based. It is essential to note that each of the terms being used (conversion, transposition, translation, etc.) refers to a passage from one physical state to another, which necessarily involves the overcoming of previously established borders. The decision to use the expression "translation of materialities"was made in consideration of the analysis of the role of translation in cultural development in a broader sense, going beyond the linguistic domain into ontological and philosophical territory.[142]

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139 Fournier D'Albe 1924: 89-93.

140 "*The term sensor should be distinguished from transducer. The later is a converter of one type of energy into another, whereas the former converts any type of energy into electrical*". (Fraden 2004: 3)

141 "*pertaining to sense or sensation*" form latin sensorius, past participle of sentire (to perceive, feel). Etymonline. <https://www.etymonline.com/word/sensor> and <https://www.etymonline.com/word/sensory?ref=etymonline_crossreference> Accessed February 24th2018.

142 This understanding is also reflected in the Berlin Media School and the name chosen for the Transmediale Festival – as a reaction to the obsolescence of the term 'multimedia', extensively used in the 1990s.

On the one hand, the theory of translation has been most established and developed in the realm of linguistics,[143] which is inherently occupied with the notion of language and meaning.[144] On the other hand, it is not by chance that the concept is also often used in other disciplines like molecular biology and genetics, in which the term transduction/translation is used to explain, for instance, the process in which cellular ribosomes create proteins within DNA.[145]

Observing such a broad spectrum of uses leads to a general understanding of translation as occupying and occurring within the space between distinct systems. Looking at the transitional characteristics of media artworks brings translation theories into closer relation with media creation. The challenge of bridging this gap can be attempted by unfolding Flusser's term '*Mediumsprünge*' and the intersections found between his theory of translations, developed in the 1960's, and his media theory of the 1980's. Flusser himself also stated: "*Perhaps, everything I am working towards is a theory of translation*"[146]. According Rainer Guldin, Flusser intersects discourses from linguistic theory, information theory and arithmetic[147], a cross-disciplinary approach that seems to be more adequate to deal with the notion of translation of materialities.

In what follows, only perspectives that address the material relationships permeating translation theories and media art production will be emphasized, and translational operations will be considered as encompassing a broader notion of language, as suggested by Klaus Krippendorff in *Discourse and the materiality of its artifacts* (2011).[148] For instance, in *Understanding Media* (1964)[149] Marshall McLuhan suggests that media are translators, without, however, elaborating the details or the complexity of the subject: "*Translation is thus a 'spelling-out' of forms of knowledge*"[150]

143 Stolze, Radegundis. *Übersetzungstheorien: Eine Einführung*. Tübingen: Gunter Narr Verlag, 2011.

144 Interestingly, the increasing proliferation of new sorts of materials in the twentieth century is accompanied by a significant increase in the attention given to the subject of translation, a topic systematically elaborated by Stolze Radegundis in his aforementioned book.

145 Guyton & Hall 1997: 28-32.

146 Flusser, Vilém. Quote at Rainer Guldin's website. Available at <http://rainer-guldin.ch/vilem-flusser/> Accessed June 1st, 2017.

147 Guldin 2010: 168.

148 Krippendorf proposes five constituent components of discourse: (1) discourses manifest themselves in the artifacts they produce, inclusive of their textual matter; (2) discourses are kept alive within communities of their practioners; (3) discourses institute their recurrent practices; (4) discourses draw their own boundaries; (5) discourses must be able to justify their practices to materially relevant outsiders. Krippendorff, Klaus. Discourse and the materiality of its artifacts. In: Khun, T.R. (Ed.) *Matters of communication: Political, cultural and technological challenges to communication theorizing*. New York, NY: Hampton Press. pp. 23-46.

149 McLuhan, Marshall. Media as translators. In: *Understanding media: the extensions of man*. London/New York: Routledge Classics, 2001[1964].

150 McLuhan 1964: 62.

and "*all media are active metaphors in their powers to translate experience into new forms*"[151]. In his typical prophetic manner, McLuhan envisioned the wonders of electronics and automation ushering in a "*golden age as one of complete metamorphoses or translations of nature into human art.*"[152] Such pronouncements, however, served mainly as seductive generic statements for the artists of his epoch searching for liberation of traditional art forms.

More intriguing and useful for the translation of materialities approach and the current dichotomies hovering around media and cultural studies, is the contribution of computer engineer and philosopher Yuk Hui. Hui has elaborated the idea of transduction as a simondonian third alternative for media philosophies and practices based on apparently opposed poles: those that nurture an understanding of media as an artificial and purely empirical realm versus those that propose a "media-technological a priori" perspective, such as the Berliner New materialist media school.[153] According to Hui, the first is based on inductive logic, where one begins with a series of facts and induces a rule that governs all of them ("*from facts to truth*"). The latter, based on deduction, when one departs from a general rule and deduces facts that accord with it ("*from true to facts*").[154] Hui's alternative way of reflecting on media aesthetics is through the logic of transduction, which enables one to think about the transformative and ruptural effects of digital media, rather than the inferential ones mentioned above. As "*effects of induction and deduction*", Hui adopts the term 'transduction' from Simondon's theory of individuation, referring to it as "*a process or actions that leads to the transformation across different domains*"[155]. This harkens back to Decartes' description of the pineal gland as the transductive corporeal element responsible for connecting soul and body, translating stimuli and language; as well as the definition used in engineering, which defines a transducer, similarly to Fraden, as "*a device for converting energy from one form to another for the purpose of measurement of a physical quantity or for information transfer*".[156] In simondonian terms, the technical meaning is kept as a means of communication and transmission across all scales and organizations of matter activity, addressing physical, biological, mental and social operations.[157]

The light-to-sound translations here exemplified in media artworks and devices were intended to provide a glimpse of some of the methods that creative agents use to connect materials and meanings while creating their media devices and artworks. They represent artists' commitment to meaning attribution by responding

151 Ibid: 63.
152 Ibid: 65.
153 Hui 2015: 3.
154 Ibid: 6.
155 Hui 2015: 11.
156 Ibid: 12.
157 Hui 2015: 11-12.

to and manipulating the cultural objects of their time. Within these circular exchange processes, material and semantic connections are organized in the form of artworks that aim to engage in dialogue with audience's sensorial and cognitive apparatuses.[158]

Investigating the immaterial-material relationships between media artworks and audience has constituted the core of queries by modern and contemporary media and aesthetic philosophers. Jean-François Lyotard (1924-1998), e.g., at the time he curated the media art exhibition *Les Immatériaux* (Paris, 1984) had just finished writing *Le Différént* (1983), a book in which the author also addressed translation issues and discussed the unsolved problem of the "*lack of rules or metanarratives which are common to two different systems of discurses*"[159]. Aiming to review the history of the so-called 'linguistic turn' by analysing the philosophy of Kant and Wittgenstein, Lyotard reflected on the interconnection of terms and their origins, revealing the common origin of 'matter' and 'matrix'.[160] Considering that language was what changed most after the conquering of the ïmmateriaux"[161], Lyotard's diagram is also a platform to approach a broader comprehension of what language is, beyond the representational tradition of linguistics and semiotics, as has been asserted by Klaus Krippendorff, among others.[162] According to Krippendorff, although the linguistic turn has demolished the Cartesian binary of objectivity and subjectitvity[163], its analytical tools have not provided solutions to post-modern issues.

Concomitantly to the reorganization of the technological environment, the postmodern concern with the material-conceptual dichotomy has led to the emergence of new materialist perspectives, such as that of Hans Ulrich Gumbrecht (1948-), which call for a return to the material aspects of communication. In a critique of the Western development of knowledge construction based on the abstract instance of meaning attribution, Gumbrecht defines materialities of communication as "*all those phenomena and conditions that contribute to the production of meaning, without being meaning themselves*"[164]. Developing the concept of "presence"

158 Sensorial and nerve cell interconnections and their biochemical processes have been studied by neuroscience with great effort, as was examined in the previous chapter in the context of explanations on the material basis of and intimate relationship between human sight sense and cognitive processes. They constitute the material level of mental representations and meta-representations that underlie any perception of the world, including that of artistic practices.

159 Hui, Yuk; Broeckmann, Andreas. *30 years after les immateriaux*. Germany/Milton Keynes, UK: Meson Press, 2015.

160 Hui and Broeckmann 2015: 11.

161 Ibid: 14

162 Krippendorff 2011: 9.

163 Regarding "*the claim of a knowable world (an ontology) existing outside of us, which we are supposed to represent as accurately as possible inside of us or in writing*". (Krippendorff 2011: 9)

164 Gumbrecht 2004: 8.

as a spatial rather than a temporal notion, Gumbrecht connects the history of media and body culture, contending that meanings, as abstractions, cannot be analysed separately from their mediality[165] and, therefore, from their materiality. Although originally from the field of literary criticism, Gumbrecht's viewpoint has special significance for producing and analysing media artworks, which can be understood as mediated aesthetic experiences that arise precisely from the tension and oscillation between "presence effects" (concrete) and "meaning effects" (abstractions).

This collection of references and the examples of light-to-sound translations permit one to grasp how the construction of material-based translations reveals human beings as generators of cultural objects in a way that cannot be understood from a platonic perspective that separates the world of ideas from the physical world. To look at the interplay between materiality and immateriality demands a post-humanist endeavor like the agential realism proposed by Karen Barad, who deals with matter (such as meaning) not as a static entity but as a doing, with an on-going historicity and as part of the constant stabilizing-destabilizing activities of all forms of agency in the world. A post-humanist approach, however, does not extinguish human activity and responsibility in those translational processes. On the contrary, within the artistic context of programming matter and meaning, the inherent immaterial and material contiguity of cultural and artistic artifacts also becomes a human existential issue:

> The abstract, objective, problematic circumstance, can be 'informed', and result in Venus of [W]illendorf (sic), in flint knife, in 'culture'. Manipulation is the primordial gesture; thanks to which the human being abstracts the time of the concrete world and transforms oneself into an abstracting being, that is, into man as such".[166]

By observing the complex interplay between the material/technical and conceptual/aesthetical layers in the case studies of light-to-sound translations, and in light of selected translation theories, four main topics deserve to be further developed as a conceptual toolbox to orient the creation of translation-based media artworks. They are: (1) the paradox of (un)translatability; (2) the abstract instantiations (represented by Walter Benjamin's (1892-1940) "pure language" in *The task of the translator* (1923)[167] and Vilém Flusser's notions of metalanguage or zero-dimensionality); (3) the inventive dimension of translation (represented by Ezra Pound's (1885-1972)

165 Gumbrecht 2004: II.

166 From the original excerpt in Portuguese: *"A circunstância abstrata, objectiva, problemática, pode ser 'informada'e resultará em Vênus de Nillendorf (sic), em faca de sílex, em 'cultura'. A manipulação é o gesto primordial; graças a ele o homem abstrai o tempo do mundo concreto e transforma a si próprio em ente abstraidor, isto é, em homem propriamente dito."* (Flusser 2008: 16, Translated by the author)

167 First published in English in Arendt, Hannah (Ed.) Walter Benjamin, Illuminations. Harcourt Brace Jovanovich, 1968.

Make it new! and Haroldo de Campos'(1929-2003) term 'transcriação'); and (4) self-translations, touching on existential sources and implications.

3.3.2 (Un)translatability

The devices and artworks here described assist in perceiving how subjectivity and choices are the foundations of translation practices. As long as each system has its own structure, it seems impossible to always find exact correspondences in translations. The same applies to the difficulties in translating poetry. Nevertheless, translations of all kinds have been made and translators struggle to find the most convenient correspondences, according to their understanding of the "soul" of the matter being translated. From written poetry to media artworks the paradox of translatability/unstranslatability becomes especially complex when aesthetic factors are involved.

Walter Benjamin, in *The task of the translator,*[168] analysed literary and written language-based translations in terms of a series of oppositions: between good and bad translations, content and form (translation is a form), original and translation[169] (probably biased by the experience of the auratic work of art and its reproductibility[170]) etc. However, the development of his argumentation points to a more complex situation and is sustained by a sort of paradoxical and ironic style[171]. Since Benjamin wrote this text in a radically different technological environment, it is interesting to notice, through the terms and metaphors that he uses, how the perspectives on translation mirror their contemporary philosophy of technology. Rereading Benjamin today requires setting aside dated issues – such as the hierarchical and servient relationship of a translation and its original – and retaining those that remain current: translatability is one of the topics that has been most discussed by subsequent theorists, who indeed have frequently established direct and indirect dialogues with his thought.

Poet, essayist and translator Haroldo de Campos has, in connection with Benjamin's theory of translation, also addressed the dogma of unstranslatability. Benja-

168 The extensive intellectual production bridging Benjamins's work and the changes triggered by electronic, digital and networked technologies is well known. A direct reference is Nichols, Bill. The work of art in the age of cybernetic systems. In: Wardrip-Fruin; Montfort, Nick (Ed.) *The New Media Reader*. Cambridge, MA/London, England: The MIT Press, 2003.

169 "*If translation is a form, translatability must be an essential feature of certain works.*" Benjamin, Walter. The task of the translator. In: Bullock, Marcus; Jennings, Michael W. (Eds.) *Walter Benjamin - Selected Writings* Vol.1 1913-1926. London/Cambridge, MA: The Belknap Press of Harvard University Press. 2002. [1968] p. 254.

170 Benjamin, Walter. A obra de arte na era de sua reprodutibilidade técnica. In: *Obras escolhidas I.* São Paulo : Brasiliense, 2012 (1935/1936) pp. 179-212.

171 In agreement with Haroldo de Campos' perspective in: *Da transcriação : poética e semiótica da operação tradutora*.

min, using the rethorical tools of his *Zeitgeist,* approached translation as a unilateral process, completely excluding the reception of the text (or artwork), making the development of his arguments easier. In dialogue with Benjamin, Haroldo de Campos suggests as alternative approach based on the communication model developed by Roman Jakobson in *Linguistics and Poetics* (1960). Supported by the contributions of the physicist Niels Bohr, Jakobson states that "*every cognitive experience can be translated (is conveyable) and classified in any existent language*"[172], assuming the referential and cognitive functions of language, as the metalinguistic operation embedded in the expressive faculty of any given language.[173]

Although Jakobson expands the notion of language by focusing on the operationality of language and envisionsing a metalinguistic level of communication based on the material activity of neurological processes, he still sets aside translation processes that occur among organisms that do not depend on developed neurologic systems. These organisms, although not communicating on the human semantic level, are also constantly transducing and translating physical information and the resulting resistence variation of their molecular activity can certainly serve as relevant information to engage and communicate with other entities pertaining to the same *millieu*. From a second-order cybernetic perspective, analysing the transference of elements from one system of logic to another cannot be separated from the circular processes of information exchange among the involved actants, which have their specific organization and means of signaling.

For Haroldo de Campos, the notion of translatability in Benjamin's theory refers to the conventional idea of textual translations: translatability is evaluated according to the "way of formingßuggested by the original text, according to its density and not according to the simple meaning to be communicated. In Benjamin's view, the translatability factor is conditioned by the quality of the text to be translated. Campos, in turn, understands translatability through proportional relationships: the lower the value of the language of the original, the higher its potential for communication is, and the less it has to offer and be enriched by the act of translation. In contrast, the more sophisticated a work is, the more it will remain translatable (in its historical relevance), though only having the most ephemereal contact with its meaning.[174] In the search for analogies to cases of the translation of materialities, Campos' perspective is partly useful, especially if one considers the attention given to the issue of the proportional relationships and to the historical relevance of media devices of various eras and the many translations and versions they have

172 Jakobson, Roman. *Linguística e Comunicação.* São Paulo : Cultrix, 1971, p. 70. (Campos 2011:19).

173 Jakobson asserts that language, as a cognitive function, depends less on its grammatical patterns than on the complementary dynamics of metalinguistic operations, which constanly demand recoding and interpretating, that is, translation. (Jakobson 1971: 70)

174 Campos 2011: 29.

inspired as a source for contemporary artists. However, Benjamin's perpective on translation as a "way of forming" makes more sense when one considers the fact that media artworks themselves (including all the media devices and artworks discussed along this chapter) can constitute a process of translation. Unfolding this idea requires another mindset, able to consider recursivity and meta-structures, translations within translations.

Furthermore, one can find correspondences between Benjamin's general notion of a 'highly developed' (sophisticated structure) work and the notion of 'aesthetic information' theorized by the cybernetician Max Bense. Regarding the elements to be translated, Bense distinguishes three different informational layers: documental, semantic and aesthetic.[175] Although closer to the current technological environment than Benjamin, Bense's perspective fails to acknowledge the material layer of information[176], which is the very first element in his general theoretical framework for aesthetic analysis. Not addressing the material aspect of translation processes makes Bense's conception, in principle, invalid for posthumanist approaches that consider the agency of non-human entities and information exchange among living organisms without developed cognitive systems, such as the activity of matter. Nevertheless, Bense's concerns with materialities become evident when one regards his notion of the fragility of aesthetic information.[177] For Bense, aesthetic information is inseparable from its concretization, *"its essence, its function are bound to the tools, to its singular execution,"*[178] and its fragility in aesthetic contexts lies in the ephemerality of both the performative act and its reception. By emphasising the real-time and material aspects of aesthetic information, Bense's cybernetic perspective offers the most suitable path to deal with media artworks based on translations of materialities, whose significance is mostly found in the act of translating itself. In this sense, translating is feasible as long as one commits to doing it. Returning to the examples of light-to-sound translations in terms of Bense's classification, reproducing the principles of classical media devices relates the artworks to the documental layer of the "originals"; whereas translating itself refers to the aesthetical information layer per se.

Regarding the translational operationality of media, one can venture to say that electronic and digital technology and their zero-dimensionality have become the sort of meta-metalanguage through which one manipulates matter in the form of

175 Information is defined by Bense as "*every process of signs that presents a level of order*" (From the excerpt in Portuguese: "*é todo processo de signos que exibe um grau de ordem*". (Campos 2011: 32)

176 Ranging from energy and electric signals to any other space-time configuration and/or modulation.

177 Plaza 2003: 28.

178 "*sua essência, sua função estão vinculadas a seu instrumento, a sua realização singular*". Bense, Max. Das Existenzproblem der Kunst. In: *Augenblick*, n.1, Stuttgart/Darmstadt, März, 1958. apud Campos 2011: 33.

energy in order to bridge and communicate between elements that do not operate according to a similar logic. In this sense, a set of new techniques that emerged with digital technology has compelled us to review the parameters being established through the translations of our media and cultural heritage. For Flusser, who was acquainted with both the materiality of electronic media and the issues of translation, translatability is also defined by the potency of articulations in the realm of metalaguages.

3.3.3 Metalanguage

On the one hand, when Benjamin discusses the kinship of languages in terms of the dichotomous relationship between content and language, he envisions the existence of a 'pure language' as the source of a supposed 'truth': *"A real translation is transparent; it does not cover the original, does not block its light, but allows the pure language, as though reinforced by its own medium, to shine upon the original all the more fully."*[179] Benjamin's notion of 'pure language' entails a univocal and absolute view of knowledge, making his position incomparable to the multiple levels of abstractions that are technically possible today, and therefore outdated to the contemporary mindset.

On the other hand, one might immediately associate Benjamin's notion of 'pure language' to the abstract instantiation that his successors call 'metalanguage': an in-between space where the paradox of translatability takes place, addressing both the illusory fidelity to the original material and the translator's freedom. For Benjamin, fidelity[180] and freedom seem to constitute conflicting values – the classic object-subject clash. Acquainted with the practice of self-translation, Flusser's writings do not contain evidence of this conflict, in fact they demonstrate his appreciation for freedom in relation to the act of translation. Although recognizing the translatability paradox, he assumes freedom to be the utopian engine triggering translation processes. According to him:

> The admission of the diversity and equivalence of languages occurs, in a certain way, beyond all languages. It is given in that terrain between languages and beyond the languages that the term translation conveys. The problem of translation is therefore the problem of transcendence, abandonment of prison, being beyond all models. In other words: it is the problem of freedom.[181]

179 Benjamin 2002: 260.

180 In the translation of materialities it becomes non-sense to discuss the issue of fidelity, which I would venture to relate, in the media context, to verisimiltude.

181 From the excerpt in Portuguese: "*A admissão da diversidade e equivalência das línguas se dá, de certa maneira, no além de todas as línguas. Dá-se naquele terreno entre as línguas e no além das línguas que o termo tradução significa. O problema da tradução é pois o problema da transcendência, do aban-*

The terms used by Flusser allow one to easily transpose his ideas from spoken and written language to electronic and digital media. Regarding the aporetic condition of translatability, Flusser states that *"translation is possible (says our theory) insofar as there is a metalanguage for the language of which and to which we are translating, common to both"*.[182] Are not electronics, coding and programming the metalanguage that humanity has been longing for since the tower of Babel?

To a certain extent, the collection of devices and artworks brought into this discussion constitute the basis for an historical perspective on the emergence of coding through audiovisual media, and the increase in complexity found in the passage from analog to digital media – ranging from the very material fragmentation of light beams using choppers, through the signal discretization of Morse code to more sophisticated programming languages like as Python in Computer Vision applications. The variety of ways to handle materials reveals both the freedom one has to transit between different physical dimensions and how this process led to media convergence: an occurrence boosted and technically enhanced by the digital technology and the cultural movement towards ever increasing levels of abstraction. In this sense, Flusser's concepts of zero-dimensionality and *Mediumsprünge* correspond, respectively, to metalanguage and translation processes.

There is much for media artists to explore through the zero-dimensionality of electronic and digital media embedded within contemporary cultural objects. Operating with the common denominator of electric or/and electrochemical changes in materials, media artists are simultaneously, and paradoxically, empowered with freedom and arbitrariness. The initial absence of meaning located in the gap between two systems, as found in the translation of materialities, gives artists an extreme range of possibilities to arbitrarily invent all possible correspondences. The question to pose is, What are the implications of this condition regarding the creation of translation-based media artworks? Flusser radically contended that if there could be a metalanguage as a class for all other languages, it would only be possible through an excessively violent effort to communicate.[183] He continues: *"this universal class will be destitute in such a way until it loses all its meaning. In other words: maximal freedom makes every choice absurd, because it lacks meaning."* [184] The question can thus be reframed as follows: While attributing meaning to the zone of absence

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dono da prisão, do estar além de todos os modelos. Em outras palavras : é o problema da liberdade". Flusser, Vilém. Da tradução. In : *Cadernos Brasileiros* n.49 Set/Out 1968. p. 77.

182 From the excerpt in Potuguese : "*A tradução é possível, (diz esta nossa teoria), na medida em que há uma metalíngua para a língua da qual e para a qual estejamos traduzindo, comum a ambas*". (Flusser 1968 : 78)

183 Ibid : 80.

184 From the excerpt in Portuguese : "*Mas essa classe universal será de tal maneira pobre a ponto de perder todo significado. Em outras palavras : a máxima liberdade torna toda escolha absurda, porque isenta de significado.*" (Flusser 1968: 80)

between systems in translations, are media artists able to establish and maintain coherence and consistency?

Philosophically speaking, if there is a universal language, or a metalanguage to use Flusser's terms, to which all languages are related, it could well be the laws of physics, and out of it the emergence of human feelings and mental activities.[185] In the arts, designing the interactions between materials and meanings on a metalevel seems to be the central challenge facing artists. Nevertheless, accepting these general statements leads back to absolute values of conceptions such as pure language, truth, or even the notion of god, i.e. it refers us back to a universal entitity existing above all else. Against any sort of absolute perspective, Flusser's analysis pleads for the use of metalanguages that emerge in relativized and specific situations.[186] The diversity of light-to-sound translations in media artworks and devices discussed in this chapter illustrates how specificity is shaped by context and context by specificity.

This perspective has been highlighted in both the context of translation and art by a variety of authors using different conceptual frameworks: For Bense, the aesthetic and semantic layers of art are initially separate and are only defined through the practice[187] within the specific contexts of the artworks. Bejamin's conception of translation as a form contends that the reproduction of meaning regarding its poetic significance *"is not limited to what is meant but rather (...) to the way of meaning"*.[188] For Simondon, specificity and the transformative processes are merged in what he calls individuation processes, which according to him happen through transductive activities.[189]

From a technical perspective, the artificial intelligence research conducted on the neural networks behind Google Translator that invented their own language[190] is a very instructive example that seems to confirm both Flusser's prediction of the meaninglessness of maximal freedom and the importance of context and specificities. The machine language that emerged is completely incomprehensible to the

185 Deacon, Terrence William. *Unconplete Nature: How mind emerged to matter.* New York/London: W.W. Norton & Company, 2012.

186 Flusser 1968.

187 Bense, Max. Einführung in die Informationsästhetik. In: Ronge, Hans von. (Ed.) *Kunst und Kybernetik: ein Bericht über drei Kunsterziehertagungen Recklinghausen 1965, 1966, 1967.* Köln : DuMont Schauberg, 1968. p. 28-41.

188 Benjamin 2002: 259-160.

189 Simondon 1958: 95; *"Transductive operation is an individuation in progress"* (Simondon 2005: 32-33 apud Hui 2015: 12).

190 Coldewey, Devin. Google's AI translation tool seems to have invented its own secret internal language. In: *Techcrunch.* Nov, 23rd 2016. Available at <https://techcrunch.com/2016/11/22/googles-ai-translation-tool-seems-to-have-invented-its-own-secret-internal-language/> Accessed April 5th 2018.

machine's creators. The in-between language itself is not interesting to an external observer, but what is relevant is its ability to bridge between languages. This bridging operation has proven to be a convenient strategy for specific purposes in specific contexts.[191] This is an excellent example of the cybernetic model of the black box and an illustration of the the impossibility of making it transparent, as Ranulph Glanville has shown. The envisioned metalanguage is likewise a black box as an epistemological object.[192]

A complementary perspective that takes the work of philosopher Jacques Ellul (1912-1994) and technological society as its points of departure is provided in Yuk Hui's discussion of the desymbolization process that occurs in the growth of technological systems, which necessarily implies the creation and attribution of new symbols. Hui suggests that the desymbolization-resymbolization process he depicts *"may sound similar to Ernst Cassirer's well-known proposal that culture is a constant movement between forma formata (structured structure) and forma formans (structuring structure)"*[193]. If the essence of digital media is the programmability that it entails, software and coding, as metalanguages, can be regarded as *"the technique of providing a dynamic background to control the automatic evolution of meaning."* [194] Such a perspective pushes the understanding of the translation of materialities as a form of transcedental empiricism, a practice that moves towards meaning attribution processes.

Attaining the ability to manipulate matter and language on a deep abstract level has obliged mankind to find a common term for it. The term systems has filled this need and served to enable interdisciplinary research and communication possibilities. The openess of the notion of systems enables, for instance, the present cultural study to identify and analyse biological and engineering approaches in relation to photosensitive elements through their similarities and analogies, such as stimulus uptake, transformation, stimulus transduction and encoding processes.[195] In the space between nature and culture, human beings work hard in decoding other

191 Viégas, Fernanda; Wattenberg, Martin; Corrado, Greg; Hughes, Macduff; Dean, Jeffrey. *Google's Multilingual Neural Machine Translation System: Enabling Zero-Shot Translation.* November 14th 2016. Available at <https://arxiv.org/pdf/1611.04558v1.pdf> Accessed April 5th 2018.

192 Glanville writes: "*The Black Box does not exist and you can't get inside it. The Black Box is a thought experiment. (...) The point of the Black Box is precisely that it allows that you don't know. The Black Box is something which almost institutionalized ignorance. So at least in that respect if I use the Black Box as a model then I can talk about it because the Black Box is about starting in spite of not knowing*". Glanville, Ranulph. Grounding difference. In: Müller, Albert; Müller, Karl H. (Eds.) *An Unfinished Revolution? Heinz von Foerster and the Biological Computer Laboratory | BCL 1958-1976.* Wien: Echoraum, 2007. p. 369.

193 Hui, Yuk. Technological system and the problem of desymbolization. In: Jéronimo M. Helene (Org.). *Jacques Ellul and the technological Society in the 21st Centrury*, 2013, p. 74.

194 Goldsteine and von Neumann 1947 apud Chun 2011: 25.

195 Barth et al 2003.

beings and encoding and recoding what they have learned in cultural objects. This constitutes a limited transcendence, since one necessarily faces the physical limits of materials. However, through experiencing these processes one comes closer to comprehending the universal dynamics of matter activity.

Benjamin also adopted a pertinent physical metaphor to refer to translations when he stated that "*Fragments of a vessel that are to be glued together must match one another in the smallest details, although they need not be like one another*"[196]. Despite referring to a sort of "reproduction of sense" and implicitly opposing an auratic original to a less valued translation, Benjamin's metaphor offers a powerful way to consider the translation of materialities in media art. It recognizes the two types of gaps: the gap between two vessels and the gaps between every piece that is glued together to form a structured unity. The vessel is only one model[197] of countless possible vessels, the rules and materials structuring the pieces are also chosen from a variety of other possibilities, and the most attractive aspect of Benjamin's metaphor is its own limitation as metaphor. It does not consider the temptations that artists face to explore other unknown existing possibilities to shape a vessel, or even, to shape other interesting objects that are not a vessel. Media artists dealing with translation of materialities should neither be concerned about betrayal and loss of information nor about verissimulitude. Translating materialities might be the most valuable exercise for becoming aware of gaps as creative sources, as open spaces for the emergence of novelty. The translation of materialiaties is a means of invention. Translation of materialities is transcreation.

3.3.4 Transcreation

"Transcreation"[198] is a term coined by Haroldo de Campos[199], who was very influenced by Benjamin's writings[200] and Ezra Pound's (1885-1972) "*Make it new!*" (an influential work within the US-American modernist literary movement).

196 Benjamin 2002 [1923]: 260.

197 Flusser also comprehends the language as equivalent to a 'model of reality' opposing his theory to those that consider the act of translation as referring to reality, as Benjamin tended to. (Flusser 1968 : 79)

198 Campos, Haroldo de. *Da transcriação poética e semiótica da operação tradutora*. Belo Horizonte: FALE/UFMG, 2011.

199 Flusser, who was involved with Brazilian concrete art and poetry, translated Haroldo de Campos' series Galáxias (1963-1976), together with Anatol Rosenfeld, for the edition rot 25, implementing a transcreative method. See Jürgen, Claus. Brasilianische Intelligenz: Zwei Charismatiker der cartesianischen Welt: Max Bense und Vilém Flusser. In: Zielinski, Siegfried; Irrgang, Daniel. *Bodenlos - Vilém Flusser und die Künste.* Berlin: Akademie der Künste, 2015. pp. 37-45.

200 Campos 2011.

Pound's practice and theory of poetry translation[201] rejected the former Victorian tradition in the English language and experimented with an array of methods for the developement of his own poetic style based on free-verse translations of classical works. For Pound, each translation was a sort of criticism of the original, revealing both its strengths and limits. In this sense, Pound believed that translators must not necessarily reproduce all aspects of the original, pleading for the freedom to rearrange the material according to one's intentions. By addressing the aporetic possibility and impossibility of translations in practice, Pound created a modernist scandal. His translations of ancient Chinese poetry are emblematic.[202] Since Pound could not properly speak or read Chinese, he invented his own way to translate the very imagetic language, which caused him to be severely criticized as a translator but praised as a poet.[203] Pound's proto-multicultural practice points towards the asymmetries in translating, planting the seeds for a decolonial perspective.[204] An astute comment by T.S. Elliot regarding Pound's practice is relevant to the current translation of materialities being done by media artists: "*Pound is the inventor of Chinese poetry for our time. I suspect that every age has had, and will have, the same illusion concerning translations. (...) Each generation must translate for itself.*"[205]

It is impossible not to notice the suitability of the US-American modernist movement to the anthropophagic and neo-baroque characteristics of Brazilian art and culture in the 1960s. These expressions show that the emphasis of avant-garde movements is not the exclusion of tradition; but rather its renewal, provoking the dissolution of absulute truths, which are purely historically created human constructs. De Campos, ignoring the referential and merely functional sorts of translation, contended that the more difficult the author, the more translatable s/he is. In his view, only the possibility of recreation and reinvention is interesting for the artist as translator.

Transcreating from the original texts using modernist attributes implied the use of free verse, spatial disposition of the words, decomposition and exploration of their phonetic aspects, and the use of neologisms. Light-to-sound translations

201 Alexander, Michael. Ezra Pound as translator. In: *JSTOR*. Edinburgh University Press: Vol.6 N.1 1997. pp. 23-30.

202 Influenced by the work of the orientalist Ernest Fenollosa, Pound, in the essay The Chinese Written Character as Medium for Poetry (1919, provides) the foundations of his poetically fruitful method of creative translation which was considered a scandalous misunderstanding of Chinese language by critics. (Williams 2009:146)

203 Williams, R. John. Modernist scandals: Ezra Pound's translations of 'the' Chinese poem. In: Sielke, Sabine; Kloeckner, Christian (Eds.) *Orient and Orientalisms in US-American Poetry and Poetics.* Frankfurt/M: Peter Lang, 2009. pp. 145-165.

204 Language is considered *"a collective force, an assemblage of forms that constitutes a semiotic regime"*, as *"site of power relationships"* susceptible to minoritizations and domestifications of languages. (Venutti, Lawrence 1998:9 apud Williams 2009:148)

205 Eliot, T.S. 1928:15-16 apud Williams 2009:147.

operate similarly, adding materials and devices, becoming a tiny fragment of the history and archaelogy of media convergence. Material translations have been increasingly prevalent with the development and dissemination of a sort of universal metalanguage (calculating and programming). The sources of inspiration are much broader than a single material or technical source, and meaning is created by artworks in the process of being constructed and/or performed. In this sense, despite the aesthetic values of the sound compositions that have been generated, the exhilaration experienced by those creating and enjoying light-to-sound translations slips to the 'making it happen' moment, and, like Pound, to the act of making it anew. In the context of art history, one can identify this sort of media art practice as a branch of concrete art and poetry, where the weight of words' meanings often loses its singular importance in space- and time-based contexts, as demonstrated by the Brazilian Noigandres group[206] and Raoul Hausmann in his phonetic poems. The zero-dimensionality of metalanguage requires embodiment in order to communicate. However, although transcreativity permits media artists to reset and recombine elements in a metalanguage, their works are not released from the dimensions of space and time, where relational and dynamic characteristics need to be managed to frame possible channels of communication.

Translation-based media-archaeological artworks merge past and future in the immediate present. Translating is the most ambitious form of reading history, since it is a productive type of consumption, as Julio Plaza puts it in his reflections on intersemiotic translations.[207] Translations encourage reinvention both by re-reading and estabilishing continuity to the way of imagining of past media inventors. In this sense, too, Pound's practice remains pertinent. Hugh Kenner, in the introduction to Pound's *Tranlations* observes: "*Translating does not, for him, differ in essence from any other poetic job; as the poet begins by seeing, so the translator by reading; but his reading must be a kind of seeing*"[208]. Analogously to poetry translation, the translation of materialities in media artworks is essentially sustained by the role of imagination. Especially because they aim to animate matter, translation-based media artworks become alive like new poems. Active matter, active poetry.

Nevertheless, due to the several layers of abstraction between the input and output of media artworks[209], one cannot immediately perceive the metalanguage operating. In most cases, understanding (if possible) which elements of the translations are generated, emphasized or omitted, requires posterior analysis of circuitry, software and the other rationalization models that enabled the installation or performance. Returning to the light-to-sound conversions mentioned, one

206 Plaza 2003: 12.

207 Plaza 2003: 2.

208 Kenner, Hugh. In: Pound, Ezra. *Translations.* New York: ND Paperbook, 1963. p. 10.

209 Except in cases of live coding performances. The aforementioned *Stofftonband* is also partially such an expression.

sees that part of the challenge of analog translations (*Photophone*, *Fotoliptófono*, *Optophone*, etc.) was matching the necessary material conditions to extract desirable sounds out of light; whereas in the digital-based translations (*Phonotube,* Neil Harbisson, and *Self-portrait of an absence*) the programmability increased the potential for arbitrarity and imagination almost infinitely.[210] In the latter cases, additional elements of specific context were required, aggregating recognizable information (meaning attributed via pattern recognition) to enable the handling of absence and the execution of the translation process itself. In *Self-portrait of an absence*, e.g., light variation entering the camera is turned into data as the eyes' movements and the difference between them is turned into relevant information to be later transformed into sound. In Harbisson's case, light variations are decomposed into luminance and chrominance to form a color system to be codified as sound, which then emerges as relevant information in Harbisson's skull and auditory system.

Although described here in a very summary way, these processes elucidate the arbitrary steps taken while programming matter and meanings. From input to output, without neglecting the circularity between them, stimuli become information as they are fragmented in several layers of abstractions (holes in the chopper, variables, functions, protocols, etc.) able to be recognized through constancies and variations, and all the derivative parameters and categories one can articulate from them. It becomes clear that in the case of the translation of materialities one is dealing with many more in-between layers of abstraction (models, software, etc.), which provokes an increase in the level of complexity. This is one of the main issues facing translatability in relation to physicochemical phenomena.

The technical ensembles based on light-to-sound translations discussed above thus identify photosensitive matter as one of the ways in the history of media to approach the programmable and dynamic quality of matter and the margin of indeterminacy existing in the absence between two logical systems. Exploring the void between two systems, the notion of transcreation with materialities emphasizes the inventive aspect of translation. Within the terrain of the gap and its uncertainties, Flusser's view of translation as play, in addition to pointing out its motivating joyful aspect, frees the creative translating act (transcreation) from the objective-subjective dichotomous relationship. Rainer Guldin summarizes this aspect of Flusser's theory as follows:

> Translating is a practical philosophy that can best be explained by the concept of playing. The translator is a player who installs himself in a regulated playful totality that, although it surpasses his subjectivity, does not exclude it. The player follows rules that he has to accept if he wants to play.[211]

210 "Almost" because one cannot simply get rid of the material limitations.

211 From the excerpt in Portuguese : "*Traduzir é uma filosofia prática que pode ser mais bem explicada pelos conceitos de jogar. O tradutor é um jogador que se instala em uma totalidade lúdica regrada que,*

Flusser's viewpoint addresses the substantive aspects of the translation of materialities more directly, especially how the 'regulated rules' of grammatic and semantic webs can be expanded to the physical and chemical rules that structure and shape the material world. Morever, the dynamic processes entailed by creative action give the notion of "playä special siginificance for the arts, and within the aesthetic realm this notion is able to transcend the dichotomous relationships of absolute values such as right or wrong, good or bad, etc. to point towards always changing hypotheses of translating.[212]

3.3.5 Self-translation

As a polyglot with an immigrant background, Flusser's philosophical method evolved naturally through the practice of self-translations and retranslations. He considered the metalinguistic in-between space confronted during the translation process as a sort of abyss – a metaphor that he stressed in his media theory in the context of the concept of *Mediumsprünge* but also applied on an existential level.[213] In contrast to what he considered the naïve reality-based theories of the past, Flusser understood language as a model of reality[214] – expressed in the form of dictionaries and comparative grammars – and hence for him the act of translation deals with structures that transcend both the source and target languages. Following this logic, Flusser concluded that "*translation is the transcendence of models of reality*".[215] This statement is especially strong if one takes into account his biography: he was forced to immigrate in order to escape the nazi regime, and this experience influenced several aspects of his philosophy.

If the creative act of translation through its direct relation with a metalevel is a transcendent act, one may use this suspension of space-time to creative purposes. Similar to Haroldo de Campos' position that the target language should be subjected to the wild wind of the foreign language as a means to enlarge its own borders[216], Flusser metaphorically calls one's native language a 'prision' suggesting

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embora supere sua subjetividade, nem por isso a exclui. O jogador segue regras que ele tem de aceitar se quiser jogar" (Guldin 2010: 98, translated by the author).

212 Guldin 2010: 98.

213 Guldin 2010: 31.

214 Several other theorists have resisted the objectivity of translation, such as Robert Kern, who stated: "*successful translation, or what passes for it […] is always a matter of temporal and linguistic localization, a perception of the foreign limited by an inescapably provincial or ethnocentric perspective*" (Kern 1996: 4 apud Williams 2009: 148).

215 From the original in Portuguese: "*tradução é a transcendência dos modelos de realidade*". (Flusser 1968:79)

216 In dialogue with Benjamins's example of Pannwitz's statement in *The task of the translator*, that: "*The basic errors of the translator is that he preserves the state in which his own language hap-*

that the possibility to think in another language is an opportunity for self-expansion. If the possibility of translation is a mark of one's freedom, its impossibility is a mark of one's conditioning; and since the return to the actual language is unavoidable, Flusser deemed the act of translation as a form of limited transcendence.

Other media theorists, each in their own specific terms, have addressed the transgressive power of media. McLuhan did so by generally considering media (as well as language) as a human extension, albeit with the recognition that extensions also imply also amputations.[217] As part of a more specific and complex line of argumentation Simondon addressed the transgression of technical objects through explanations of their individuation processes and their ihnerent interactions with other associated objects, ensembles or *millieux*. He deemed that the material limit of a technical individuum is not a functional limit and pointed out the existence of relative levels of individuation, which are a necessary condition for the technical object to mantain its independence within a self-regulated system.[218] Simondon also comprehended that a "*transductive operation is an individuation in progress*"[219]. Hui, interpreting Simondon's thinking, proposes that "*transduction demands a system that is already energetic and ready to undergo a structural transformation. Such a system is neither fully open nor closed, since it depends on the compatibilities between the incoming elements and the system itself.*"[220]

Analogously, as discussed by Paul Ricoeur,the desire to translate[221] might correspond to the pre-existing tension that triggers an individuating and transductive movement, as a material activity in search of a more stable status.[222] In this sense, creating media artworks based on translations of materialities is a transformative act, and the continuity of the practice can be a method for self-cultivation. Flusser, who adopted translation as his philosophical method, contended that, through the translation practice, as in a spiralic evolution, upon returning to the language of departure one comes back to a more maleable, plastic and extended prision.[223]

Regarding the potential energy between systems in translation, whether in the artistic urge to express or in the desire to translate, Flusser poses a crucial question:

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pens to be instead of allowing his language to be powerfully affected by the foreign tongue". (Pannwitz apud Benjamin 2002 : 262)

217 McLuhan : 1964.

218 Simondon 1958 : 77-80.

219 Simondon, Gilbert. *L'individuation à la lumière des notions de forme et d'information.* Grenoble: Millon 2005. pp. 32-33.

220 Hui 2015: 12-13.

221 Ricouer, Paul. *On translation*. London/New York: Routledge Taylor & Francis Group, 2006. p. 21

222 Hui 2015:12.

223 Flusser 1968: 81.

"How can I transform the limited freedom offered by translation into significant action?"[224] This question applies equally well to the contemporary translations of materialities being executed by media artists.

The role of absence as creative matter and potential was not discussed above by accident. The in-between space achieved in translation processes is very close to the vacuum of one's own meaningless existence. Translations are therefore an existential reaction aimed at making the life of mankind, which is in principle meaningless, less painful. When Benjamin suggests looking at life beyond our biological limits, extending it to the scale of history[225], he approaches the biological impetous behind the human cultural practice of knowledge production and transmission through the attribution of meaning and the emergence of significance – a mysterious and multifaceted survival strategy.[226] In this sense, Neil Harbisson's work and *Self-portrait of an absence* present multiple levels of self-referentiality: they refer primarily to absent elements of idealized standard human vision, but also to the absence of meaning initially present in the gap between the input and output sides of the artwork's systems, as well as to the artists own effort to make sense of their individual existence.

At first glance self-referentiality might sound pretentious. However, this initial impression dissolves once one overcomes the Renaissance myth of the artist as genius and beholds them as social catalysts working hard in the continuos evolutionary process of translating sensations and materials into significant experiences. Concerning the self-critique that was begun above in relation to the ineffectiveness of *Self-portrait of an absence* at sharing the real feeling of absence, one means to handle this material aporia can be found in the elementary subject-object dichotomy of human existence, which is elegantly expressed in the cybernetic dialogue between Heinz von Foerster and Humberto Maturana. Humberto Maturana, explaining the foundations of his epistemological biology, stated, "*Anything said is said **by** an observer*"; and Heinz von Foerster added, "*Anything said is said **to** an observer*".[227]

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224 Original excerpt in Portuguese: *"Como posso transformar a liberdade limitada oferecida pela tradução em ação significativa?"* (Flusser 1968: 80).

225 Benjamin wrote: "*the range of life must be determined by the standpoint of history rather than that of nature*". (Benajmin 2002: 255)

226 Gotschall, Jonathan. *The storytelling animal*. New York: Mariner Books, 2013.

227 "*whereas I am fascinated by images of duality, by binary metaphors like dance and dialogue where only a duality creates a unity. Therefore, the statement that opened our conversation – 'Anything said is said by an observer' - is floating freely, in a sense. It exists in a vacuum as long as it is not embedded in a social structure because speaking is meaningless, and dialogue is impossible, if no one is listening*". Foerster, Heinz von. At each and every moment, I can decide who I am. In: Poerksen, Bernhard. *The certainty of uncertainty*. Charlottesville,VA USA: Imprint Academic, 2004. p. 12.

This conversation shows the inherent flux and inseparability between individual and social layers[228] in the creative process of translations, and it also resembles Paul Ricoeur's praise of the role of otherness and the coexistence of otherness in the depth of the self. Richard Kearney, in the introduction to Paul Ricouer's *On Translation*, synthetizes this view as follows:

> For Ricoeur, the task of outer translation finds echoes in the work of inner translation. Indeed the very problem of human identity, as he shows in *Oneself as another*, involves a discovery of an other within the very depth of the self. This other within is itself plural, signifying by turns the unconscious, the body, the call of conscience, the traces of our relations with other human beings, or the sign of transcendence inscribed in the deepest interiority of the human heart.[229]

Self-translations create the potential for the coincidence of subject and object. The translation of materialities in media art is a very concrete example of a transcendental empiricist exercise. This theoretical framework led to understanding the work and challenges of (media) artists as that of finding material solutions to address local-universal relationships through the interplay between metalanguage (the realm of potentiality) and language (the realm of actualization) in its most expansive sense.

Media artists often ignore their activity as translators, which implies being responsible for recognizing otherness.[230] The urge to translate comes from curiosity about the foreigner, about the alien matter. Interest in otherness concerns both the alien materiality used in artworks and the audience itself.[231] Media artists, while inscribing their modifications on models of reality that they manage to render by recombining materials and devices, can provide significance to their own existence. Just as Flusser used translation and retranslation processes as a philosophical tool to react against the absence of meaning in life, media artists can use these processes to create more meaningful artworks.

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228 At this point it is also relevant to recall the corraboration from the perspective of contemporary neuroscientists: "*there is no real person whose embodiment plays no role in meaning, whose meaning is purely objective and defined by the external world, and whose language can fit the external world with no significant role played by mind, brain or body. Because our conceptual systems grow out of our bodies, meaning is grounded in and through our bodies.*" (Lakoff and Johnson 1999:06)

229 Kearney, Richard. Ricouer's philosophy of translation. In: Ricoeur, Paul. *On translation*. London and New York: Routledge Taylor and Francis Group, 2006 [2004]. p. xix.

230 Ricoeur 2004: 25.

231 Based on Husserl's philosophy, Ricoeur writes: "*There is something foreign in every other. It is as several people that we define, that we reformulate, that we explain, that we try to say the same thing in another way*". (Ricouer 2004: 25)

The fact that media artworks can become the ultimate expression of contemporary art's self-referentiality[232] inevitably makes these artworks more hermetic. The challenges facing (media) artists thus center around the following questions: How can the extraordinary discoveries one experienced through creative translational processes be communicated in a way that enables external observers to join the jam? How can one keep the system open for further conversation, allowing meaning to emerge through experience itself among individual and/or collective bodies? Concepts, like materials, can be understood and treated as abstract machines that demand to be articulated in order to render enriched exchange processes in any aesthetic system.

3.4 Epistemological materialities

Despite technological changes, the search for significance[233] and purpose in life still constantly occupies humans, including, as Benjamin suggested, on the broader scale of history. Rationalization is one of the innate tools that humans have to learn from nature and make sense of the world and life. The body organizes the world to oganize itself, and this continuous circular dynamic consitutes the prevailing exchange mechanism between nature and culture. Framing media art through the lens of the translation of materialities was only one of the possible ways to systematize the constant stimuli and information exchange between things and beings.

Part of this sytematization has been based on the knowledge produced through the objectification and management of the senses and cognitive abilities, especially regarding the transformation of sensory experience from differences in qualities to differences in quantities.[234] Nonetheless, it is not productive either to regret or neglect the rationalization of perception. Through the possibility of *Mediumsprünge* and the notion of the translation of materialities, media artists can envision creating based on the interplay between matter, number and language; this represents an enhancement of the former paradigm of artistic creativity that considered materials as obstacles to be overcome. The complex task is then to find correspondences among the diversity of universes one places conversation with one another. Creating media artworks requires awareness of the confrontation between the metalan-

232 Within discussions on contemporary art theory, although the role of self-reflection is associated with the end of art, the role of innovation is not placed apart. Louise, Schouwenberg. Innovation as a premise of art and design education. In: Schouwenberg, Louise (Ed.) *Material Utopias.* Sandberg Series n.3. Amsterdam: Sternberg Press, 2017. p. 24.

233 *Sinngebung* in the philosophical tradition: From Flusser, through Husserl to Ricoeur.

234 As expressed by Jonathan Crary: "*this new valuation of perception, this obliteration of the qualitative in sensation through its arithmetical homogenization, is a crucial part of modernization*". (Crary 1991: 147)

guages of beings and machines. Although able to communicate, meaning attribution and translation processes tend to be distinct in machinic and living entities. As neuroscientists Lakoff and Johnson contend:

> There is no such a thing as a computational person, whose mind is like computer software, able to work on any suitable computer or neural hardware – whose mind somehow derives meaning from taking meaningless as input, manipulating them by rule, and giving meaningless symbols as output. Real people have embodied minds whose conceptual systems arise from, are shaped by, and are given meaning through living human bodies. The neural structures of our brains produce conceptual systems and linguistic structures that cannot be adequately accounted for by formal systems that only manipulate symbols.[235]

Contemporary art (including media art) is often criticized for being purely conceptual and hermetic, requiring a manual of instructions on how to experience and understand the artworks. Frequently, a media-illiterate person visits a media art exhibition and leaves the space disappointed with what one she experienced simply because she could not grasp anything that had been proposed. The media artworks currently being produced could also be seen as a sort of further stage of the *Neo Dada* movement, insofar as the freedom to articulate alien elements is immense and artists are indeed exploring radical combinations. Common examples today include installations and performances that use plants or other organisms as interfaces to process sounds or disrupt images. However, in many cases one barely notices any connections between the interface materiality, its embedded symbol(s) and the kind of sound or image being produced. Furthermore, most of these expressions lack any kind of political statement and can hardly be grouped together as an artistic movement like Dadaism was. To grasp the significance of contemporary media art, it is necessary to identify what is relevant to translate, why and, above all, how.

On the one hand, it is true that the hermeticism originating from the self-referentiality of media art does make artworks very dependent on the discourses attached to them. This is part of the knowledge construction processes, analogously to how high level programming languages refer to low level languages and so forth.[236] On the other hand, recalling Lakoff and Johnson again, artists must remember that "*there is no Chomskyan person, for whom language is pure syntax, pure form insulated from and independent of all meaning, context, perception, emotion, memory, attention, action, and the dynamic nature of communication.*"[237] Given these circumstances, the key challen-

235 Lakoff and Johnson 1999: 6.

236 Chun explains how the metonymic role of higher-level programming languages emerged, enabling developers to forget the machine. For her, the creation of metaphors in the field of informatics favours the democratization of knowledge, because it permits professionals other than hardware engineers to code. (Chun 2011: 41)

237 Lakoff and Johnson 1999: 6.

ge for artists becomes finding the clearest ways to translate their ideas, concepts and/or sensations into the materialities they are working with. This proposition is not new within art, but the increase in the complexity of the artworks demands proportionally increased attention to steering the translational process. Fernando Pessoa's sensationism theory recapitulates the essence of the aesthetic creation and fruition processes through the following circular set of statements: *"(1) Every object is a sensation of ours; (2) Every art is a conversion of a sensation into an object; (3) Therefore, every art is the conversion of a sensation into another sensation."*[238] Media artists should consider this approach while creating their artworks, posing themselves the challenge of how to create artworks that do not depend on parallel explanations and permit access to the abstract operations that they are mobilizing.

It is possible to consider media art as a sort of material philosophy and media artworks as epistemological materialities, but merging sensorial experience and philosophical questions requires a logic for handling the organizational systems of each.[239]Tackling these issues requires reflecting upon the primary elements of communication, one of the reasons for the existence of artworks. If communication is understood as the exchange between systems in the interest of shared understandings, the role of structuring and structured information, such as spatial configuration, rhythm, metaphors,narratives, leit motives, etc., is crucial. They are key elements to trigger curiosity and empathy in the reception of aesthetic experiments.

Artistic problems become more complex when meaning attribution and the question of a work's reception come into play. Since this is unavoidable, instead of adopting Benjamin's premise that an artwork is not intended for the audience[240], it seems more fruitful to adopt the cybernetic perspective on the interaction between observer and object as well as the efforts required to match the space-time frame of interaction for mutual understanding of a shared reality.[241] The artworks can themselves be invitations for dialogic engagement through meta-structures able to frame and match realities, rendering ephemeral channels of communication during the interaction.

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238 From the excerpt in Portuguese: "*1.Todo objeto é uma sensação nossa./2. Toda arte é a conversão de uma sensação em objeto./ 3.Portanto, toda arte é a conversão duma sensação numa outra sensação*". (Plaza 2003: 11)

239 For Lakoff and Johnson "*the fact that abstract thought is mostly metaphorical means that answers to philosophical questions have always been, and always will be, mostly metaphorical*". (Lakoff and Johnson 1999: 7)

240 Benjamin 2002: 253.

241 Glanville, Ranulph. *Freedom and the machine.* Inaugural professorial lecture at The Bartlett International Lecture Series 2009/2010. Video-documentation available at <https://www.youtube.com/watch?v=Z8g7GA6DEU8> Accessed February 15th 2018.

Creating shared channels of communication relies on the human capacity to categorize, which serves as a "*gateway between perception and cognition*"[242]. Categorization occurs essentially by means of comparison, in which perceived phenomena are grouped into types on the basis of their (mutual) similarity. Over time, previously formed categories enable past perceptions to be used for the interpretation and organization of new events and experiences. [243]

> The primary purpose of perception is to identify objects and places, to classify them, and to attach meaning and significance to them, thus enabling later responses to them to be selected appropriately. As a consequence, perception is concerned with the enduring characteristics of objects so that they can be recognized when they are encountered in different contexts.[244]

In this sense, creating frameworks for conversation and shared action depends on the selection of elements within a network of spatial, temporal and semantic structures, since they suggest the possible operations and narratives. The attributes are created on different levels, ranging from the code and its instructions, through the shape and disposition of objects in space to established relationships with other elements that could be present. This also applies in relation to the axis of time: algorithms and storytelling are made out of temporal elements.[245] The semantic network emerges from those other two primary categorizations, which mutually influence one another and can be expressed, for instance, through the manifold possible figures of speech, such as metaphors[246], metonymies, etc., that are able to merge figurative and literal aspects of language. In the realm of music and sound art, categorization and pattern recognition also play a very significant role, essentially formalized through its mathematic foundations ranging from the regularity of parameters that forms the rhythm and harmony of classical music compositions,

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242 Ziem, Alexander. *Frames of understanding in text and discourse: Theoretical foundations and descriptive applications.* Berlin/Boston: de Gruyter, 2014, p. 214.

243 Konerding 1997: 57 apud Ziem 2014: 215. According to Ziem, "*Every form of categorization encompasses a schematization process, as categories themselves are of a schematic nature: Categories are formed on the basis of past perceptions that are grouped into types with respect to similarity and contiguity. Perception, regardless of its modality, is unimaginable without categorization processes*". (Cohen and Lefebvre 2005 apud Ziem 2014: 219)

244 Milner, David; Goodale, Melvyn 1995:163-4 apud Gregory 1998: 160.

245 Essential reading on the aesthetic function of time, a topic extensively explored in cinema theory are: Deleuze, Gilles. *L'image-temps. Cinéma 2.* Paris : Les éditions de minuit, 1985. and Tarkovsky, Andrey. *Sculpting in time: Reflections on the cinema.* Austin, TX: University of Texas Press, 1989.

246 Essential reading on the role of metaphors in cognitive process, their spatial qualities, partiality and other relevant problems in their use is: Lakoff, George; Johnson, Mark. *Metaphors we live by.* Chicago and London: University of Chicago Press: 1980.

to the game of chances of probabilistic theories, as expressed in the work of Iannis Xenakis[247] and Karlheinz Stockhausen[248].

An explicit concern with merging material and conceptual approaches can also be observed in Marcel Li Antúnez Roca's concept of '*Sistematurgia*', a term he uses to describe a creative method he developed to think of possible dramaturgies with electronic and computational systems.[249] In 2005, Antúnez Roca used this method to enact a series of aesthetic experiments that implemented the technological possibilities of electronic and digital media in a dramaturgical context. The mastery of his pieces is based on his understanding of the specificities of electronics and computing, together with his ability to play simultaneously with concepts and materials by reinventing ways of storytelling. Moreover, his artworks maintain a critical perspective on the technical means he uses, means which he invents while developing a work's own aesthetic language. One notices his investigation of interlacing motor sensory and cognitive challenges that aim to achieve both presence and meaning effects for the works' reception. This mixture also constitutes the core of Gumbrecht's proposal that the materiality of communication can be used as a key parameter to analyse both the maturity and consistency of media artworks.

Gordon Pask once maintained that äesthetically potent environments", like, e.g., interactive media artworks, should provide the conditions needed to attract the audience's attention, allow them to understand the system, and thereby provide the possibility of co-creation within the system.[250] One can add to Pask's argument that this is possible if the artwork – involving its entirety as technical and aesthetic ensemble, as well as the narrative it is rendering – somehow connects to the audience's sensorial and cognitive systems. "*We are, as a species, addicted to story,*"[251] and "*we just can't resist the gravity of alternate worlds*" [252], as the media scholar Jonathan

247 Lammert, Angela; von Amelunxen, Hubertus. (Eds.) *Kontrolle und Zufall - Iannis Xenakis.* Berlin: Akademie der Künste, 2011.

248 Droseltis, Alexandros. *Zufall und Determination in der westeuropäischen Musik um 1960 Dargestellt an Werken von Iannis Xenakis und Karlheinz Stockhausen.* Dissertation von der Fakultät I – Geisteswissenschaften der Technischen Universität Berlin 2011.

249 Roca, Marcel-Li Antúnez. *Sistematurgia*. Vol.1 Abril 2005. Available at <http://marceliantunez.com/texts/sistematurgia/sistematurgia.pdf> Accessed April 23rd 2016.

250 Pask wrote: "*It is clear that an aesthetically potent environment should have the following attributes: (a) It must offer sufficient variety to provide the potentially controllable novelty required by a mon (however, it must not swamp him with variety – if it did, the environment would merely be unintelligible). (b) It must contain forms that a man can interpret or learn to interpret at various levels of abstraction. (c) It must provide cues or tacitly stated instructions to guide the learning and abstractive process. (d) It may, in addition, respond to a man, engage him in conversation and adapt its characteristics to the prevailing mode of discourse.*" Pask, Gordon. A comment, a case history and a plan. In: *Cybernetics, Art and Ideas.* 1968. p. 76.

251 Gottschall, Jonathan. *The storytelling animal. How stories make us human.* Boston, New York: Mariner Books/Houghton Mifflin Harcourt, 2012. p. xiv

252 Ibid: 3

Gottschall (1975-) puts it. By characterizing humans as a sort of *Homo fictus*, Gottschall describes the innate human drive to create and consume stories as an urge to express and, borrowing Pessoa's terms, to communicate by translating sensations into sensations. However, there is no formula to be followed as Hollywood has done in creating a storytelling industry. In media artworks, technical and conceptual ensembles are only significant in their very specific and diverse contexts. As technological artifacts, in contrast to utilitarian ones[253], media artworks *"reside in interdiscursive relations and constitute dialogical reality constructions, which are essentially cultural by involving several discourses."*[254]. This explains the role of media and artists as actants in creating, storing and transmitting knowledge.

What one can learn and grasp from the examples and citations above is that media art is a field of action for breathing new life into and transcreating other space-time based expressions. They establish creative processes in media art as being essentially about systemically imagining, fictionalizing and inventing with materials in specific contexts. The correspondences and exchanges between materials and symbols, between physical laws and languages, as well as the energetic and information flux between communicating systems, are the foundation of the creative process. Since media artists are required to create all the in-between layers that constitute, and permit access to, the artwork, the translation of materialities is the transcreative act sustaining the epistemologic experience that every media artwork has the potential to create. In contrast to general technological devices generated for mere entertainment and commercial purposes, media artworks are pieces of framed realities, which come with their own dynamics and internal rules. The audience is free to engage (or not) in a shared space-time.

The notion of epistemological materialities encompasses a sort of manifesto calling for more critical viewpoints and the creation of more mature relationships between the apparently opposed technical and conceptual approaches in media art. Yet, in addition to the technical knowledge needed to execute the project, when attributing symbolic layers to the work media artists need the sensitivity required to enhance an artwork's potential for communication. The term "mediaïn "media artßhould do justice to the communicative ability and intentions of its technical and historical roots.

The notion of the translation of materialities can be considered as an analytical lens and tool for media art practitioners. Beyond the projects discussed here, this approach can guide other artists to reflect upon the process of meaning attribution through organization and recombination of materials in the specific contexts they

253 *"A computer interface employs icons and metaphors from everyday life to be understandable by many" and that 'the materiality of a computer resides in at least two discourses, the public discourse of its interface and the discourse of those who participated in designing it".* (Krippendorff 2011: 16)

254 Krippendorff 2011: 16.

are working in. The same is valid for critics and audience, who can use the notion of the translation of materialities as an analytical lens to discuss media artworks.

Final considerations
...and making sense

From the very material aspect of light-matter interaction to the participation of photosensitive matter in more complex technical ensembles, this thesis addressed key elements in play for the conceptualization and construction of media artworks. This has been explained through their connections with historical media devices and a series of scientific knowledge they embed. In addition to the encyclopaedic knowledge that every photosensitive item carries, the thesis carefully looked at the material interaction to clarify how media artworksare the fruit of a close interaction between art and science.

The analysis of photosensitivity provided a representative research object to address the dichotomies material-immaterial, organic-machinic and theory-practice in relation to media art. The mobilization of these dichotomous relationships hardly finds ways to completely deconstruct them, however, the discussion led to a partial comprehension of their foundations and especially their mutual influence and interaction. Each chapter addressed each dichotomy differently through the assistance of a mixed theoretical framework. Nevertheless, the articulations of ideas derived from the consolidated fields of cultural techniques, media-archaeology, second-order cybernetics and new materialism. This cross-disciplinary analysis provided an appropriate historical approach to address contemporary issues for media art. From each chapter's analysis emerged different aspects of media history and/or media art aesthetics that are commonly disregarded as criteria for creating media artworks.

The first chapter, *Photosensitivity: materialities and operations,* details the atomic and molecular activity behind photosensitivity and related techniques, thereby reconstructing a historic path of physical and conceptual transformations of optical media devices. This analysis leads to the comprehension of a set of recurrent trends found in media development: immediacy, convergence, verisimilitude, fragmentation, black-boxing and operationality.

The brief historic overview of pioneering exhibitions and analysis of various media artworks demonstrated that both materiality and immateriality have consistently been essential elements in the history of art; and what differs in the case

of media art is the care devoted to each of these elements in the discourses of art critics, theoreticians and artists.

The requisite relational nature of sensitive elements leads also to an overview and categorization of some of the operations related to photosensitivity that are frequently used or addressed in media artworks: measuring, automating, controlling, self-regulating and self-organizing. These operations ground the imbricate material-immaterial condition of media artworks and clarify the guidelines for understanding their informational aesthetics, refocusing attention on their communicational values and to the implications of this characteristic.

The research indicates the material-immaterial dynamics of media art's informational aesthetic requires more attention. Sensitive apparatuses are one of the core elements for bridging the poles of this dichotomy and enabling — through communication strategies — relational material perspectives that can accommodate unknown otherness, irrespective of the material actualization it presents. This perspective endorses the media artist's responsibility in regard to the ethical and environmental implications of media art's post-humanist practice – issues that remain open questions for the reader and invite further research.

The second chapter, "Photosensitivity shaping hybrid systems", inquires into photosensitive elements used in media artworks, which assist in deconstructing the organic-machinic dichotomy led to the analysis of light-sensitivity as vision. This is achieved through the comparing and contrasting of the eye and camera's materialities and operations. The comparative examination of these elements demonstrates how organic and machinic structures have been intimately coupled within the media art context, exemplified through the path towards the implementation of hybrid visions.

Despite the preference given for vision as a guideline, the focus of the examination on photosensitivity and the contemporary technological conditions for working with a common denominator for material interaction – electrical signal – ended overcoming the visual predominance associated to photosensitive matter and optical devices. As operational entities and released to be appropriated as data generators, photosensitive optical devices may be attached to other technical ensembles and produce materialities other than visual images.

The examination also elucidates how the emergence of optical media is tightly intertwined with investigations on human sensorial and cognitive apparatuses and processes. Although a worthy inquiry, investigating this issue further would reach beyond the scope of media artwork production.

We have learned that, rather than assuming a position between conflicting vitalist or mechanistic viewpoints, it is more interesting and fruitful to observe and engage in the oscillating movement between purification and translation – processes that can be understood in varying degree in media art production. From our understanding, purifying refers to the deepening of specializations, discoveries or

findings of specificities. Translating concerns the simultaneous movement toward expansion; it is the recognition of external references to be connected to, favouring hybridizations and thus contributing to the increase in the variability of modes of existence – organic and machinic. This approach also contributes to the blurring of borders between nature and culture. We are aware that the attempt to deconstruct this broader dichotomy is a recurring topic in the history of science and knowledge. From a media art perspective, especially when considering research on photosensitivity, it is difficult to grasp the reasons why it still persists.

The first and second chapters prepare the conceptual and technical basis for the higher complexity achieved in the third chapter, *Light-to-sound translations*. By stressing the manipulation of photosensitive materials through the zero-dimensionality of electricity – either through electrolytes or electrons flux –, and the possibility of translating light into sound, the chapter takes heed of the apparent opposing conceptual and technical approaches of media art practitioners and theoreticians.

As the research indicates, the materiality of media artworks turns simple matter into symbolic entities, whose meanings are open and malleable according to their contexts and actualizations. The notion of materialities' translation can guide artists to reflect upon the process of meaning attribution through organization and recombination of materials in the specific contexts on which they are working. The same is valid for critics and the audience, who can also use this notion as analytical lenses to discuss media artworks. Translations of materialities implies thinking on translatability and the manipulation of elements on an abstract level of meta-language, a process full of arbitrariness that must carried out by means of enjoying the freedom it represents, while also considering the involved responsibility.

Media artists as transcreators, i.e., those able to work with translation of materialities, are responsible for bridging a series of dichotomous structures present in Western societies and their way of thinking. Conducting the analysis we have been able to discuss only three of them.

The theory-practice dichotomy was especially apparent in the conceptualization and execution of *Self-portrait of an absence* – a performance whose technical basis is, in fact, a light-to-sound translation, and was conducted through the confrontation of operations of the author's eyes and a camera. The practice-led research has been an important acknowledgement of the various handcraft layers of media artworks.

In close dialogue with Flusser's concepts of *Mediumsprünge*, as well as Guldin's perspective on the connection between Flusser's media and translation theories, *Self-portrait of an absence* evinces the powerful and multifaceted role of absence in media creativity. Initially taking full advantage of the limitation of my blind eye in its image-forming capacities, the absence was a simple monocularity, an absence of body symmetry. Suddenly, the absence became the engine for the creative process of meaning attribution between light input and sound output. This finding in particular has only confirmed and reinforced our understanding of how light-

to-sound translations were achieved in historical media devices and how they are done in contemporary media artworks.

Absence also closely relates to other facets of media development, specifically the ideals of verisimilitude and normativity – the reasons behind the creation of cyborgs or the prosthetic quality of media. This relates to the human learning paradigm of fragmenting in order to understand and act upon the world. Identified in studies on both biological senses and man-made devices, the fragmentation phenomena and the respective found or generated absences inquire into the heart of human existence. For example, if radiation in nature is a continuum and we act in framing and channelling them, we ourselves are the gap that does not allow us to completely integrate with our surroundings. Further research developing these associations are strongly encouraged and desired, however, in this particular project which were avoided due to the extensive additional and diverse theoretical framework required.

Enthusiasts of a transcendental empiricism, media artists may animate and edit matter towards the creation of possible imaginary and non-trivial hybrid machines. Programming exchanges of electric and electrochemical signals through sensitive materials also play with the feedback principle – the core of hybrid systems. The hybrid aspect and the acoustic biofeedback experienced with *Self-portrait of an absence* led my own body to a self-regulating and self-organizing situation. I became aware and learned how to control the muscles of my blind eye. We have not theorized about the second-order observer, rather we have enacted it. In this sense, this experience suggests that the object-subject dichotomy is another gap artists and their artworks are able to bridge. One of the challenges while creating aesthetic experiences resides in finding or inventing significant relationships between objects and subjects, between objectivities and subjectivities.

The idea of framing media art through the lenses of translation of materialities is only one of the possible ways to find a systematization of elements, which in turn partakes in the creative process of media artworks. As communication systems, media artworks are like invented micro-universes framed within continuous stimulus and information exchange between things and beings.

The notion of epistemological materialities discussed at the end of the last chapter draws a conclusion that media devices and artworks – as cultural objects – witness the human activity in knowledge construction. Back to the media artist's bridging role: epistemological materialities suggest the bridge between sensing and making sense – bridges continuously constructed in each framed context, some consistent and stable, while others fragile and ephemeral. At the same time, the notion of epistemological materialities re-opens the discussion for considering similar approach in relation to other materialities beyond photosensitive elements and beyond art.

In addition, the sequence of chapters led to the realization that, given the increasing possibilities of material manipulations, another challenge for media artists today is discovering what is relevant to translate, how and why. To address the translation process behind media artworks – considering its historical, technical and aesthetical aspects – is a constructive instrument to unveil elements that, if consciously articulated, empower both media art practitioners and theoreticians.

For further research, there are still two mains suggestions: one concerns the development of biosensors and hybrid synthetic materials to enhance photosensitivity, so as their aesthetical appropriations. Still open questions to address: Why is it still not possible to make a CCD out of organic matter and, if possible, how would such technological artifacts influence media art aesthetics? A second promising investigation vector would be to address the networked possibilities of photosensitivity and the emergence of artificial quorum sensing. Dealing with networked photosensitivity inevitably touches even more complex systems that involve non-human agency, requiring additional theoretical frameworks, such as Bruno Latour's actor-network theory, other approaches of the science of complexity, so as dialogues with another branch of media art aesthetics specialized in initiatives based on non-centralized and collective regulation and communication, such as Net Art and telematic performances. Naturally, such investigations profit more if inserted in practice-based research contexts.

Conclusively, we can summarize that while working with biologic matter, electronic and digital apparatuses in the symbolic level, media artists continuously bridge scientific and artistic knowledge, abstraction and concreteness, nature and culture, tradition and future, sensations (stimulus uptake) and senses (meaning attribution). Looking at media artworks through the notion of translation of materialities is a didactic process for understanding that, within the contemporary technological and cultural environment, senses are not predefined; rather they become in the context they emerge and are constantly being redefined through the individuation and formation of complex technical ensembles.

For further studies involving the agency of media artists in other possible scenarios, we suggest to include and test the consistency of the notions of translation of materialities and the media artist's role as translator (or bridge builder) in the various possible scenarios.

Regarding the ethical and environmental concerns, we hope that instead of bridging separate systems randomly, media artists investigate which are the absences and gaps worth to address, so as which systems are relevant to connect in order to appraise the otherness and to increase the variability of modes of existences.

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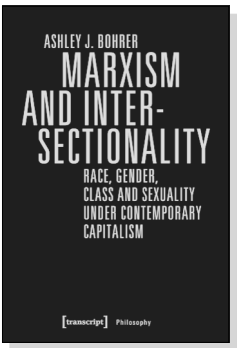

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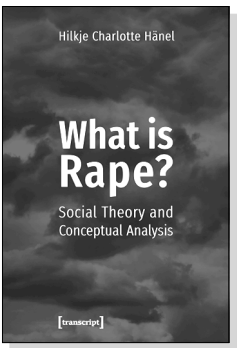

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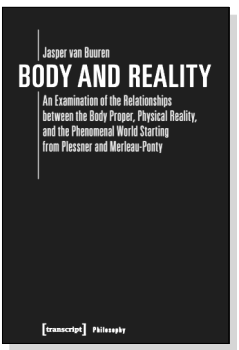

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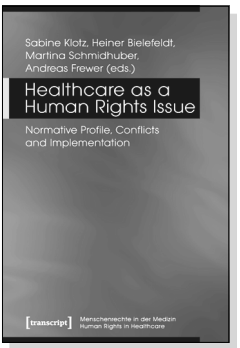

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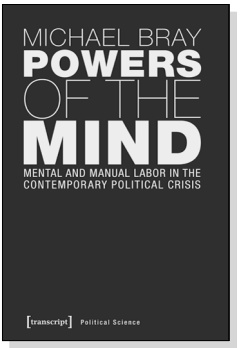

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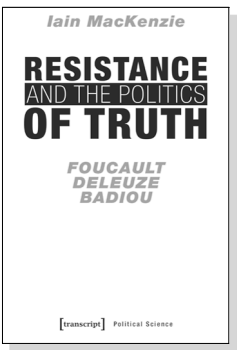

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