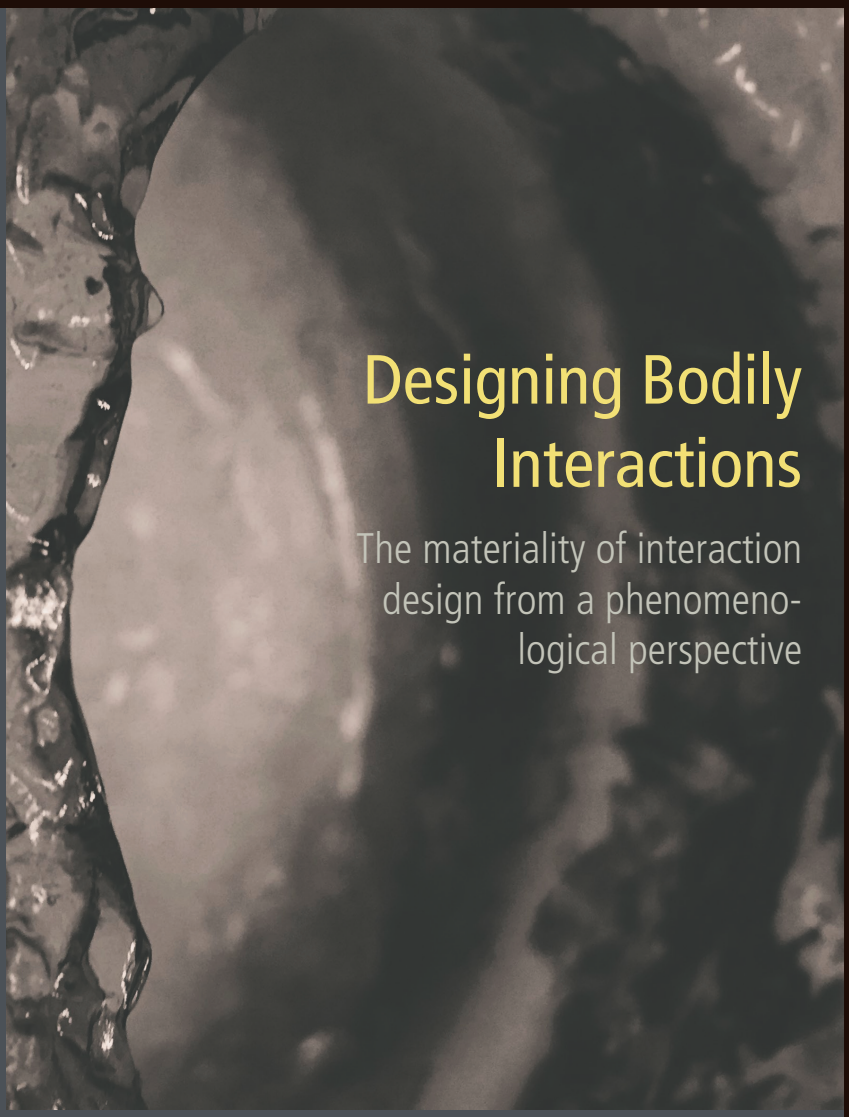
Maja Fagerberg Ranten



Designing Bodily Interactions

The materiality of interaction design from a phenomenological perspective

A Ph.D. Dissertation from the Doctoral School af People and Technology

RUC

Maja Fagerberg Ranten

Designing Bodily Interactions

The materiality of interaction design from a phenomenological perspective

Maja Fagerberg Ranten

Designing Bodily Interactions

The materiality of interaction design from a phenomenological perspective

Supervisor
Associate Professor Troels Andreasen,
Roskilde University

Co-Supervisor
Professor Susan Kozel,
Malmö University

Ph.D. Dissertation
Doctoral School of People and Technology
Ph.D. program in Information Technology
Department of People and Technology
Roskilde University, March 2022

Maja Fagerberg Ranten:
Designing Bodily Interactions: The materiality of interaction design from a phenomenological perspective

A publication in the series: *PhD dissertations from Doctoral School of People and Technology,*
Roskilde University

1st Edition year 2022

ISBN: 978-87-91362-13-2 (paperback)
ISBN: 978-87-91362-14-9 (e-pub)

Cover: Maja Fagerberg Ranten & Niels Hilfling
Typeset, layouts and illustrations: Maja Fagerberg Ranten
Print: Prinfo Paritas Digital Service

Order at Academic Books at RUC:
Building 26
Universitetsvej 1
4000 Roskilde
T: +45 4422 3830
E: ruc@academicbooks.dk

Published by:
Doctoral School of People and Technology,
Department of People and Technology,
Roskilde University
Building 02
P.O. Box 260
DK-4000 Roskilde
Denmark
T: +45 4674 2732
E: forskerskolen@ruc.dk
Website: https://ruc.dk/phdskolen-mennesker-og-teknologi

Preface by the Doctoral School

A PhD dissertation is like a proof showing that the author has "carried out an independent research work under supervision" as stated in the Ministerial Order on the PhD Programme at the Universities. The PhD dissertation is regarded as frontier research, being critically reviewed and approved by scientific peers, to secure the state of knowledge, clarify contradictions and evaluate the contributions to emerging research areas.

The Doctoral School for People and Technology frames research that seek to address sustainability often by applying experimental approaches providing individuals active and learning involvement. The research comprises approaches of human, societal, health and information technology, often applying planning, interventions, and design-oriented subject areas. The Doctoral School has 5 Ph.D programmes with each of their focus points.

The PhD programme in Information Technology encompasses the design, construction, validation, and evaluation of IT systems. The ever-increasing complexity and sophistication of systems brings both basic and applied research challenges. Understanding the needs of users, customers and businesses starts with understanding people in context, which in turn drives the management of IT projects and the design of innovative IT solutions and information systems. Research in these areas relies on and is inspired by theories of organizational behaviour, sociology, psychology, and management. The construction of reliable, intelligent, resource-efficient systems requires basic research in the mathematical and logical foundations of knowledge representation, algorithms, programming tools and languages. The purpose of the programme is to provide PhD education in informatics and computer science at a high, internationally recognized level with the objectives to stimulate research, to provide competent supervision, to organize education in areas covered and to establish international relations as a basis for student visits to foreign universities.

Maja Fagerberg Ranten's PhD thesis is a hybrid between a monograph and a paper-based dissertation. Four previously published papers are included. All documents collaborative works and are co-authored with colleagues. The papers provide a background for Maja's presentation of her own views, ideas, and unique suggestions in the monograph part. The monograph part, pages 7 – 211, comprise 13 chapters and is divided into three. The first part, Beginning, introduces to the thesis, describes the methodology, introduces to the research program, and presents the large and significant portfolio of engagements. Part two, Performing, includes the three main chapters of the thesis covering the research program's themes: the Bodily Interaction Design perspective, the Phenomenological Research through Design methodology, and the Materiality of Bodily Interaction Design.

Part three, Forwarding, provides a case interview, a description of the original contribution and a closing with reflections and concluding remarks.

Maja explores design of bodily interactions and discusses how designers can work with particular attention to a phenomenological perspective in the design development process. The main emphasis is on the perspective of the designers working in the fields of interaction design, human-computer-interaction (HCI), and interactive art.

The approach taken is programmatic research based on practical work with interactive installations that elicit embodied behavior from a first-person experience of attention to embodiment in the design development process.

With this dissertation Maja provides a strong contribution to Interaction Design exploring and developing Bodily Interaction Design. Taking a phenomenological perspective, Maja presents a methodology, phenomenological research through design, intended for designers to work within the body perspective, and unfold the materials of the methodology.

The assessment committee notes in summary that the dissertation is ambitious in its conceptual, methodological, and material explorations of Bodily Interaction Design. The trans/interdisciplinary nature of the thinking and projects all testify to Maja's ability to bring into resonance an impressive range of perspectives and practitioners into her thesis work. Indeed, entanglement might be a keyword when describing the actual composition of the dissertation.

It is the hope of both the committee and the doctoral school that the dissertation available here will be presented to a wider audience.

Enjoy the reading.

Troels Andreasen,
Department of People and Technology
Roskilde University
March 2022

Acknowledgement

Thank you for generously lending me your shots: Mads Hobye, Mathias Vejerslev, Maj Vanilli, Nicolas Padfield and UNMAKE (Halfdan Hauch Jensen & Author). And thank you, Sylvia Holthen, for the visual inspiration.

A special thanks to...
My supervisors Associate Professor Troels Andreasen and Professor Susan Kozel.

The PhD committee. Professor Jesper Simonsen, Associate Professor Jonas Fritsch, and Professor Kristina Höök.

Halfdan Hauch Jensen for the shared repertoire of work in our UNMAKE collaboration, and friendship.

Mads Høbye for being my close colleague, friend, and collaborator in experiments, thoughts, concepts, and papers.

Marika Hedemyr, Sarah Homewood, and Susan Kozel. Our collaboration broadened my bodily perspective.

To my colleagues at Exocollective (Mads Høbye, Troels Andreasen, Michael Haldrup, Nicolas Padfield, Henning Christiansen, and Anja Mølle Lindelof).

Knudsen/Bøen Collective (Karen Eide Bøen and Lise Aagaard Knudsen).

CLICK /Barbara Scherfig, HAUT/Naja Lee Jensen, and CATCH/Majken Overgaard.

David Kadish and Megan Hines for a great exploration into Eco-Technogenesis.

All the labs I have worked in, visited and collaborated with: Exostudio, FabLab RUC. AirLab ITU, and CATCH center for art design and technology.

illutron for shaping my practical work.

My fellow PhD scholars. And my students.

All the artists, developers, collaborators, and participants of the many interactive installations throughout the years.

Friends & family ♥

Abstract

This dissertation is about Bodily Interaction Design and how designers can work with particular attention to a phenomenological perspective in the design development process. It is aimed at designers working in the fields of interaction design, human-computer-interaction (HCI), and interactive art.

The work is conducted as programmatic research based on practical work with interactive installations that elicit embodied behavior from a first-person experience of attention to embodiment in the design development process. The research program is informed by Merleau-Ponty's phenomenology, and by materialism. The overall goal is to raise awareness of the fact that the body is an active part of the design process and to present a broader outline of work around the conceptions of bodies within research through design, and to position the bodily view in a material interaction design context.

The dissertation explores and present knowledge contributions about designing bodily interactions from three angles: firstly, *Bodily Interaction Design,* a bodily perspective informed by a phenomenological perspective; secondly, *phenomenological research through design*, a suggested methodology for designers to work within the body perspective; and thirdly, the *materiality of bodily interaction design,* an unfolding of the materials of the methodology.

The perspective *Bodily Interaction Design* is a contemporary revised phenomenological perspective that acknowledges that the designers' lived bodies play a significant role in design development within a more-than-human view of the body in which bodies are recognized as being multi-faceted and socio-culturally entangled.

The methodology – *phenomenological research through design* – is a broad umbrella term for the use of the lived body in the design process. Four methodological aspects of phenomenological research through design are suggested: (a) prototyping with the lived body, (b) the interplay between touch and touchback, (c) social interrelation, and (d) drifting.

The material contribution presents an unfolding of *the materials of bodily interaction design,* acknowledging interaction design as a form-giving practice designers can choreograph. It includes a specific focus on the body as material in conjunction with tangible materials and computational material. It is further entangled with half entities and affects and is affected by context, intention, society, politics, and ethics. Additional knowledge contribution includes the model *Feedback Loop of Bodily Interaction Design*, where the focus is on the constituent relationship between bodily action and bodily impact, thus positioning a phenomenologically informed perspective to the definitions of materiality in HCI and interaction design as a form-giving practice.

Finally, this work suggests dividing performing phenomenological research through design into three parts – before, during, and after. The three parts further act as a placeholder for the contributions presented throughout the dissertation as inspirations for designers to think through and with the program of Bodily Interaction Design.

Resumé

Denne afhandling handler om kropslig interaktionsdesign *(Bodily Interaction Design),* og hvordan designere kan arbejde med særlig opmærksomhed på et fænomenologisk perspektiv i designudviklingsprocessen. Den er rettet mod designere, der arbejder inden for interaktionsdesign, menneske-computer-interaktion (HCI) og interaktiv kunst.

Arbejdet udføres som programmatisk forskning baseret på praktisk arbejde med interaktive installationer, der fremkalder kropslig adfærd ud fra et førstepersons erfaringsperspektiv med opmærksomhed på kroppen i designudviklingsprocessen. Forskningsprogrammet er baseret på Merleau-Pontys fænomenologi og et materiale perspektiv på interaktionsdesign. Det overordnede mål er at øge bevidstheden om, at kroppen er en aktiv del af designprocessen og at præsentere en bredere oversigt over arbejdet omkring kropsopfattelser inden for forskning gennem design. For derefter at positionere kropssynet i en materiale-interaktionsdesign kontekst.

Afhandlingen udforsker og præsenterer vidensbidrag om at designe kropslig interaktionsdesign ud fra tre vinkler. Først: et kropsligt perspektiv informeret af et fænomenologisk perspektiv; *Bodily Interaction Design*. Derefter: en metodologi for designere der arbejder inden for kropsperspektivet; fænomenologisk *research through design*, og slutteligt: en udfoldelse af metodologiens materialer; *kropslig interaktionsdesigns materialitet*.

Kropslig interaktionsdesign er et nutidigt revideret fænomenologisk perspektiv, der anerkender, at designeres levede kroppe spiller en væsentlig rolle i designudvikling i et *more-than-human* kropsligt perspektiv, der anerkender kroppe som mangefacetterede og sociokulturelt sammenfiltrede.

Metodologien – *fænomenologisk research through design* – er en bred paraplybetegnelse for brugen af den levede krop i designprocessen samt et forslag om fire metodiske aspekter af fænomenologisk research through design: (a) *prototyping* med den levede krop, (b) samspillet mellem at røre og blive berørt, (c) social interrelation og (d) *drifting*.

Materialebidraget præsenterer en udfoldelse af materialerne i kropsligt interaktionsdesign, der anerkender interaktionsdesign som en formgivende praksis, designere kan koreografere. Det omfatter et specifikt fokus på kroppen som materiale i samspil med fysiske materialer og *computational* materiale. Og yderligere i samspil med "half entities" hvor vi både påvirker og påvirkes af kontekst, intention, samfund, politik og etik. Vidensbidraget omfatter desuden modellen *Feedback Loop of Bodily Interaction Design*, hvor fokus er på det konstituerende forhold mellem kropslig handling og kropslig påvirkning. Således placeres et fænomenologisk informeret perspektiv til definitionerne af materialitet i HCI og interaktionsdesign som formgivende praksis.

Endelig foreslås det at opdele *fænomenologisk research through design* i tre dele - før, under og efter. Som inspiration for designere, at tænke igennem og med, fungerer de tre dele ligeledes som pladsholder for de bidrag, der præsenteres gennem afhandlingen: perspektivet, metodologien, og materialiteten i programmet *Bodily Interaction Design.*

PART ONE | BEGINNING

PART TWO | PERFORMING

PART THREE | FORWARDING

AND | PAPERS

Table of Content

PART ONE | BEGINNING

1 | Introduction

1 | Introduction

In his *Phenomenology of Perception*, Merleau-Ponty (1962) presents the bodily perspective – that "the body is our anchorage in a world" (p.146), as a new concept of experience. Later, in his unfinished *The Visible and the Invisible,* he introduces the concept of flesh, exploring the interrelations of the inner and the outer, the subject and the object, as the lived body (Merleau-Ponty, 1968).

In the fields of interaction design and human-computer interaction (HCI) there is a growing focus on embodiment, the lived body, and somatic design (Höök, Ståhl, et al., 2015; Höök, Jonsson, Ståhl, & Mercurio, 2016; Höök, 2018; Schiphorst & Loke, 2018; Svanæs, 2013; Loke & Robertson, 2011). From the KTH Royal Institute of Technology in Stockholm there is an evolving program around Soma Design involving training designers in somatic sensibility through Feldenkrais inspired methods (Höök, 2018). In performance art, especially represented by dance – there is a wide tradition of including a phenomenological perspective to the expression of artistic practice (Kozel, 2007; Fraleigh, 2018).

Despite this growing and maturing focus, bodily perspectives in interaction design and HCI are still considered experimental. Examples of bodily interaction design are few and far between, and concrete methods for the application of philosophical perspectives in the design process are underrepresented.

By re-formulating and re-visiting Merleau-Ponty's phenomenology, I believe we can develop and mature methodological approaches to incorporate *Bodily Interaction Design* and reconsider the materiality of an interaction designer.

The Research

This dissertation is about Bodily Interaction Design and how designers who produce interactive installations can work with particular attention to a phenomenological perspective in the design development process. It is intended for designers working in the fields of interaction design, HCI, and interactive art.

This research is based on practical work with interactive installations that elicit embodied behavior and first-person experience with attention to embodiment in the design development process. The goal is to raise awareness of the fact that the body is an active part of the design process and to present a broader outline of work around the conceptions

of bodies within research through design, and to position the bodily view in a material interaction design context.

The argument presented assumes that research through design and construction- and artistic practices (Frayling, 1993; Koskinen et al., 2012; Zimmerman, Stolterman, & Forlizzi, 2010; Zimmerman, Forlizzi, & Evenson, 2007) are concerned with our lived bodies, perception, embodiment, and relation to material, context, and social material. And that the designer's embodied interaction with materials can be understood by applying a phenomenological approach to research through design. Designer's act and make meaning through bodily relation with the material in the process of making. Hence focus is on the designer's process when developing, making, and performing design as opposed to a focus on the user experience.

The dissertation will present Bodily Interaction Design from three angles: firstly, *Bodily Interaction Design,* a bodily perspective informed by a phenomenological perspective; secondly, *phenomenological research through design*, a suggested methodology for designers to work within the body perspective; and thirdly, the *materiality of bodily interaction design,* an unfolding of the materials of the methodology (Figure 1).

PERSPECTIVE	**Bodily Interaction Design** In a revised phenomenological perspective.
METHODOLOGY	**Phenomenological Research Through Design** The methodology of the perspective.
MATERIALITY	**The Materiality of Bodily Interaction Design** An unfolding of the materiality of the methodology.

Figure 1. The three angles of Bodily Interaction Design: Perspective, Methodology, and Materiality

Perspective

The research is positioned in the transition between third wave and the nascent fourth wave of HCI (Frauenberger, 2019) where the view of the body is entangled, and there is a need to develop, re-formulate, and mature old methods that accommodate and expand bodily aspects of designing technologies to include a revised phenomenological perspective of bodies entangled with other bodies and objects, embodied, interrelated, and to acknowledge that bodies in the design process are socially, politically, and culturally shaped: *Bodily Interaction Design.*

Methodology
Phenomenological research through design is proposed as a new field within research through design, where the designer acknowledges her own sensory perceptive presence, not just by handling materials and materiality, but also through her own subjective sensory materiality. It will function as an expansion of phenomenology in interaction design, providing a methodological contribution to research through design that allows room for active participation of the lived body in the various stages of the design process.

Materiality
In an unfolding of the entangled nature of materials around phenomenological research through design- physical tangible materials, computational material, and the body as material -it is shown how materials influence each other and are part of an entangled assemblage that designers can tweak and choreograph.

The work contributes to the unpacking of new ontology, epistemology, and conceptions of the role of bodies in the process of making. Ultimately, a phenomenological account of the lived experience contrasts with the traditionalist scientific approach and applying phenomenological theories to the technical field of science potentially raises epistemological conflict.

The project contributes to conceptual literature in both phenomenology and research through design by close reflection on practical design processes. The work furthermore pays dual attention (Giaccardi & Karana, 2015) to interaction design, where the focus is not solely on the outcome of design, but rather on a particular attention to the development process in which emphasis is placed on the designer's process when designing bodily interactions.

Motivation

My path into practice has crossed through various expressive fields of art: photography, painting, singing, dance, and theatre, until I joined the collaborative art group illutron and then completed my master's degree in Interaction Design. I also co-created UNMAKE with my former graduate study partner. I now consider myself an interaction designer as a practitioner of design, a design researcher, and designer-practitioner-researcher.

My first encounter with phenomenology and design methods in a technological design context was in a 2003 e-design program at the Copenhagen School of Design and Technology. Mixing philosophical concepts with design practice continued as I joined the Humanistic-Technological Bachelor program at Roskilde University in 2009.

This is where I first encountered extracts from Poul Dourish's *Where the Action is* (2001). I was introduced to different philosophical stances and methodological approaches. My attention was most captured whenever the researcher included themselves in the research and when socio-technical relations around our relationship with technology unfolded, e.g., through science and technology studies and actor network studies to include both human and non-human artifacts, culture, politics etc. in the making of technology.

During the master's program in Interaction Design at Malmö University (2012-2014), my thoughts coalesced in my encounter with a tighter interaction design program and a course dedicated to theory about embodied interaction held by Susan Kozel.

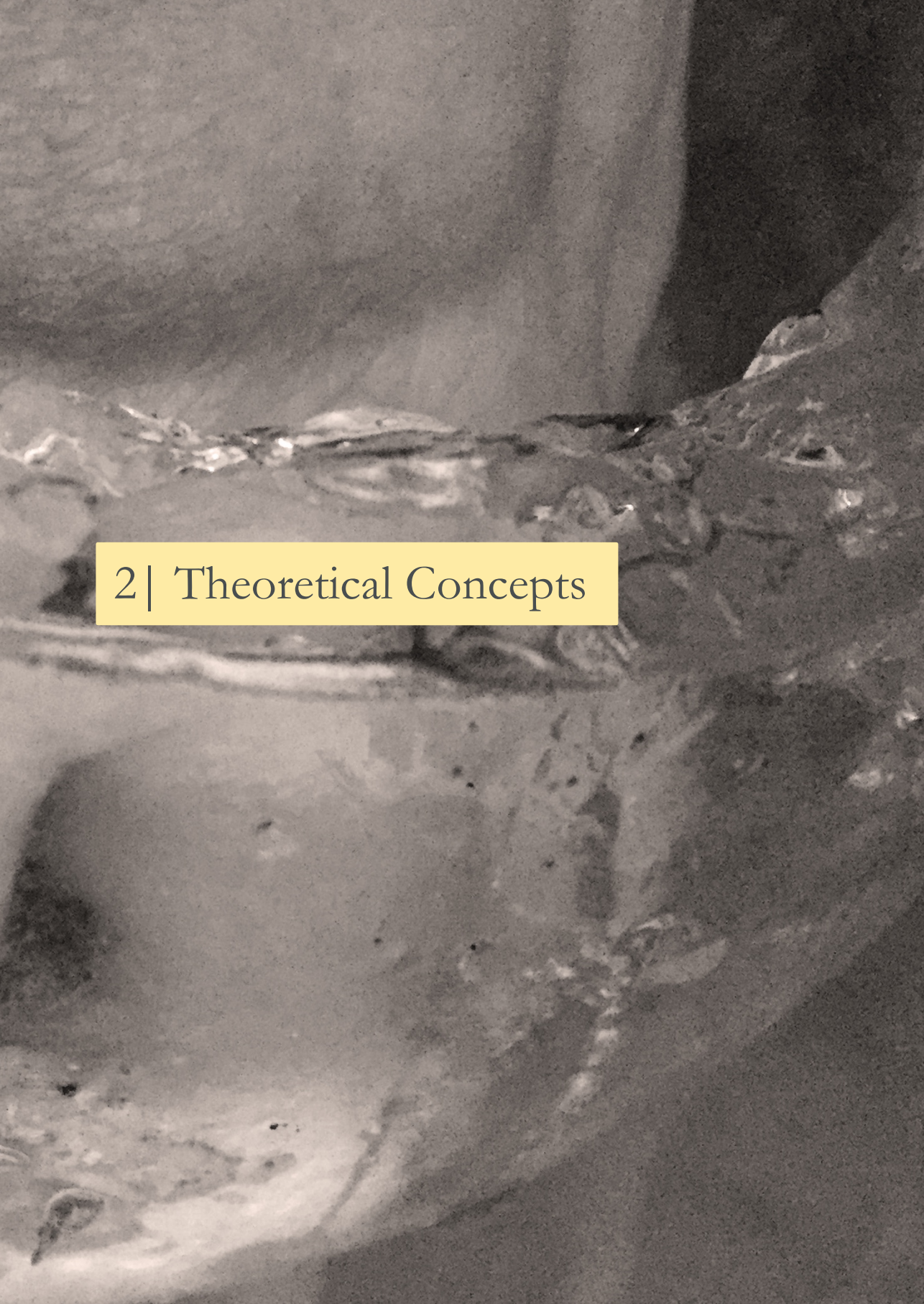
The idea to merge phenomenology with research through design and the term "phenomenological research through design" was first proposed in my first partial thesis in 2013 on the subject of Wearables: "Phenomenology in IxD methods is an attribution to IxD to allow room for active participation of the lived body in different stages of the design process [...] – acknowledging the interplay between bodies and technology, that users, artifacts, and contexts affect each other" (Ranten, 2013, p.48).

Everything I Touch Touches Me

As a practitioner of design, it is evident (at least to me), that research through design and construction- and artistic practices are concerned with our lived bodies, perception, embodiment, and relation to material, context, and social material. Phenomenology is omnipresent in the investigation of the body/tech relationship.

In my view, the active participation of my lived body is the foundation of the creative design development process. However, since I predominantly work collaboratively, the work is framed, formed, inspired by, and connected to my collaborations. Therefore, it is not only a question of my body alone, but rather multiple bodies, and how our bodies are interconnected in the process and form a collective archive of materials. We act and make meaning through our lived bodies – we touch and are touched back by various materials and one another.

Design knowledge is produced through the making of design. And design practice is the essence of design research. As a designer-practitioner-researcher (Vaughan, 2017), I acknowledge that not every designer has an embodied relation with materials. But I believe that the process of art/tech, speculative futures, and artistic research can inspire other sub-fields of design research to include notions of the body in the process of making. And acknowledge that we interpret through our bodies: we sense, we perform, and our bodies and memories influence the process of making.



2| Theoretical Concepts

2| Theoretical Concepts

In the following, I will present a brief overview of the major strands of theoretical concepts in this dissertation. It is divided into the following three chapters. Firstly, *From the Somatic Turn to Fourth Wave HCI* as a positioning of the research within HCI transitioning from the third-wave somatic turn to the nascent fourth wave. Second, *Revised Phenomenology*, my own contemporary interpretation of phenomenology in a complex entangled worldview. Third, *The Materiality of Interaction Design*, which includes an unfolding of the body as material.

From the Somatic Turn to Fourth Wave HCI

With the turn to third wave in HCI (Bødker, 2015, 2006), new ways of accounting for experience arise. Since Dourish (2001) introduced the term *embodied interaction*, a wide range of research into phenomenology, affect, and exploration of the active engagement of the body in the making of tangible, embedded, and embodied interactive technologies has been generated (Höök, 2018; Höök, Jonsson, Ståhl, Tholander, et al., 2016; Höök, Ståhl, et al., 2015; Kozel, 2007; Kozel, 2010; Loke & Robertson 2013, 2011; Schiphorst, 2011; Svanæs, 2013; Schiphorst & Loke 2018). The shift from focusing on user experience to a focus on the designers in the design process highlights a dual perspective of the relationship between the bodies making the design process and the user's bodies in the final work.

Frauenberger (2019): suggests the next wave in HCI is entanglement. That our intimate relationship with digital technology requires us to evolve existing HCI practice and research: "...existing practices and theories are starting to show conceptional shortcomings in describing and conceptualising the changes we see in our relationship with digital artefacts" (p.21). He states that the third wave's focus on situatedness, values, and embodiments "...is ill-equipped to deal with the increasing ontological uncertainties that technologies such as virtual reality, artificial intelligence, or neuro-implants pose" (Frauenberger, 2019, p.21).

Overall, he points out the shortcomings in current HCI, thinking through a selected range of entanglement theories (ANT, Post-Phenomenology, OOO, and Agential Realism). He segments entanglement theories as socio-material arrangements that decline to study humans or technology in separation (Frauenberger, 2019).

"Summarising, I have argued to leave user-centred design behind us, and with it the mantra of user experience. Instead, I suggest to move towards design practices that feed off controversies, that are *participatory*, involving human and non-human actors, that are *speculative* to create spaces in which we negotiate desirable futures that are *agonistic* to the creation of technology as a political arena and that reach across *design* and *use*. I am suggesting to move from optimising user experience to designing *meaningful* relations that are enacted as part of our ongoing re-configuring the world" (Frauenberger, 2019, pp.20-21).

I believe that for the nascent fourth wave to evolve, we need to develop and mature old methods that accommodate and expand bodily aspects of designing technologies to include bodies entangled with other bodies and objects, embodied, interrelated, social, and shaped by politics and culture. We need to constantly expand how HCI handles bodies, diversity, and politics to design for more-than-human bodies.

Revised Phenomenology

> "*Phenomenological research is the study of lived experience*. To say the same thing differently: phenomenology is the study of the lifeworld - the world as we immediately experience it rather than as we conceptualize, categorize, or theorize about it" (Manen, 1984, p.2).

Phenomenology is increasingly used in interaction design to ground methods, but it is seldom presented as a concrete methodological approach. "The philosophical tradition of phenomenology is increasingly called upon to ground qualitative, applied or speculative methods, ways to account in theory and practice for subjects, objects, plants, things and orientations…" (Kozel, Gibson, & Martelli, 2018, p.11).

Phenomenology recognizes that the world exists prior to any analysis or act of consciousness. The significance of pre-reflective experience where the subject is not detached from the world it experiences (Diprose & Reynolds, 2011). Merleau-Ponty (Merleau-Ponty, 1962, 1968) can therefore be said to introduce examples of the body as a form of communication that disregards the object-subject model of exchange. We interpret, evoke, and transform meaning through our bodies. Disregarding the idea of the body as either object or subject: "...thinking beyond mind-body, subject-object and inner-outer, emotion-reason, and affective-cognitive polarities" (Diprose & Reynolds, 2011, p.164).

In *Phenomenology of Perception*, Merleau-Ponty (1962) introduces the concept of the living body. The concept of *flesh* and reversibility as the sensation of both being touched and touching is introduced in his later work, *The Visible and the Invisible* (Merleau-Ponty, 1968). Understanding the creative expression of meaning "*...more in terms of a fundamentally ambiguous nexus of hidden, reversible and intertwining forces"* (Diprose & Reynolds, 2011, p.164).

My reading of Merleau-Ponty's phenomenology and the notion of the living body is that his concepts are open-ended, unfinished thoughts. To me- when applied to the design process -what I have lived and felt is at the same time intangible, invisible, ephemeral, and yet very concrete. It is related to intuition, memories, and felt experience. And it is understood through my own artistic design practice inspired by Kozel (2013), who states the importance of challenging phenomenology similar to the artistic process of iterative cycles of design, that needs to be reassembled, revised, and reworked: "As a practical philosophy, phenomenology is not a system, not a dogmatic set of instructions. It is a sensibility and a way of living in the world. In scholarly terms, it is concerned with the construction and validation of knowledge, and it is utterly essential for it to be transformed from its original tenets: for it to be challenged, revised, reworked, critiqued, dismantled, and reassembled" (p. 167).

I believe that there remains more to gain from a Merleau-Pontian (Merleau-Ponty, 1968, 1962) phenomenological perspective in interaction design and HCI, and that it can serve as a contribution to *research through design* as a methodology that allows room for active participation of the designer's lived bodies in the design process (Ranten, 2013) and in return direct attention to the future bodies we are designing. I suggest that phenomenological research through design as a methodology can include entanglement, interrelatedness, feminism, social, political, and culturally shaped perspectives.

The Materiality of Interaction Design

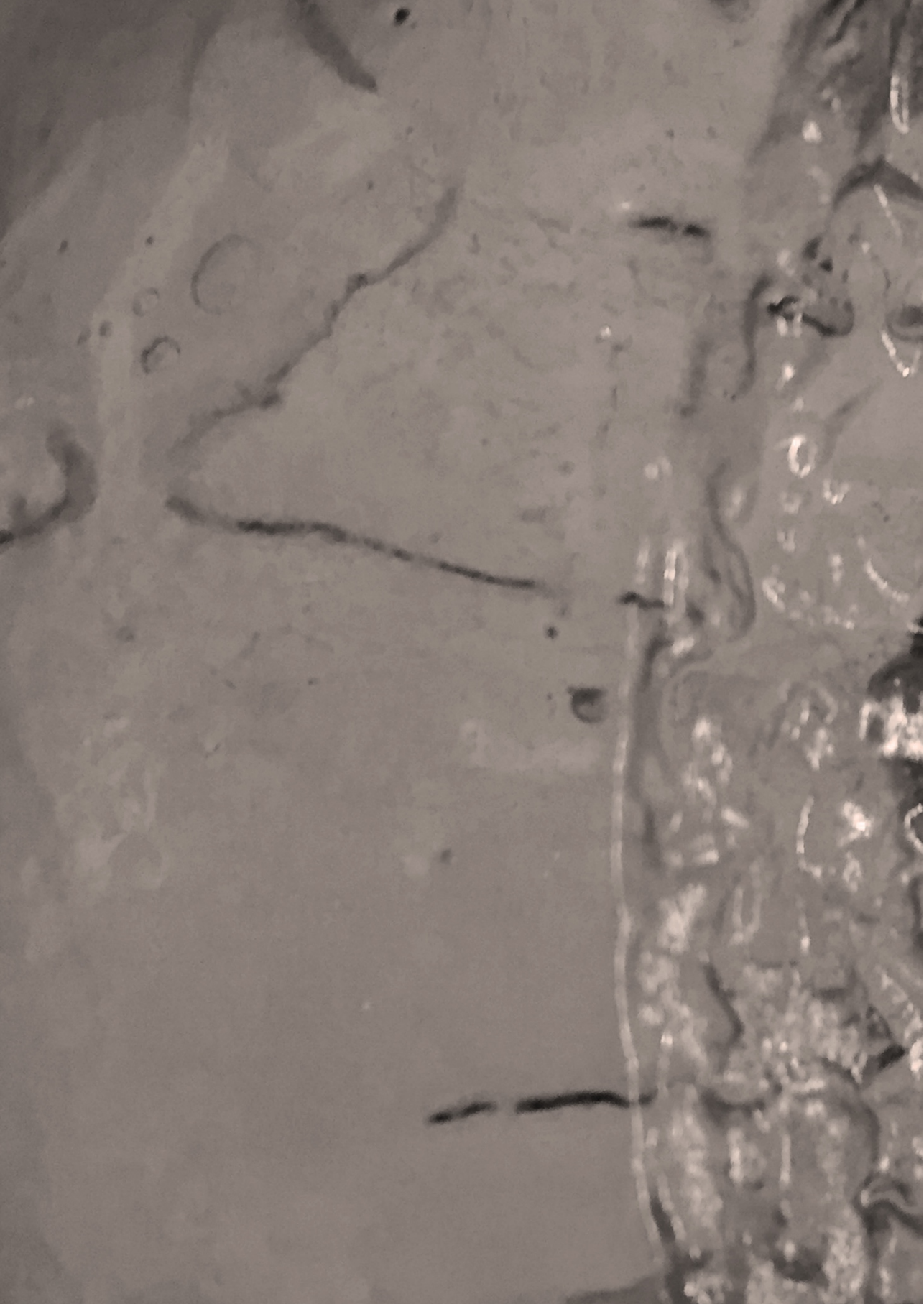
The argument presented in this dissertation assumes that research through design (Bang & Eriksen, 2014; Frayling, 1993; Gaver 2012; Koskinen, et. al., 2012; Redström, 2018; Zimmerman, Stolterman, & Forlizzi, 2010) construction- and artistic practices are concerned with our lived bodies, perception, embodiment, and relation to material, context, and social material. The designer's interaction with the material, her body, and memory influences the process of the making.

The designer's embodied interaction with the materials and the prototypes when working with materials can be understood by applying a phenomenological approach. I touch and I am touched back by the materials: "Merleau-Ponty elaborates reversibility initially with respect to seeing, but immediately introduces the tactile: I touch, and the world touches me, I touch my own act of touching and am subject and object both within myself. Things become appropriately sticky: I touch the world, certainly I do when I handle materials in the creative process, and these materials touch me back, challenging my autonomous role as creator of knowledge and bestower of meaning" (Kozel, 2010, p.206). Phenomenology plays a significant role, not only in the exploration and prototyping process in the lab and

when testing in the field, but also during the execution of a project when the designers use their own bodies to make iterations to the system and the end experience.

The final part of this dissertation is an unfolding of the materiality of Bodily Interaction Design. Specifically, an unfolding of the body as material. And how both bodily material, tangible/physical material, and computational material in conjunction with this are significant to the bodily experience, and how designers can play, tweak, and choreograph the material into an interactive experience.

This part builds on a wide range of definitions of the materiality of interaction in HCI and interaction design. A range of researchers acknowledge interaction design as a form-giving practice (Hallnäs & Redström, 2002b; Hallnäs, 2011; Vallgårda, 2014; Vallgårda et. al., 2015; Wiberg, 2018). I add, position, and unfold the bodily aspects to this. And reflect on the material perspective in a phenomenological view inspired by new materialism where politics and ethics are entangled with the material. Here bodies both construct and contribute to the social and the cultural. And matter has agency, can act, and affect (Frost, 2011).



3| Methodology & Methods

3| Methodology & Methods

The first two sections in this chapter describe the two intertwined approaches in this dissertation: *Methodology: Programmatic Research* and *Collaborative Material Approach*. The programmatic approach is the overall research methodology, and the collaborative material approach relates to the programmatic approach in the practical engagements.

The third section in this chapter describes the concrete methods used throughout the process under the collective designation *Methods: Drawing Things Together* with the subsections: *First-Person Perspective, Sketching and Diagramming*, and *Annotated Portfolio* (Figure 2).

Finally, the fourth section describes the *Programmatic Process*.

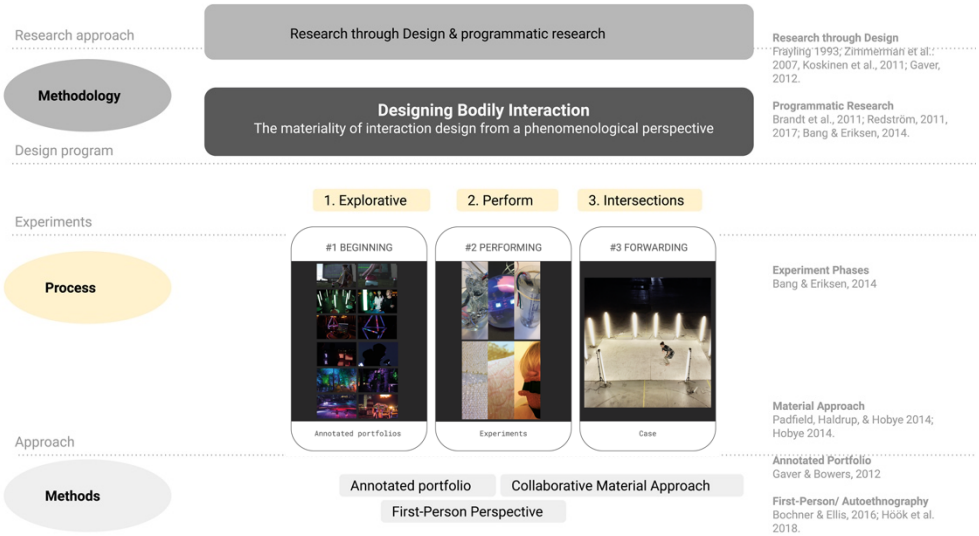


Figure 2. Methodology and methods visual overview; methodology, process, and methods

Methodology: Programmatic Research

The overall methodology in this research is Research through Design (Frayling, 1993; Zimmerman, Stolterman, & Forlizzi, 2010; Koskinen et al. 2012; Zimmerman, Forlizzi, & Evenson, 2007) in recognition of the fact that design examples and design practice contribute to knowledge production.

Furthermore, I have adopted a programmatic approach to knowledge production and will introduce my research as a research program (Redström, 2011, 2018; Brandt et al., 2011.). Rather than a problem-oriented approach to design with a definitive answer or design solution, research through design and programmatic research is open experimentation where experiments unfold and are *unpacked through definitions* (Redström, 2018) Hence my project is a practice-based exploration, where the design development of experiments and prototypes are conducted under the collective term Programmatic Research (Redström, 2018).

In its basic form, programmatic research consists of the two elements: program – a set of basic beliefs, design ideals, intentions, and experiments: a set of design experiments expressing the program (Redström, 2018). The program serves as a framework for carrying out experiments in a dialectical relationship where the program and experiments influence, challenge, and transform each other over time (Redström, 2011). Löwgren, Svarrer Larsen & Hobye (2013) suggest viewing programmatic research as a hermeneutical loop, a dynamic between the two parts of optics (their renaming of program) and engagement (renaming of experiments), and consider a holistic view of knowledge construction from the program as a whole rather than solely from the outcome of the experiments in their illustration of programmatic research. "Saying that the loop of optics and engagements is hermeneutic also means saying that it is an organic whole, a process of ongoing interpretation where optics inform engagements and engagements inform optics" (Löwgren, Svarrer Larsen, & Hobye, 2013, p.93).

I named my program Bodily Interaction Design. Bodily Interaction Design is my account of the type of interaction design I do. As a program it is still under development. My account of programmatic research is an overall way of illustrating how knowledge is produced through the different elements; how the program, optics, and worldview around the theme of designing bodily interactions relate to the practical engagements; experiments, and projects performed and how that assemblage of program and experiments constitutes the knowledge contribution. The program includes theoretical concepts in the exploration of the overall theme around designing bodily interactions. And the engagements include several projects, small collaborate experiments, and a case. I have merged Redström with Löwgren, Svarrer Larsen and Hobye's terminology in a visual overview of my programmatic research (Figure 3) inspired by their model (Löwgren et al., 2013). In the model the ongoing work of the program between the two parts engagements and optics (in a Redström terminology between program and experiments). "The arrow from left to right emphasizes the fact that the program changes and progresses over time. Finally, we indicate in the top right that eliciting takeaways from the program, such as when preparing an academic publication, represents an act of remediation leading to another entity that is not the program itself" (Löwgren at al., 2013, p.87).

The model illustrates the different elements and their relations, but the reality of design research performed as a programmatic approach is much more entangled, assembled, and messy than a clean model of the various parts relationship to each other.

In my view, a programmatic way of working allows for a complex assemblage between practice and theory and generating knowledge through design research. One important thing to include is Redström's emphasis that the notion of research *through* design in terms of epistemology is not solely about design experimentation; equally viable is the theoretical when we work towards results and in the making of the conceptual (Redström, 2018).

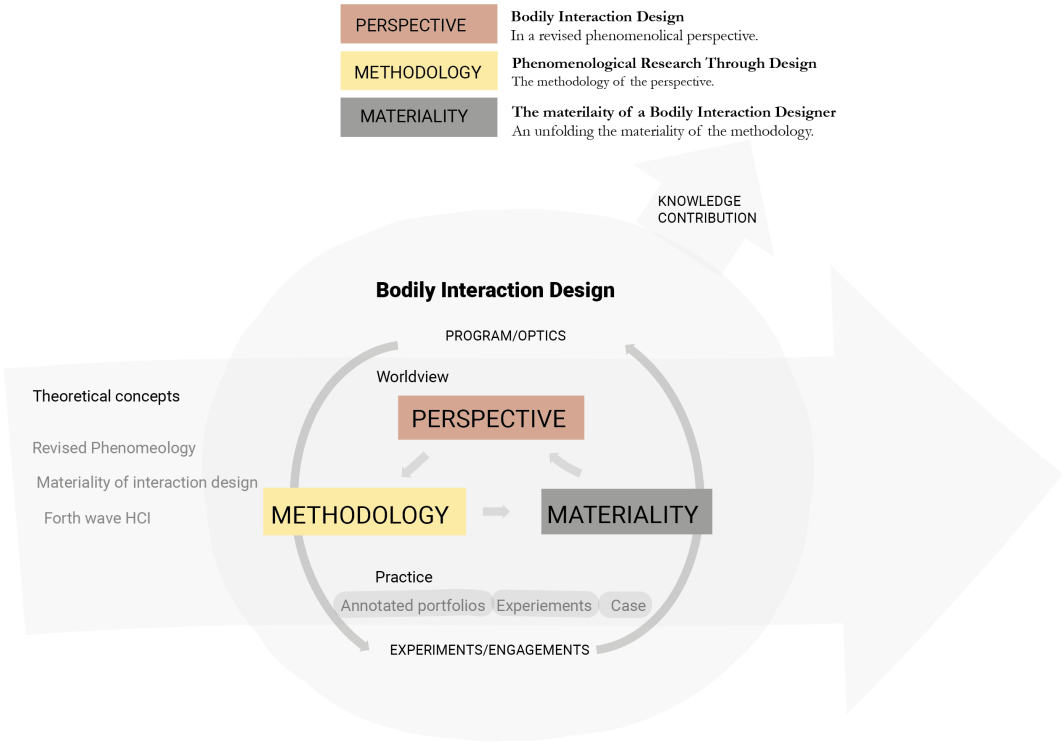


Figure 3. Illustration of my programmatic research Bodily Interaction Design. Model adapted from Löwgren, Svarrer Larsen & Hobye (2013, p.87)

In contrast with a traditional scientific positivistic focus of epistemology as verified knowledge, design knowledge is of a generative and suggestive nature, an *intermediate-level knowledge* (Höök & Löwgren, 2012), rather than a series of verified facts. In design research the need to twist and turn method and theory are essential. Methods merge and iterations between different approaches are needed.

In addition, the process of generating knowledge from practice is connected to our bodies as being bodily embedded and evolve over time as part of the everyday creative process – connecting a designer's repertoire with embodiment and reflection-in-action. Design-based research is a complex process designed, co-created, and influenced by people, materials, and contexts. Generating knowledge from an articulated program based on and informed by design projects and theoretical concepts acts as a standpoint – a framed position in the field.

Collaborative Material Approach

Collaborative Approach

All my practical engagements- interactive installations, experiments, and the memoryMechanics case -are carried out as collaborative work with a focus on material exploration.

The approach to material exploration and collaborative approaches partly stems from my involvement in the collaborative community around illutron.

illutron was formed in 2007 by a group of people with a wide range of backgrounds: artists, engineers, and musicians, all tech-skilled people experimenting with technology and expressive art forms (Hobye, 2014). Part of the organizational values are formulated through a manifesto, one of the principal tenets is for members to become participants, rather than solely spectators or consumers: "...you want to be recognized for what you do, not by being the first in the world to make something, but by sharing your skills and work in a community of interesting and interested peers" (Hobye, 2014, p.145). Another value formulated is a generous attitude to ownership and crediting through the statement in the manifesto that "Everyone is an artist hence nobody is an artist." By crediting everyone involved in a collaborative work- even the person making the tea -everybody is valued (Hobye, 2014). Despite a seemingly flat structure all the projects I have been involved in have an organizational approach to the division of roles with assigned leads that resemble design roles from participatory processes with threads to participatory design and collaborative interaction design (Löwgren & Reimer, 2012; Ehn, Nilsson, & Topgaard, 2014).

illutron has many branches. It is a culture house and a venue, with small and big projects happening simultaneously initiated by solo members or large groups of people from the community. My involvement has primarily been developing large-scale collaborative interactive installations executed at festivals between 2014-2018.

Digital Sketching at illutron

My colleague and co-founder of illutron, Mads Hobye, has described the illutron ways of working as digital material exploration being a facilitator for creative projects that starts from a technical exploration though rapid prototyping using software environments and embedded platforms such as Arduino (Hobye, 2014). Digital material here is a combination of electronic scrap material and embedded microcontrollers: "The electronic scrap material could be old diode displays that once were used to show the score at a soccer stadium. The exploration in relationship to digital material is understood as the process of hacking (as in repurposing old technology for new things) and modify those components into novel interactive design" (Hobye, 2014, p.137).

Embodied Interaction with UNMAKE

The UNMAKE collaboration was formed after graduation from the Interaction Design program in 2014 from Malmö University. My research partner Halfdan Hauch Jensen and I were both members of illutron at the time. We combined the ways of working we inherited from the illutron community and collaboration with the methodological approach and theoretical concepts from our education. Which evolved into a digital sketching approach with an embodied focus in our shared projects of interactive installations between 2014-2019.

Both the illutron and UNMAKE projects can be categorized as having been made through *digital sketching* (Padfield, Haldrup, & Hobye, 2014) and as *digital material exploration* (Hobye, 2014). We generally categorize the installations as large-scale interactive installations. And what they typically have in common is that they elicit embodied behavior and make people move or act together in social, embodied, and playful expressions. They represent a move away from screen-based interaction into a physical environment at festivals and social gatherings (Hobye, 2014). Or as "beyond the desktop," tangible interaction, whole-body interaction, physical computing, pervasive interaction, ubiquitous computing, and embodied interaction.

Material Exploration in the Exostudio

During my PhD work I co-founded the Exocollective and the Exostudio, a group of researchers and practitioners conducting material explorations into interactive design, art, and technology (www.exocollective.com). Exostudio is a shared studio based in the Informatics and Computer Science facilities at Roskilde University. Throughout my time as a PhD fellow (2018-2021) the Exostudio has been the venue for collaborative experiments, prototyping sessions, collaborative writing sessions, and reflective sessions on creative work. This work was done primarily with my colleague Mads Hobye and the rest of our Exocollective group (Michael Haldrup, Nicolas Padfield, Troels Andreasen, Henning Christiansen, and Anja Mølle Lindelof).

The environment is intricately connected to FabLabRUC, representing a broader FabLab approach to experimental research and learning environment at Roskilde University (www.fablab.ruc.dk).

Community Digital Sketching

I believe the community approach to material exploration that we execute at illutron, UNMAKE, and in various studios, labs, and workshops (at Roskilde University represented by Exostudio and FabLabRUC) is a key in unfolding the practical methodological approach of our relationship between body and technology. The communities offer a space for design exploration to a working prototypical approach, enabling low threshold and iteration cycles in digital sketching (Padfield, Haldrup, & Hobye, 2014). In the lab, the relationship with the technical material becomes a lived, embodied experience rather than an abstract sketch of possibilities (Ranten, 2013).

Methods: Drawing Things Together

Following programmatic design research, Redström uses the concept of assemblages in the context of defining a researchers' work with examples (a set of particular designs) vs. overall program framing as a meaningful whole: "It is an assemblage of definitions that aims towards a meaningful whole, not towards isolated and contained concepts. It is a hands-on way of working with, and explicitly addressing, the tension between the making of the particular and an overall orientation towards the more general through design" (Redström, 2018, p. 115).

My work with the projects of this dissertation spans from 2015-2021. Therefore, not all of them are created under the umbrella of research through design, but as an unfolding of a program through a mix between analytical backdrops and ongoing projects and experiments. They could thus be said to blend what Redström describes as three tactics to bridge the gap between practice and theory: *parallels*, *sequencing*, and *intermediaries*. In parallels, making and theorizing are separate, as one is "...building a set of works that is later used as a basis for a research project..." (Redström, 2018, p.15). In sequencing, one aims to merge making and theorizing by introducing theoretical notions to design – e.g., by introducing phenomenology to ground design practice. The third tactic, intermediaries, focuses on the tension between the general and the particular to ask what kind of knowledge is needed to create new theories (Redström, 2018). The assemblage of definitions can make a general theoretical contribution. As the tension spectrum between the particular and the general moves from "...how experiments become projects and a project becomes a program when they address matters related to worldviews" (Redström, 2018, p.115).

The sensemaking of drawing things together – how practice and theoretical concepts generate new knowledge – is further informed by concrete methods. The knowledge contribution the dissertation makes is based on arguments, subjective reading of theoretical concepts, design examples, and experience with developing interactive installations, rather than building on empirical data. The concrete methods are First-Person Perspectives, Sketching and Diagramming, and Annotated Portfolio.

First-Person Perspective

Even though more people were involved in the various practical projects- the projects were done in collaborations involving anywhere from 2 to 25 people -I will only account for my own experiences as a first-person perspective through autoethnography. The aspects of phenomenological research through design stem from my own empirically phenomenological relation with materials as a design practitioner and state how creation and meaning making are bodily bound in all phases of the process of making; from the exploratory initiation phase throughout the iterations of testing and tweaking in the production and making phase, and the tweaking and playing during execution of an interactive installation.

Bochner (2017) describes auto-ethnography as "an experience of our experience". Originating from social science, auto-ethnography acknowledges that researchers use their subjective experiences and express personal experience: "...human suffering, injustice, trauma, subjectivity, feeling, and loss; encouraged the development of reflexive and creative methodologies through which to navigate the landscape of lived experience; and legitimated unconventional forms of documenting and expressing personal experience in literary, lyrical, poetic, and performative ways" (Bochner & Ellis, 2016, p.45).

Autoethnographic work, or first-person perspectives, has been included in HCI as a method to acknowledge the designer's own embodied experience when designing systems (Neustaedter & Sengers, 2012), and how experiences can translate to design (Höök, 2010), and as a first-person perspective to shape design experiences (Höök et al., 2018).

Furthermore, existential phenomenology as a method can function as a first-person voice for a performer or an audience, for example, and thus as research, phenomenology functions as qualitative science (Fraleigh, 2018). Kozel states how phenomenology as a method allows her to listen to her inner senses and experience of being: "...a listening to the senses and insights that arrive obliquely, unbidden, in the midst of movement experiments or quite simply in the midst of life. Phenomenology, in short, allows me to respect these sensations and inner voices, these unformed ideas, thoughts, or images that emerge directly from the experience of being in computational systems ..." (Kozel, 2007, p. xvi).

Diagramming and Sketching

Making diagrams, visualizing, and sketching has been a method of abstraction and ongoing reflection throughout my work, from framing the first thoughts about the program, during the process with the engagements, readings, collaborations, and towards framing new theory and concepts. I have outlined interesting concepts, listed them, printed them, visualized thoughts and ideas as sketches, in mind-mapping, as notes. I re-read, scaffold, describe, talk, think, discuss, move. I sketch on paper, in notebooks, and on the computer. I draw models and frameworks. Print them. Draw on them. Cut them into new pieces. I make endless presentations to organize my thought, my structure, my research. I print them. Draw on them. Re-organize them on a table, on the wall, in new clusters and new formats. I draw things together (Figure 4).

The concept of diagramming and sketching is firmly established in design as a prototyping and ideation tool (Buxton, 2010). In a network theory context, Bruno Latour's concept of *drawing things together* as complex networks (Latour, 1986) has been adopted as the framing to describe the designer's competencies as designerly skills working with sociomaterial things (Telier, 2012). And as a philosophical notion, Gilles Deleuze discusses the concept of the diagram as means of constructing new realities (Vellodi, 2014).

In research through design with a programmatic approach, Markussen et al. (2012) suggest *dynamic research sketching* as an exploratory tool to map and visualize theory construction. Building on Brandt and Binder's (2007) diagram for a methodological grounding of research through design defined through question, program, and experiment, Markussen et al. (2012) stress that the integration of theory construction should be included and present three approaches: theory refinement, theory extension, and theory merging.

Diagramming and sketching are part of my method. All my models and frameworks are results of ongoing sketching and thinking. For me, visualizing is part of the thinking process. I will not include all my visual conceptual processes here, but the visual models, lists, aspects, and insights I do include are to communicate ideas and thoughts. They are meant as companions for designers in the development process to think with and through. They are not meant as a taxonomy of a finished general framework to follow from start to finish.

Figure 4. Pictures from print sessions at the Exostudio

Annotated Portfolio

The framing of the engagements of the project was initially based on annotated portfolios of interactive installations. Annotated portfolio is a methodology of communicating design research by annotating a collection of designs to show the connection between the design and the issues of concern to the research. By mixing pictures and text as annotations, an annotated portfolio can highlight resemblance or differences, and be formulated to reflect different audiences or purposes (Gaver & Bowers, 2012).

Gaver and Bowers (2012) suggest that the annotated portfolio can be part of theory formation in design research. By moving beyond looking at one single design at a time – the creation of an annotated portfolio can serve as an alternative to formalized theory. In line with Redström's concept of an assemblage of definitions that aims towards a meaningful whole (Redström, 2018): "If a single design occupies a point in design space, a collection of designs by the same or related designers establishes an area in that space" (Gaver & Bowers, 2012, p. 44).

"Theory promises generality and guidance but seems inadequate to capture the situated, multidimensional, and configurational nature of design, and moreover threatens to occlude the potency of unique, embodied artifacts in a cloud of words and diagrams. Methodologies and theories may well produce respectable research, but the danger is that this will come at the expense of design"(Gaver & Bowers, 2012, p.42).

The Programmatic Process

Inspired by Schön's (1983) classification of experiments Bang and Eriksen (2014) divide programmatic design research into the three stages in relation to the role of design experiments and engagements throughout the research: *Beginnings: exploratory experiments* – at this stage, the framing process and study contextualization is started, *Perform: move-testing experiments* – here experiments are performed in iterations, and *Intersections: hypothesis-testing experiments* is where the study will be completed in a mix between experiments and theoretical perspectives. I divide my programmatic process into the three stages to account for the role of the experiments in the different stages of the research program.

#1: Beginning

Beginnings: Exploratory experiments

The initial framing of the project was based on an annotated portfolio (Gaver & Bowers, 2012) of interactive installations from my collaboration with the art group illutron and the design collaboration UNMAKE. This provided a context for the project's overall program and contextualization. In parallel with theoretical concepts from phenomenology and an exploration of the materiality of bodily interaction design.

#2 Performing

Perform: Move-testing experiments

In the Perform phase the program unfolded through practice-based exploratory prototypes made as experiments in a lab setting. The annotated portfolio was frequently revisited in new iterations. The experiment sessions provide insight for investigating phenomenological concepts into aspects, and aspects for the materials of bodily interaction designers. The annotated portfolios are part of unfolding the materials.

#3 Forwarding

Intersections: Hypothesis-testing experiments

In the final phase, the work-in-progress case is analyzed through an interview with the performers of the installation to test the hypotheses and takeaways from the previous stages, which is set into perspective according to the knowledge contribution and a reformulation of the program.

4| Research Program

4| Research Program

This section is the formulated research program titled *Bodily Interaction Design*. It will be further evolved in chapter 7, *Perspective: Bodily Interaction Design*.

Bodily Interaction Design

For Bodies | Through Bodies | With Bodies

A bodily interaction design research program that presents the lived experience of designing.

> "...the program is not just a declaration of intent [...] it is the expression of a worldview, a provisional and incomplete one, but nonetheless a view" (Redström, 2018, p.117).

Bodily Interaction Design is a design research program that explores the materiality of interaction design from a phenomenological perspective. The program is a phenomenological perspective and material investigation of interaction design, as a way of doing phenomenology for practitioners of interaction design with an emphasis on the bodily experience a designer has with and through materials.

The Merleau-Ponty-inspired phenomenological perspective is applied to interaction design as a design perspective of the designer's bodily relation with the material. Designers act and make meaning through bodily relation with the material: in so doing, designers perform phenomenology.

Phenomenology is increasingly used in interaction design to ground methods, but seldom presented as a concrete methodological approach. With a practical approach beyond the use of theoretical terms with no stance in practice, the project acknowledges the need to translate from abstract theory into design practice. By viewing both research through design and phenomenology, an exploratory process of performing, the active participation of the lived body is the foundation of being, meaning, and making.

In the field of HCI and interaction design there is a continuously need for scholarly and practical depth in the areas of performativity, embodiment, and phenomenology that goes beyond the focus on usability in traditional HCI (Fallman, 2008), beyond the notion of embodiment as situatedness (Dourish, 2001), and beyond theoretical terms such as somaesthetics (Shusterman, 2008), physical and tangible computing (Baskinger & Gross, 2010; Ishii & Ullmer, 1997), towards a practical approach in which interaction design is

developed based on knowledge about our phenomenological relationship with technology.

The program unfolds through practice-based research of large-scale interactive installations that elicit embodied behavior executed in social settings at events and festivals and exploratory prototypes developed as experiments in a lab setting investigating the program.

Speculatively the program asks *what if* (Dunne & Raby, 2013) to provoke and probe new values and worldviews (Redström, 2018):

Question/curiosity/provocation/investigation/exploration/what if...
...the materiality of interaction design was considered from a phenomenological perspective. How can we design bodily interaction design as a way of doing phenomenology for practitioners of interaction design?

I explore and unfold the research program's *what if* -provocation through the three angles: *perspective*, *methodology* and *materiality*, and through the three sub explorations:

Perspective: Bodily Interaction Design: A revised phenomenological perspective.
What is the worldview of Bodily Interaction Design?

Methodology: Phenomenological Research Through Design. The methodology of the perspective. *What is the lived experience of designing as a methodology?*

Materiality: The materiality of a Bodily Interaction Designer. Unfolding the materiality of the methodology: *What are the materials of a bodily interaction designer?*

See illustration of the research program (Figure 5):

Contributions

The project will contribute to conceptual literature in HCI and interaction design through close reflection on practical design processes. As a contribution to scholarly research in design, this dissertation has the broad goal of exploring the materiality of interaction design from a phenomenological perspective. Specific aims include:

1. Expanding a bodily perspective from a phenomenological perspective.
2. Developing a methodology of phenomenologically based research through design approach.
3. Development of a material unfolding of the methodology as the materiality of Bodily Interaction Design.

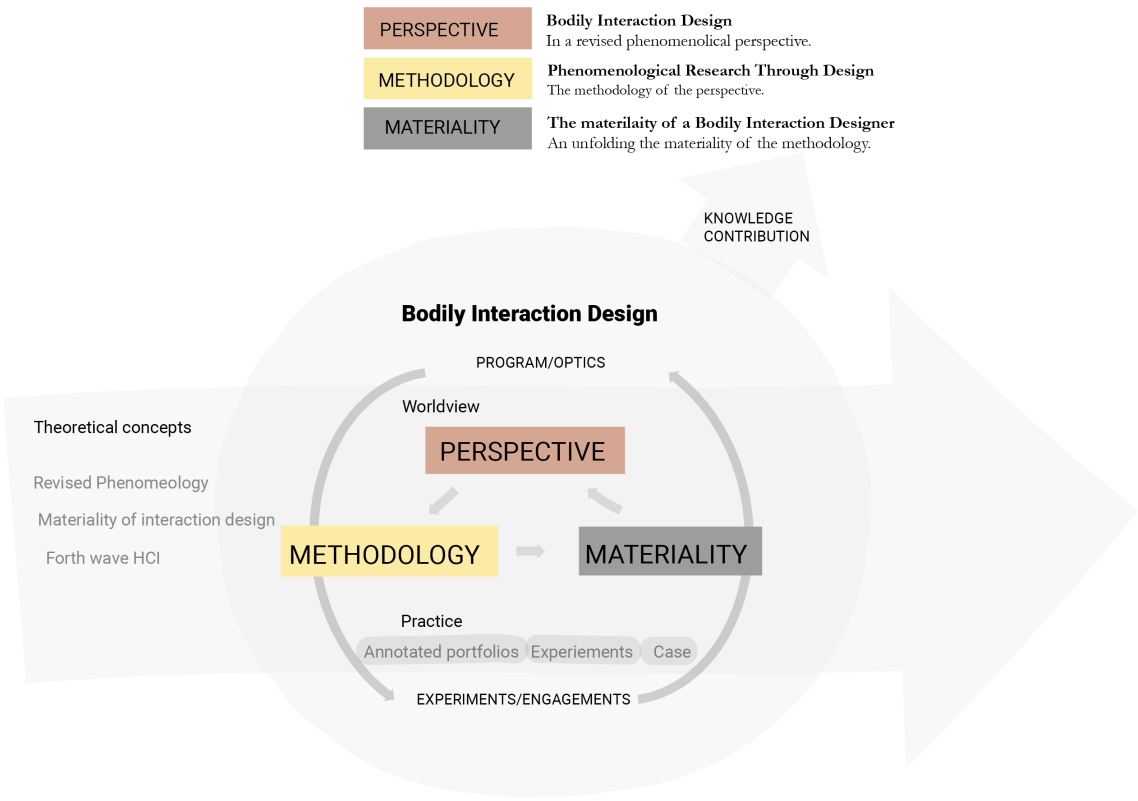


Figure 5. Illustration of my research program. Model adapted from Löwgren, Svarrer Larsen and Hobye, (2013, p. 87.)

The Perspective: Bodily Interaction Design

Bodily Interaction Design will present a bodily perspective to designing interaction design in a worldview of the body that acknowledges that bodies are multifaceted and sociocultural entangled.

The perspective is a contemporary phenomenological perspective that views the body as entangled and the designer's bodily relation with the material as a basis to the idea that designers are performing phenomenology.

The Methodology: Phenomenological Research through Design

Phenomenological research through design will represent a new field within research through resign. Here the researcher acknowledges her own sensory perceptive presence, not only by handling materials and materiality, but also through her own subjective sensory materiality. Additionally, four methodological aspects of phenomenological research through design are presented: (a) prototyping with the lived body, (b) the interplay between touch and touchback, (c) social interrelation, and (d) drifting.

The Materials: The Materiality of Bodily Interaction Design

The material contribution will serve as an expansion of the materiality of Bodily Interaction Design. Specifically, this is aimed at design practitioners of interaction design. For designers, materiality is the act of being (and doing). Materials in interaction design include physical/tangible materials, computational material, and the body as material.

Additionally, it is stressed that materials should be considered entangled with socio-cultural aspects, politics, and ethics.

5| Portfolio of Engagements

5| Portfolio of Engagements

This chapter is a portfolio of all the practical engagements. The engagements are chronologically divided into the three stages of the programmatic process: beginning, performing, and forwarding. The beginning includes six interactive installations presented as two annotated portfolios of previous interactive installation from my UNMAKE and illutron collaboration. The performing phase includes two exploratory experiment sessions. Forwarding includes the case memoryMechanics (Figure 6). The chapter includes the following subsections: *Large-Scale Installation: Dream Forest*, *Portfolio Tangible Interactions*, *Portfolio: Bodily Actions*, *Experiments*, and *Case*.

The purpose of this chapter is to create an overview of the engagements. Throughout the dissertation they will serve as examples and be part of unfolding the research program.

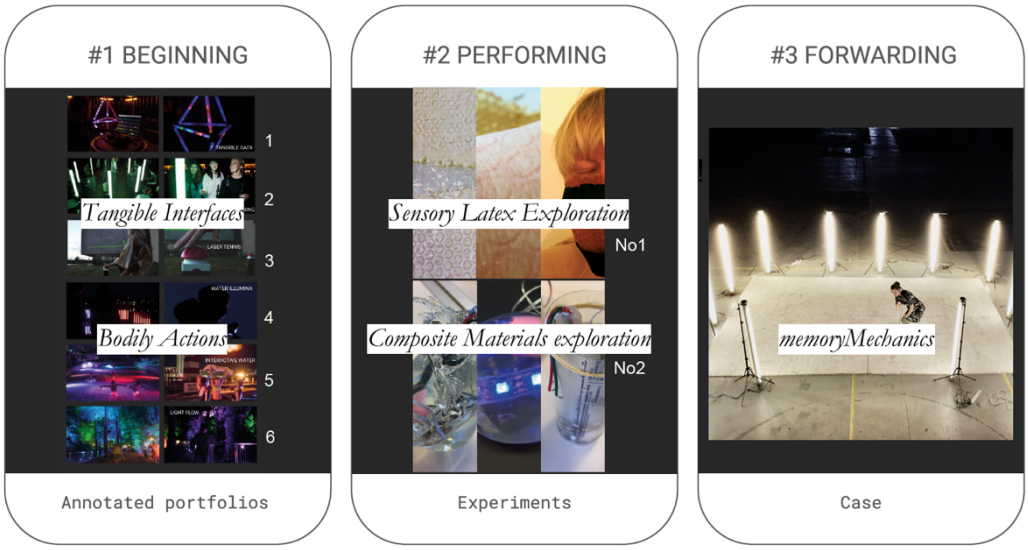


Figure 6. Visual overview of practical engagements: beginning, performing, and forwarding

But first, to initiate an example of large-scale interaction, I will begin with a description of walking through the installation Dream Forest.

Figure 7. Dream Forest. Photo by Mathias Vejerslev

Large Scale installation: Dream Forest

Dream Forest is an interactive installation by illutron at a large, annual, week long music festival set in the woods. The intention was to create an audiovisual walking experience as a break from the noisy festival in a huge, untouched area of the woods where participants could exit the festival though a hole in the fence and enter a magically lit up area of the wood. They are given a headset playing a calm soundscape and go for a walk passing lit trees that change patterns when they walk by. They meet a performance halfway through and exit the area at a different place from where they entered before returning to the noisy festival site again. The installation was only open at night, after dark (Figure 7).

The technical setup involved an incredible number of controllable LED light strips arranged as an entrance gate (controlled through a PixelPusher and a Mac mini) and the trees along the pathway each had a (distance) sensor and a microcontroller (sending data via wi-fi network to a computer). In addition, the soundscape was playing via an FM radio transmitter to the headset.

Nicolas Padfield, Schack Lindemann & I comprised the principal players in charge of organizing and facilitating the development, while a smaller group helping with production and a large group of illutron members and friends joined us at the festival.

Credits: Dream Forest is an illutron installation. Created and executed by illutron members and friends: Alice Walsh, Franz Ejskjær, Helinska Katarzyna, Jason Knight, Kasper Jonas Buus Pedersen, Keith Lim, Naya Moll Olsen, Nicolas Padfield, Nikolaj Møbius, Mads Hobye, Mai Rytter Frederiksen, Maja Fagerberg Ranten, Mathias Vejerslev, Peter Emanuel Fabricius Duer, Pia Nielsen Padfield, Schack Lindemann, Simion Lulian Belea, Tea Toteva, Tobias Lukassen, Tine Vraast-Thomsen, and Vanessa Carpenter. It was executed at Smukfest (a five-day Danish annual music festival) in 2016 in collaboration with Martin Ersted and Stig Andersen. http://www.illutron.dk/filter/showcase/Dream-Forest-illutron-Smukfest-2016

Festival participants meet a hole in the fence... (Figure 8)

Figure 8. Dream Forest. Photo by Nicolas Padfield

They are welcomed, handed a headset, and invited to go for a walk in the forest... (Figure 9).

Figure 9. Dream Forest. Photo by Mai Vanilli

...and go through a tunnel of light towards the woods, and a soundscape of calm ambient music starts playing in the headset... (Figure 10*)*

Figure 10. Dream Forest. Photo by Mathias Vejerslev

The noise from the festival disappears completely. Breathe. Slowly... (Figure 11)

Figure 11. Dream Forest. Photo by Mai Vanilli

They follow the path through the woods and pass illuminated trees, and other people walking slowly through the woods… (Figure 12*)*

Figure 12. Dream Forest. Photo by Maja Fagerberg Ranten

Halfway through the walk, they get to an open area lit up by white light, where they meet a performance of aerial dancers. The breath from the dancers is visible like smoke in the heavy white light. (Figure 13)

Figure 13. Dream Forest. Photos by Mathias Vejerslev

They continue the walk and follow the path of lit up trees. They get to the end of the walk. They return the headset and exit through a door to return to the festival again (Figure 14)

Figure 14. Dream Forest. Photo by Mai Vanilli

Dream Forest. Photo by Mathias Vejerslev

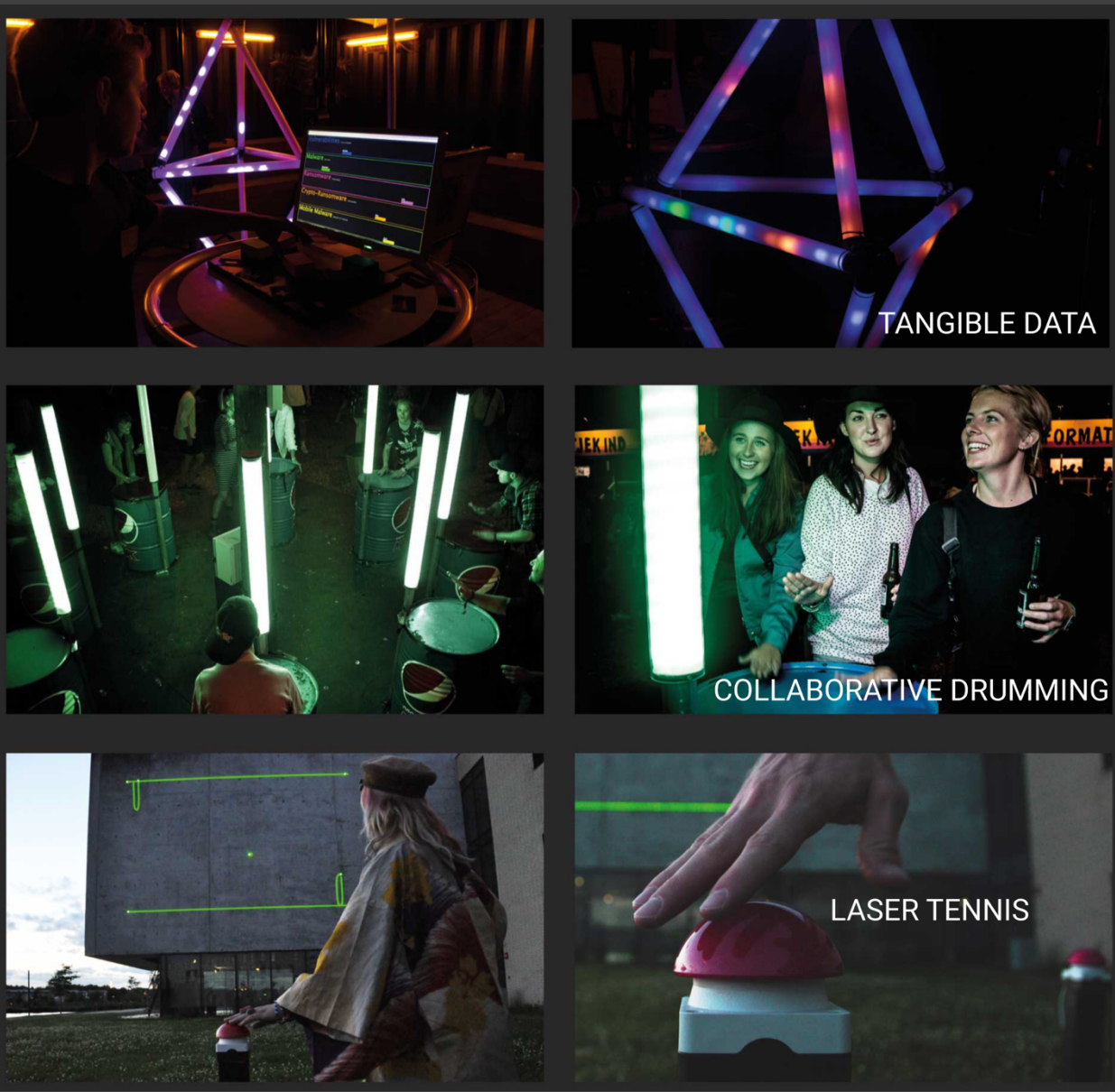


Figure 15. Portfolio of the three installations Tangible Data, Collaborative Drumming, and Laser Tennis

Portfolio: Tangible Interfaces

Portfolio: Tangible Interfaces is a portfolio of three interactive installations- *Tangible Data, Collaborative Drumming,* and *Laser Tennis* -where the input of the installation is made through a tangible interface (Figure 15). It was initiated as an annotated portfolio in an abstract presentation (Ranten 2018) at the Affects, Interfaces and Events conference in 2018. The projects are viewed from a material approach, dividing the individual projects into three categories: tangible material, computational action, and experiential aspects. Note that I use the term *experiential aspects* to indicate intended experience from a development point of view rather than an actual user experience (which would require data about the user's experience). The three projects all aim to elicit embodied experience through tangible interfaces.

The portfolio will be completed as annotated portfolio in chapter 9, *Materiality: The Materiality of Bodily Interaction Design* in the subsection *Tangible Material.*

Figure 16. Tangible Data. Photo by UNMAKE

1. Tangible Data (2015)

Tangible Data is a light sculpture with a tangible interface visualizing data. The installation has two parts: a tangible interface and a light sculpture as the output. The tangible interface consists of small plastic boxes with known icons for playing, stopping and rewind. The colors each represent a data type (the number of different hack attacks in a year). The participants can play with the interface by moving the objects to activate data as color on the sculpture and reflect on the statistical data through touching as physical contact (Figure 16).

Tangible Data was part of a Bits and Beers evening hosted by DELTA/IdemoLab as part of the WHINN conference with the annual theme of cyber security. Participants could join the Bits and Beers evening after attending a day of talks about cyber security and hacking into the health sector as one of the activities and play with statistical data in a playful tangible interface (Figure 17).

TANGIBLE MATERIAL	COMPUTATIONAL ACTION	EXPERIENTIAL ASPECTS
Tangible objects	RFID activation	Move objects to activate data
Light sculpture	Reactiveness	Playful
Info screen	Game elements	Reflection vs play
	Data to color translation	

Figure 17. Tangible Data, overview of tangible material, computational action, and experiential aspects

Credits: Tangible Data is an UNMAKE installation. Created and executed by Halfdan Hauch Jensen & Maja Fagerberg Ranten. It was executed at Delta Labs Bits and Beers WHINN event in 2015. https://www.unmake.dk/ux-portfolio/tangible-data/

Figure 18. Collaborative Drumming. Photo by Mads Hobye

2. Collaborative Drumming (2015)

Collaborative Drumming is a large-scale playful social installation. Lighted barrels comprise the tangible material. The action is to "catch" the light. Participants collaborate to catch the light by drumming on the barrels. Each barrel has a piezo sensor mounted sending a signal to an Arduino board. There is a game logic of three rounds and if they complete the rounds the light will change to a blinking red color followed by a big explosion from a fire cannon. (Figure 18)

The large-scale interface compels the participants to use their full bodies and collaborate to complete the game play. The competitive aspect- as well as the surprise from the fire cannon -can create bodily reactions like excitement, fear, pleasure, or pain. (Figure 19)

TANGIBLE MATERIAL	COMPUTATIONAL ACTION	EXPERIENTIAL ASPECTS
Barrel with light	Simple i/o logic	Movement (drumming)
Output light change	Game structure	Playful (social game)
Fire cannon	Reactiveness	Competition (excitement)

Figure 19. Tangible Data, overview of tangible material, computational action, and experiential aspects

Credits: Collaborative Drumming is an illutron installation. Created and executed by illutron members and friends: Carsten Namansa, Christian Liljedahl, Harald Viuff, Halfdan Hauch Jensen, Lars Kynde, Maja Fagerberg Ranten, Nikolaj Møbius, Schack Lindemann, Peter McKenna, Mona Jensen, Nicolas Padfield, Mads Hobye, Vanessa Carpenter, Mai Vanilli, Ursula Fredlund, Rasmus Jørgensen, Morten Luckow, Magnus Fredlund, Søren Buhl Pedersen & Katarina Sočan. It was executed at Smukfest in 2015 (in collaboration with Martin Ersted, Stig Andersen, and Jonas Halberg). http://www.illutron.dk/filter/showcase/Skanderborg-Festival-2015

Figure 20: Laser Tennis. Photo by UNMAKE

3. Laser Tennis (2016)

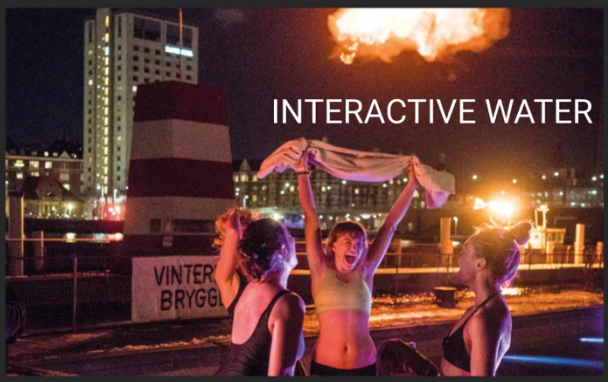
Laser Tennis is an old school arcade game transformed into an installation with a laser projection on a wall and an input interface of buttons in front of the wall. Each side has two buttons- one controls up, the other down -so two or more people can play in teams against each other (Figure 20).

The tangible input interface is comprised of oversized buttons – a classic game interface. Since the interface area is supersized, the participants need to use their full bodies to play the game. The computational action is a simple input/output (i/o) logic with a built-in game structure of four rounds and an announced end winner (Figure 21).

TANGIBLE MATERIAL	COMPUTATIONAL ACTION	EXPERIENTIAL ASPECTS
Supersized buttons	Simple button i/o	Playful (game)
Output: laser 'screen'	Reactiveness	Competition (reward based)
	Game structure	Bodily & social interaction

Figure 21. Laser Tennis, overview of tangible material, computational action, and experiential aspects

Credits: Laser Tennis is an UNMAKE installation. Created by Halfdan Hauch Jensen & Maja Fagerberg Ranten. It was executed at Roskilde University's annual party in 2018. https://www.unmake.dk/ux-portfolio/laser-tennis/



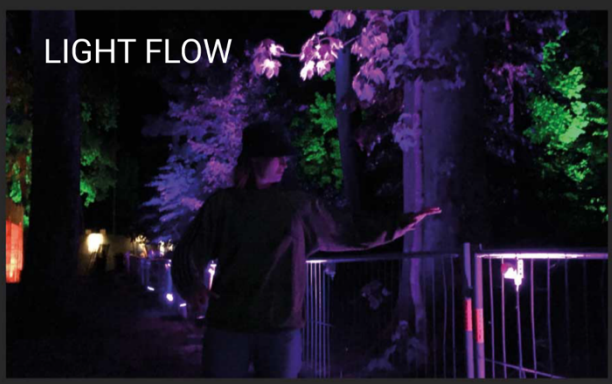


Figure 22. Annotated portfolio of the three installations Water Illumina, Interactive Water, and Light Flow

Portfolio: Bodily Actions

Bodily Actions is a collection of three interactive installations that all have bodily action as the initiator of the installation: *Water Illumina,* and *Interactive Water, and Light Flow* (Figure 22).

These projects are described from a material approach with the categories tangible material and computational action. The third category from the previous portfolio *experiential aspects* is replaced with the bodily perspective of *bodily action* and *bodily impact*. The bodily action is the input and bodily impact is the possible bodily impact you get in return from the bodily action.

I have previously clustered the three installations as an example of works where the participants bodies are incorporated as part of the installation (Ranten, 2020) in a short contribution to an anniversary Performance Design publication.

The portfolio collection is completed as an annotated portfolio in chapter 9, *Materiality: The Materiality of Bodily Interaction Design* in the subsection *Bodily Material.*

Figure 23. Water Illumina. Photo by UNMAKE

4. Water Illumina (2016)

Water Illumina is an interactive light installation where participants can activate fluid colors on a light installation by blowing air into a funnel.

The tangible material is two funnels and a sculpture of light. When participants blow air into the funnels, they create a colored fluid light change in the sculpture (Figure 23). One funnel creates blue light, the other red, making it possible for two participants to either blend and collaborate in creating colors together or compete to fill out the installation with their designated color. The amount and duration of air blown/breathed into the funnel determines the amount and speed of colored fluid light generated. The bodily impact can be physically embodied as you use your breath to interact with the light, creating a playful and social interplay (Figure 24).

TANGIBLE MATERIAL	COMPUTATION ACTION	BODILY ACTION	BODILY IMPACT
Funnel (with a microphone) Sculptural light	Reactiveness Activate fluid color Liveness	Blow air (to activate color)	Body awareness Physically embodied Playful/social interaction

Figure 24. Water Illumina, overview of tangible material, computational action, and bodily action/impact

Credits: Water Illumina is an UNMAKE installation. Created by Halfdan Hauch Jensen, and Maja Fagerberg Ranten. The project was supported by Roskilde Municipality and FabLab RUC. It was executed at Trekroner Lake in 2016. https://www.unmake.dk/ux-portfolio/water-illumina/

Figure 25. Interactive Water. Photo by Mathias Vejerslev

5. Interactive Water (2017)

Interactive Water is based on a cold-water winter bathing experience. Participants enter the bathing area from the warm sauna in groups of ten. They jump into the water one person at a time, and as the number of participants goes up, the light in the water changes from cold blue colors into warm red ones (Figure 25) and culminate as all ten participants are in the water by blinking and a fire cannon goes off and spreads warmth to the cold bodies. The possible bodily impact ranges from shock from the cold water to warmth and excitement (Figure 26).

TANGIBLE MATERIAL	COMPUTATION ACTION	BODILY ACTION	BODILY IMPACT
Changing light pattern (in the water) Light sculpture Fire cannon	Activate color patterns Light sculpture counts up i/o logic Reactiveness	Jump (into the water)	Chock/freezing Excitement /endor-phins Warmth

Figure 26. Interactive Water, overview of tangible material, computational action, and bodily action/impact

Credits: Interactive Water is an UNMAKE installation. Created and executed by Halfdan Hauch Jensen, and Maja Fagerberg Ranten. Featuring illutron on fire cannon by Harald Viuff. It was executed as the event *Ildddåb* at Frost Festival 2017 in collaboration with Kulturhavn365, Vinterbad Bryggen, and Team Bade. https://www.unmake.dk/ux-portfolio/interactive-water/

Figure 27. Light Flow. Photo by UNMAKE

6. Light Flow (2018)

Light Flow is an interactive installation, arranged as a 100-meter-long pathway of dynamically changing lights in the woods of a music festival (Figure 27). The pathway has a system of motion sensors and as participants walk by, the light visualization changes as if following the participants' movement. The light is placed on both sides of the pathway, lighting up the huge trees with dynamically changing colored light. Simply by walking, participants can get the experience that the light is following them, or they can explore the visualization by walking back and forth (Figure 28).

Besides being part of the annotated portfolio Bodily Actions unpacked in chapter 9, *Materiality: The Materiality of Bodily Interaction Design*, Light Flow is also used as example of a phenomenological design process in chapter 8, *Methodology: Phenomenological Research through Design*, in the subsection on *Phenomenological Design Process*.

TANGIBLE MATERIAL	COMPUTATION ACTION	BODILY ACTION	BODILY IMPACT
Movement sensors Light changing	Reactiveness Activate dynamic light	Movement (walking, running, passing by)	Playful Nothing

Figure 28. Light Flow, overview of tangible material, computational action, and bodily action/impact

Credits: Light Flow is an UNMAKE installation. Created by Halfdan Hauch Jensen, and Maja Fagerberg Ranten. Executed by Halfdan Hauch Jensen, and Maja Fagerberg Ranten, Carsten Namansa, Schack Lindemann, Nicolas Padfield, Leonora Bryndum, Morten Bønke & Philip Pihl. It was executed at Smukfest in 2018 (in collaboration with Jonas Halberg). https://www.unmake.dk/ux-portfolio/light-flow/

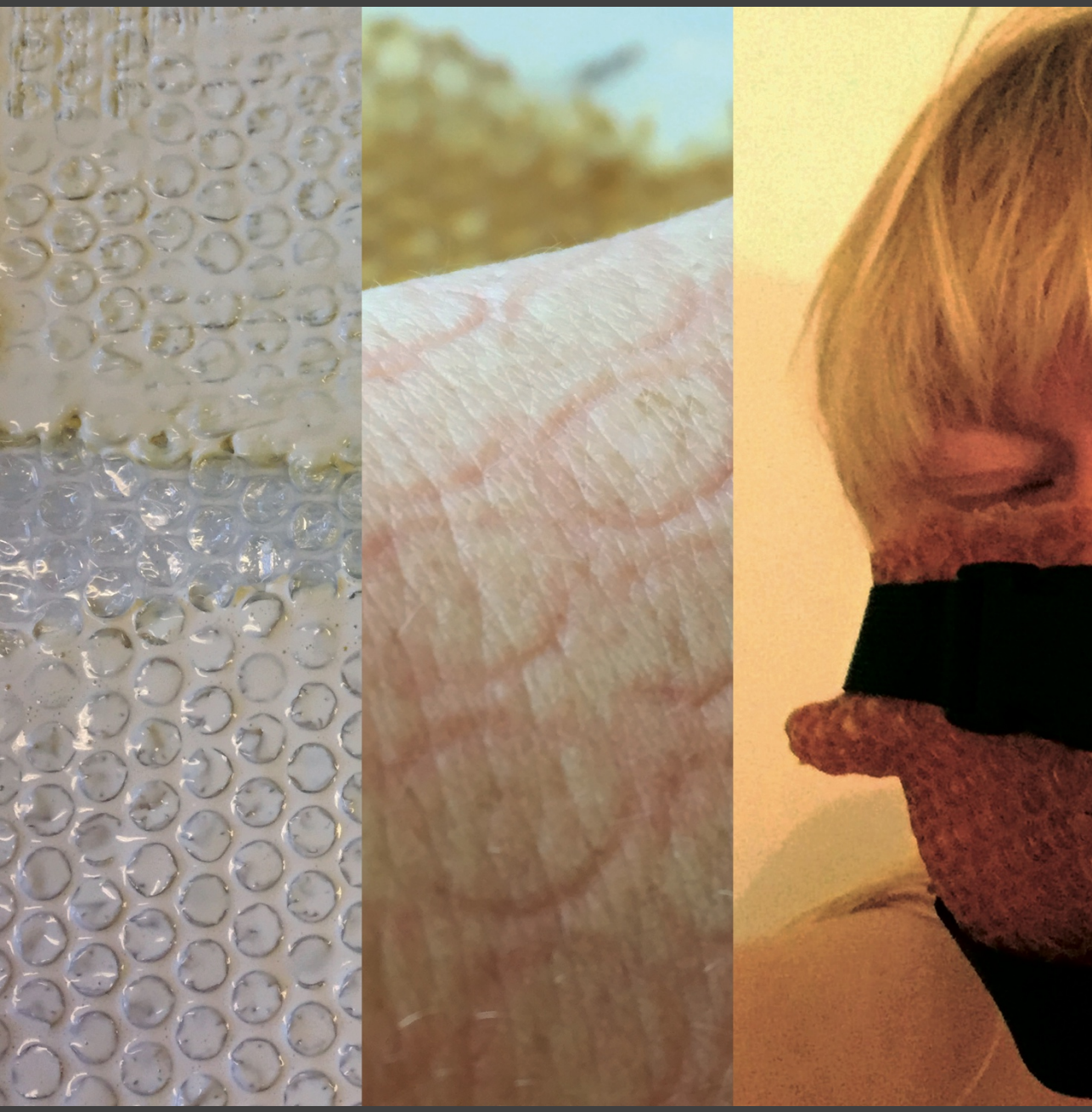


Figure 29. Photos from the latex explorations. Photos by Maja Fagerberg Ranten

Experiments

The two experiment sessions; the sensory latex exploration and composite material explorations were performed during 2018-2019. They both serve as phenomenological insights about tangible and bodily aspects of working with material exploration in a lab setting in chapter 8, *Methodology: Phenomenological Research through Design* in the subsection *Material Experiments*.

Series No. 1: Sensory Latex Exploration (2018-2019)

The sensory latex exploration involves various material sessions of investigating latex as material and as second skin to the body. The sessions can be divided into three different stages of material exploration, as liquid material, as second skin material, and as material in combination with electronics as wearables (Figure 29). The session resulted in notes about bodily insights as takeaways.

Credits: Latex exploration was performed during 2018-2019 in various locations, and different collaborations. In 2018 executed solo in my home, and at CATCH with David Kadish as part of a collaborative prototype. In 2019 in material exploration sessions at Exostudio with Mads Hobye.

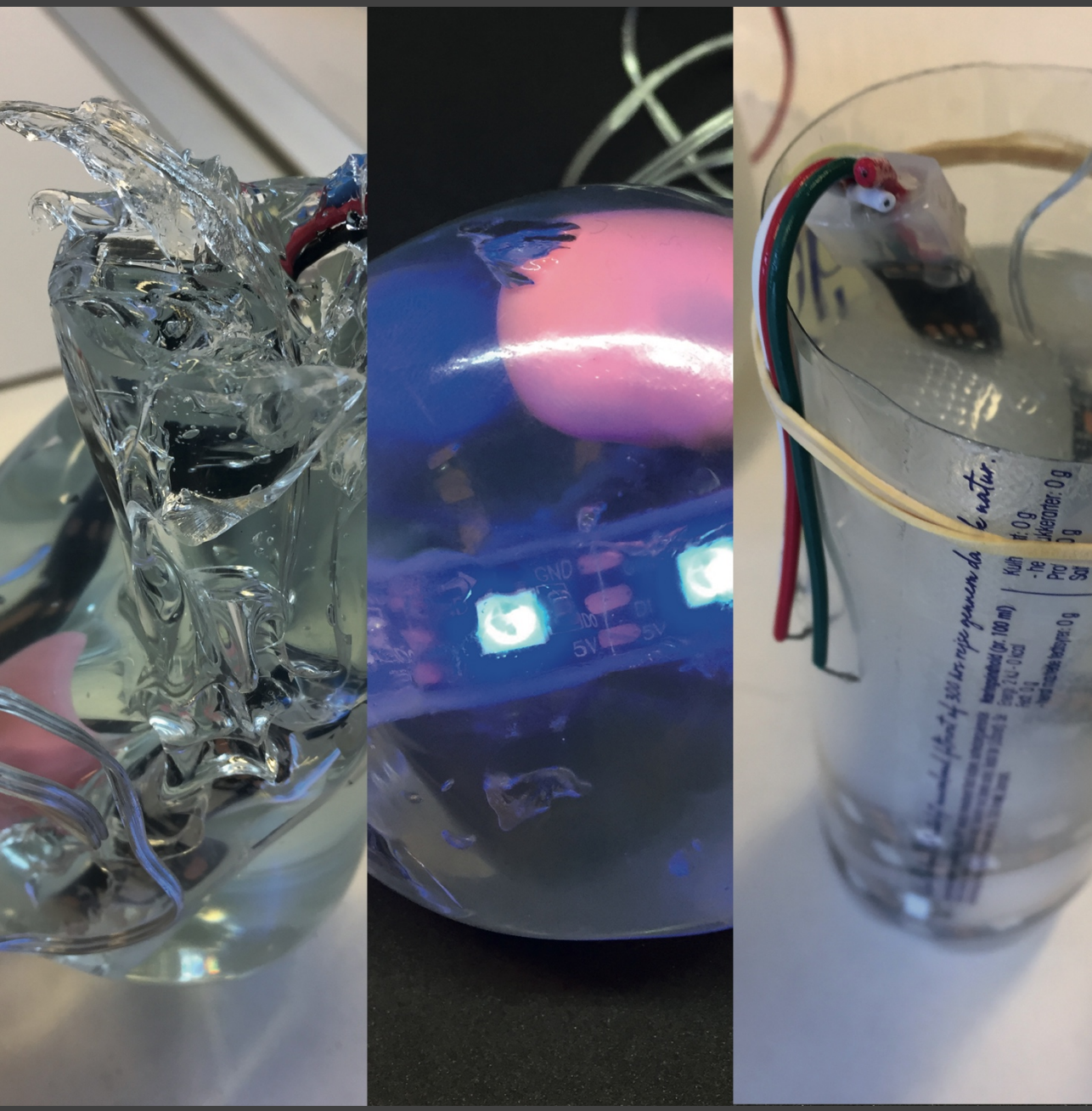


Figure 30. Photos from the composite material explorations. Photos by Maja Fagerberg Ranten

Series No. 2: Composite Materials Exploration (2019)

Composite material exploration was a collaborative session with my colleague Mads Hobye in the Exostudio, where we explored a collection of glass, electronics, and glass-like materials; epoxy, glue, latex, paper, and fabric (Figure 30). The intention was to explore composite materials as detached from object meaning. The session resulted in notes of tangible insights as takeaways.

Credits: Composite materials exploration was performed at Exostudio with Mads Hobye in 2019.

Figure 31. memoryMechanics. Photo by Mads Holbye

Case

memoryMechanics (2019-2021)

memoryMechanics is an ongoing collaborative project initiated as an exploration of performance art and artificial intelligence. In its current form, it is an installation and a performance space of a memory bank. Participants can either contribute to the work with their own memories told as recollections from bodily postures or explore the space through bodily postures and find other people's memories. (Figure 31)

memoryMechnics is unpacked as an example of work outside of the UNMAKE and illutron installations and to test the phenomenological concepts and insights from working with Bodily Interaction Design through an interview with the two performers Lise Aagaard Knudsen and Karen Eide Bøen in Part Three | Fowarding, chapter 10, *Case Interview*.

Credits: memoryMechanics is created by the two collaborations Exocollection (Maja Fagerberg Ranten, Mads Høbye, and Troels Andreasen) and Knudsen/Bøen Collective (Lise Aagaard Knudsen and Karen Eide Bøen) https://www.memorymechanics.net/. memoryMechanics is part of the project Staging the Future of Technologies (SFT) vol. 2, an open call project by CLICK (Barbara Scherfig), HAUT (Naja Lee Jensen) and Catch (Majken Overgaard). The project was funded by Bikubenfonden & Copenhagen Municipality. It has been executed in four different settings and versions. A virtual version at ARS Electronica 2020: https://ars.electronica.art/keplersgardens/de/collectivememories/. And executed at CLICK AI days at the Culture Yard in Elsinore, August 2021: https://kuto.dk/lobende_events/memorymechanics/. At the NOVA festival (in collaboration with Emilia Paunescu) in Bucharest, August 2021: https://www.novanova.ro/memorymechanics. And finally, at HAUT works in process festival in October 2021. https://hautscene.dk/works-in-process/

6| Paper Abstracts

6| Paper Abstracts

A Hybrid Dissertation

Formally speaking, this is a hybrid dissertation – a hybrid between monograph and paper-based dissertation. The dissertation includes four papers. All the papers are collaborative works. My co-authors have been a big part of shaping, initiating, forming, and expanding my research. But in the monograph part of the dissertation, I present my own account of my research as a solo author, where the papers serve as background work, offset, expansion, and inspiration.

The papers are included as the fourth and final part of the dissertation. In the following, I present an overview of how the papers contribute to the dissertation and present the abstract for each paper. Throughout the dissertation, I will point out when they come into play as background work, offset, enlargement, offset, or inspiration.

Paper 1 | Bodily Concepts

Tracing Different Concepts of the Body in HCI: From User to More-Than-Human

Homewood, S., Hedemyr, M., Ranten, M.F., Kozel, S. *Tracing Different Concepts of the Body in HCI: From User to More-Than-Human.* In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. No.: 258 pp. 1–12. Honorable Mention Award.

Abstract: "This paper traces different conceptions of the body in HCI and identifies a narrative from user to body, body to bodies, and bodies to more-than-human bodies. Firstly, this paper aims to present a broader, updated survey of work around the body in HCI. The overview shows how bodies are conceptualized as performative, sensing, datafied, intersectional, and more-than-human. This paper then diverges from similar surveys of research addressing the body in HCI in that it is more disruptive and offers a critique of these approaches and suggestions for where HCI might go next. We end our paper with recommendations drawn from across the different approaches to the body in HCI. In particular, that researchers working with the body have much to gain from the fourth-wave HCI approach when designing with and for the body, where our relationships with technologies are understood as entangled, and the body is always more-than-human" (Paper 1, p.1, Homewood, Hedemyr, Ranten, & Kozel).

Contribution to the dissertation: This paper serves as background work for chapter 7, *Perspective: Bodily Interaction Design*. Specifically, I adopt the suggested bodily view to acknowledge bodies as more-than-human and briefly summarize the different conceptions on bodies in the subsection *Bodily Concepts in HCI*. In Chapter 8, *Methodology: Phenomenological Research Through Design*, I suggest that the different bodily conceptions can be included in the umbrella term *Phenomenological Research through Design*.

Paper 2| Computational Material

Behavioral Complexity as a Computational Material Strategy

Hobye, M. & Ranten, M. F., 2019. *Behavioral Complexity as a Computational Material Strategy*. International Journal of Design. 13, 2, pp. 39-53 35

Abstract: "This paper presents the concept of behavioral complexity as a computational material strategy. The materiality of the designed interaction is a relatively new perspective on interaction design. From this perspective, the behavioral complexity should be understood as the underlying algorithms in the computational code. Complexity in the code enables multiple unique material qualities of computational materials to adapt and come to life through interaction. We propose that behavioral complexity contributes to creating expressive complexity, and present strategies of behavioral complexity as annotations in an annotated portfolio of design examples. For each annotation, simple computational programming patterns are included to illustrate practical implementations. The strategies are to create Reactiveness, Multiple Modes, Non-linearity, Multiple Layers, and Alive Connotations. Finally, we point to the potential of mixing the strategies to expand the complexity of alive and adaptive expressions and discuss strategies for preserving coupling" (Paper 2, p. 39).

Contribution to the dissertation: This paper acts as offset for the unfolding of materials in chapter 9, *Materiality: The Materiality of Bodily Interaction Design*. Specifically, I briefly summarize the iceberg model and point to the lack of bodily material in the model. Furthermore, I refer to the paper's presentation of computational material as behavioral, and list the computational strategies presented in the paper as an example of working with the behavior and properties of computational material in the subsection *Computational Material*.

Paper 3| Specific Context

The Implications of Using Interactive Artifacts to Bridge the Divide Between Audience and Stage in a Conventional Hall Setting.

Ranten, M. F., Hobye, M. & Gram, N., 2020. *The Implications of Using Interactive Artifacts to Bridge the Divide Between Audience and Stage in a Conventional Hall Setting.* PARtake: The Journal of Performance as Research. 3, 1

Abstract: "Within the field of performance art, where the audience and the performance stage are separated, there is a paradox in keeping a conventional divide between the audience and the performing stage while expanding the possible space of engagement between the two. Interactive technology yields tantalizing promises of creating an underlying layer so the conventional divide is still respected and somewhat preserved. This paper presents a cross-sectional view of experiments done with the Royal Danish Theatre to explore different strategies of creating interactive mediation to bridge this divide. We will introduce examples of passive spectatorship modeled performances that attempted to integrate digital interaction. Through the experiments, we have become aware of central implications that one needs to be aware of to fully succeed in integrating in a manner that does not negatively impact the experience of the audience members. The three implications are context expectations, level of audience control, and the embodied experience. Based on the experiments and the implications, we suggest two things to consider: First, we discuss the possibility to work across disciplines and stakeholders to custom design mediated experiences for a particular production. Second, we propose the possibility to think in terms of designing artifacts that can be integrated into the hall setting across different plays without larger interference with the overall experience" (Paper 3, Ranten, Hobye, & Gram. Abstract from https://journals.colorado.edu/index.php/partake/article/view/465).

Contribution to the dissertation: This paper points to the relation between interaction, bodily experience, and context. Specifically, I refer to the two proposed strategies from the paper, and the relationship between meaning-making and the specific context and artform in the subsection *The Context* of chapter 9, *Materiality: The Materiality of Bodily Interaction Design.*

Paper 4| Sound as Material

Sound as Material for Eco-technogenesis

Hines, M., Kadish, D. & Ranten, M. F., May 2020. Sound as Material for Eco-technogenesis. *Proceedings of RE:SOUND 2019*. British Computer Society, s. 195-201 (Electronic Workshops in Computing)

Abstract:
"This paper delineates the conceptual outcomes from a two-week intensive cross-disciplinary conversation between an art historian, an interaction designer, and an artist/engineer. With the aim of applying the concept of technogenesis to an exploration of sound as material for art and design, we consider sound as a material force within an ecosystem. Through this lens, sound produced by either life- or technological-forms allows us to consider the ecological impact and potential meanings of generated sound. Drawing on biosemiotics, we propose that the co-evolution of sound, technology, and environments, what we call eco-technogenesis, demands relational, and thus ethical, thinking. The Rowdy Krause, an autonomous sonic agent designed by Kadish to identify and inhabit an acoustic niche within an ecosystem, serves as a case study for thinking through eco-technogenesis" (Paper 4, p.1, Hines, Kadish, & Ranten).

Contribution to the dissertation: The paper explores notions of sound as material. In chapter 9, *Materiality: The Materiality of Bodily Interaction Design*, subsections *Tangible Material* and *Computational Material*, I refer to the paper's description of sound as computational and as an example of 'half entities.' Furthermore, the term eco-technogenesis presented in the paper can be interpretated as a more-than-human perspective to sound as material.

Reading Guide

The complete dissertation has the following four parts: Part one: Beginning (that you, dear reader, have just read), Part two: Performing. Part three: Forwarding, and the final fourth part; Papers (Figure 33). Dividing the monography part of the dissertation into the three headlines: beginning, performing, and forwarding is inspired by Bang and Eriksen's (2014) three stages that I also used to outline the different stages of my engagements and experiments concerning programmatic research in chapter 2, *Methodology and Methods*.

Part one: Beginning has covered the *Introduction*, *Theoretical Concepts*, *Methodology and Methods*, *Research Program*, *Portfolio of Engagements*, and *Paper Abstracts*.

The upcoming part, Part two: Performing, is the heart of the dissertation. It includes the three main chapters that cover the research program's sub-themes: Chapter 7, *Perspective: Bodily Interaction Design*, Chapter 8, *Methodology: Phenomenological Research through Design,* and Chapter 9, *Materiality: The Materiality of Bodily Interaction Design* (Figure 32).

Part three: Forwarding, include the four chapters: *Case Interview*, *Original Contribution*, *Re-Program,* and *Closing*. It is the final part of the monography part of the dissertation where I 'forward' my research program as a knowledge contribution.

And the final part includes the papers divided into the four themes: Bodily Concepts (*Tracing Different Concepts of the Body in HCI: From User to More-Than-Human)*, Computational Material (*Behavioral Complexity as a Computational Material Strategy)*, Specific Context (*The Implications of Using Interactive Artifacts to Bridge the Divide Between Audience and Stage in a Conventional Hall Setting* and Sound as Material *(Sound as Material for Eco-technogenesis).*

PERSPECTIVE	**Bodily Interaction Design.** A revised phenomenological perspective. *What is the worldview of Bodily Interaction Design?*
METHODOLOGY	**Phenomenological Research Through Design.** The methodology of the perspective. *What is the lived experience of designing as a methodology?*
MATERIALITY	**The materiality of Bodily Interaction Design.** Unfolding the materiality of the methodology: *What are the materials of a bodily interaction designer?*

Figure 32. Overview of the three sub themes and chapters: 7, Perspective; 8, Methodology; and 9, Materiality

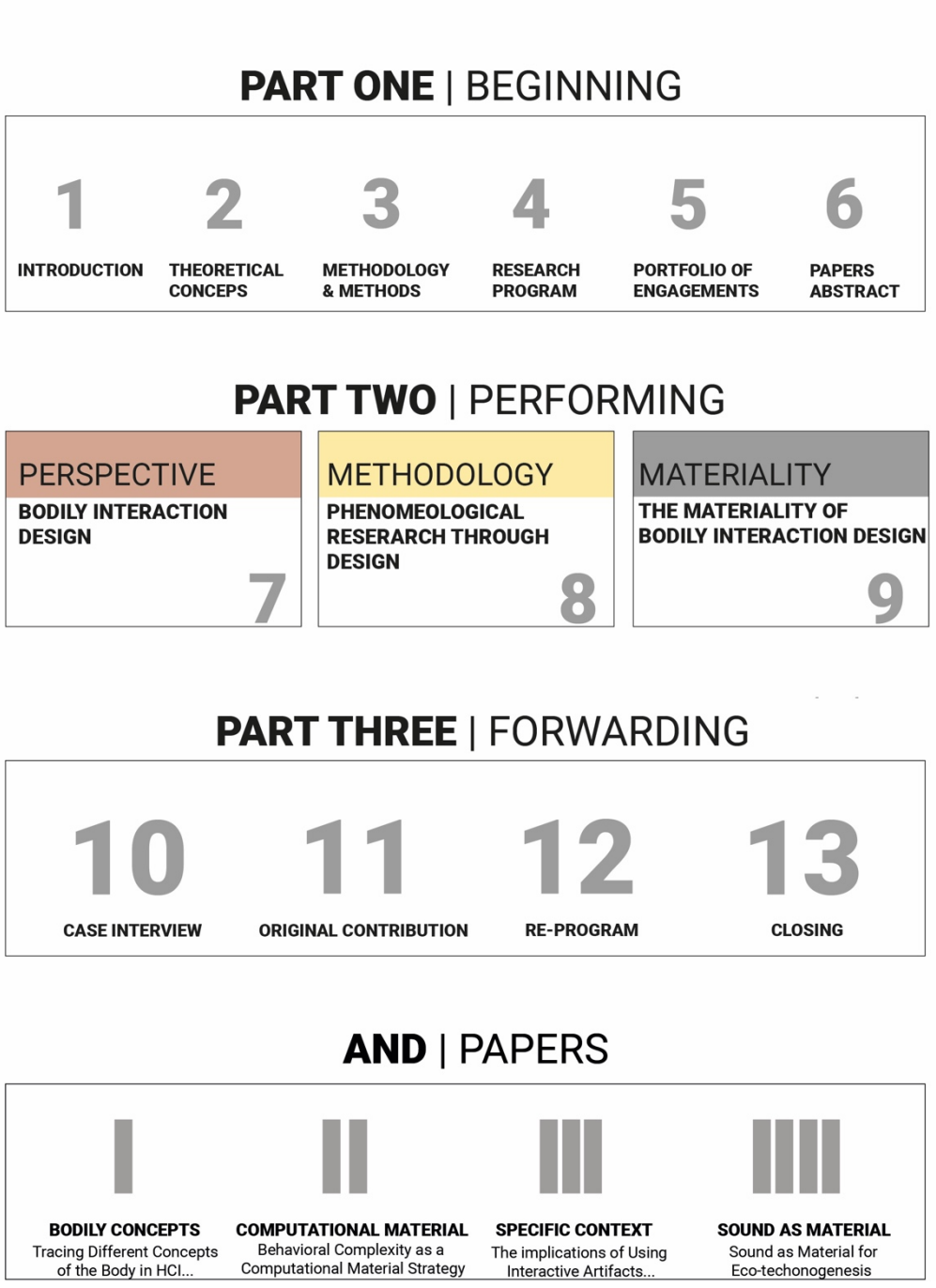
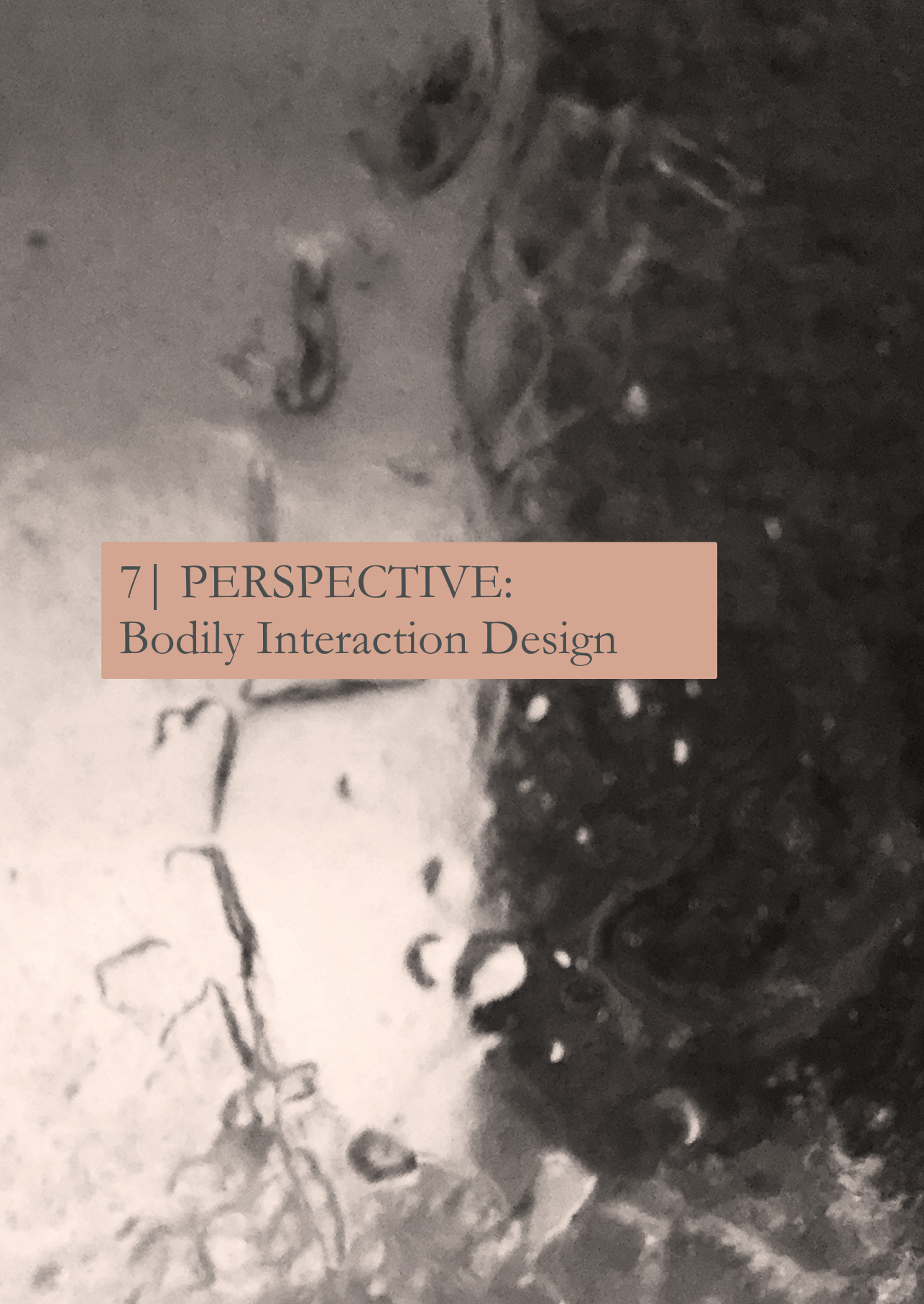


Figure 33. Overview of the four parts and chapters

PART TWO | PERFORMING



7| PERSPECTIVE: Bodily Interaction Design

7 | PERSPECTIVE: Bodily Interaction Design

This chapter is a continuation of the program description. It introduces the perspective of Bodily Interaction Design in a revised phenomenological perspective. It also explores the question: *What is the worldview of Bodily Interaction Design?* through the three subsections *Bodies Making Made Bodies*, *Bodily Concepts in HCI*, and *Related Phenomenology*.

PERSPECTIVE	**Bodily Interaction Design.** A revised phenomenological perspective. *What is the worldview of Bodily Interaction Design?*

Paper 1, "Tracing Different Concepts of the Body in HCI" serves as inspiration in my body view, as bodies being more-than-human. The section Bodily concepts in HCI is a short overview of the narrative arc and body lenses excerpted from the paper.

Bodies Making Made Bodies

> "Bodies, in the end, are also that-head and tail: the very discreteness of the sites of sense, of the moments of an organism, of the elements of matter. The body is a place that opens, displaces and spaces phallus and cephale: making room for them to create an event (rejoicing, suffering, thinking, being born, dying, sexing, laughing, sneezing, trembling, weeping, forgetting …)"(Nancy, 2008, p.17).

Within HCI, there is a growing interest in the notion of living bodies and felt experience (Loke & Robertson, 2010; Höök, 2018; Loke & Schiphorst, 2018; Svanæs, 2013). Still, it is seldom specified what kind of bodies, thereby risking that a universal body is implicit in the design work. Furthermore, there is a lack of positioning notions of bodies in a socio-cultural context and a failure to examine what kind of bodies we design for and how we as designers use our subjective bodies in the design process.

What kind of Bodies?
Loke and Robertson (2011) present different concepts of the body in the following categories: The body as anatomy and physiology, body as expression, body as knowledge, body as physical skill, body as felt experience, and body as social, cultural.

Physically we have a body. When we design for and with bodies, we are [as designers] bodies making made bodies [the user's bodies].

We use the body as a tool to practice design, and the body as a site for design. Hence the body is both an instrument and a material for exploration and expression (Schiphorst & Loke, 2018). Furthermore, our bodies exist in relation with other bodies. In paper 1, "Tracing Different Concepts of the Body in HCI," we unfold the complexity of bodies. That we have and are bodies, and how we exist in continuous relationships with other bodies. Besides being a material object, the body is also the root of our subjectivity: "The body is both a material object and the root of our subjectivity [Leder, 1990; Merleau-Ponty, 1962]. It seems stable, but in fact it is in a constant state of coming to be. This complexity has resulted in work within HCI that integrates a range of disciplines, rationales, methods and ontologies revealing that the term "body" can mean different things to different groups of people in different circumstances" (Paper 1, p. 1, Homewood et. al.).

There is a growing argument to think of bodies in plural (Di Paolo, Cuffari, & De Jaegher, 2019; Spiel, 2021; Höök et al., 2019). Speaking of the body in the singular "... hides the intricate complexity and diversity of bodies under a false universality ("the") and singleness ("body"). Thus, the image the phrase invokes is that of an abstract, adult, healthy, isolated, nondescript, typically male, typically white body. If we speak of bodies, instead, we immediately connote relations and plurality, at least leaving the door open to think them" (Di Paolo, Cuffari, & De Jaegher, 2019. p. 98).

In *Linguistic Bodies*, Di Paolo, Cuffari, and De Jaegher (2019) present four conceptions of bodies and stress the need for a theoretical articulation of the interconnections and contradictions between the diverse types of embodiments. The biological body (often abstracted as a universal body). The situated body. The phenomenological body. And the cultural social conception of bodies (from cultural psychology where bodies are active beings doing things together in the world). As seen in feminist and gender studies, human bodies are no longer universal blueprints, they are actual living material bodies (Di Paolo et. al., 2019). Their phenomenological body is one that breaks free from the functionalist domain and lives through experience, but primarily focused on the individual body: "Despite claims regarding the inter-subjective constitution of human experience, many phenomenological analyses are limited in that they remain focused on the individual subject, positioned center stage and intentionally confronting her world, and not as a material and living part of it…" (Di Paolo et. al., 2019, p.13). They further present a conceptual toolkit – the concept of autonomy, sense-making, agency, sensitivity, mastery, social interaction and participatory sense-making to link the different incommensurate conceptions of human bodies (Di Paolo et. al., 2019, pp.13-15).

In my view, it is obvious that the concept of bodies is multifaceted. We are and have a body. It is biological, it is situated, and it is socially constructed. So, where some see phenomenology as limited to the individual subject, not as a material living part of the world, influenced by culture, etc., for me the notion of the living body is obviously entangled with- and impossible to separate from -social norms and biology amongst other things. In scholarly terms, phenomenology in a social constructivist perspective.

This raises questions about ontological expansion of the understanding of bodies. That the body is multifaceted, and that methods and approaches need updating. We need to ask ourselves, *what kind of bodies*? What kind of bodies are *making* the design and hence what kind of bodies are *made*? What does it mean to consider bodies a material in the design process?

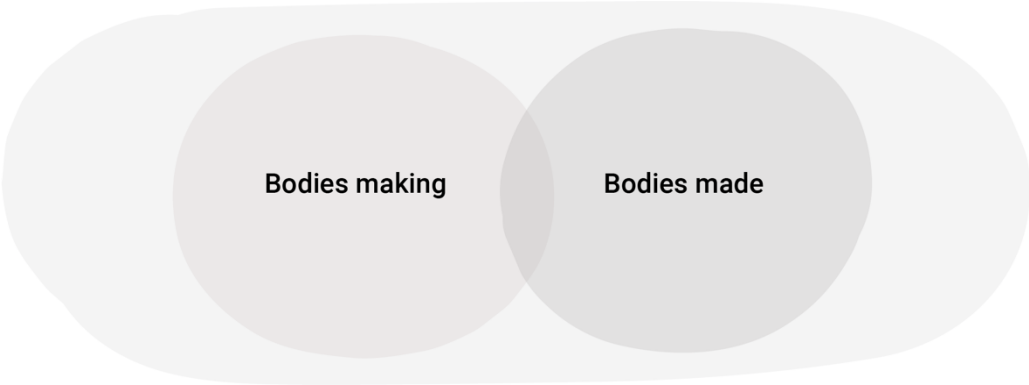


Figure 34. Illustration of bodies making made bodies

I believe we as designers use our bodies in the process. We use it to sense and experience materials; we use it as creators and in the design process when we "make" designs. Hence, we are bodies making. Participants or users' bodies experience the work in the execution, but the way we design influences the bodily experience in the end work. We are bodies making made bodies (Figure 34).

To me the lived experience of designing includes more-than-human bodies. It includes object/subject exchanges, subject/subject exchanges, and nature/subject exchanges. It has a feel dimension that can be physical, functional, and biological. It is in flux and includes the notion of being changeable and in relation to other beings, objects, and elements. Bodies are social, biological, situated, political and cultural. Hence the lived experience is entangled with culture, politics, biology and the socio-cultural.

Designing Bodily Interaction is a bodily perspective to designing interactive installations in a worldview of the body that acknowledges that bodies are multifaceted and socio-culturally entangled.

Bodily Concepts in HCI

In Paper 1 "Tracing Different Concepts of the Body in HCI," we present the notion of the body as following a distinct arc from first wave HCI to the nascent Fourth Wave (Figure 35). The narrative of the arc is *from user to body*, followed by *from body to bodies*, and finally from *bodies to more-than-human bodies*. Within that we place different conceptions of bodies through the lenses *performing*, *sensing*, *datafied*, *intersectional*, and *more-than-human* (Paper, 1. Homewood et. al).

From 'user to body' is the first move, representing the shift from a user focus to the early 'somatic turn' in HCI and a reconceptualization of the user as embodied. It includes the two lenses: 'performing bodies' informed by theories and methods from performance studies and performing arts, and 'sensing bodies' focusing on the body's sensing capabilities (Paper 1. Homewood et. al., pp. 2-3).

The second is 'body to bodies,' representing the shift in considering bodies in plural "…that it is unethical to treat all bodies as if they have the same lived experience" (Paper 1, Homewood et. al., p.4). This shift is represented by the two lenses 'datafied bodies' where the body is considered measurable by technology, and 'intersectional bodies' as interconnected to race, class, gender, ability, age, and sexual orientation (Paper 1. Homewood et. al., pp.4-5).

And finally, the move from 'bodies to more-than-human bodies' as the emerging conception of bodies in HCI. In this approach bodies are considered inseparable from everything that surrounds them: "Rather than framing the human as an independent actor manipulating the world around her, more-than-human perspectives highlight the co-constitutive role of non-human aspects. This reflects a relational ontology and a focus on the agency of more-than-human objects and entities such as things, spaces, people, and materials" (Paper 1, Homewood et. al., p.7).

I adopt the more-than-human approach to the body in my view of bodies in this dissertation. And further suggest that the different lenses and bodily aspects can all be included under the methodological umbrella term phenomenological research through design.

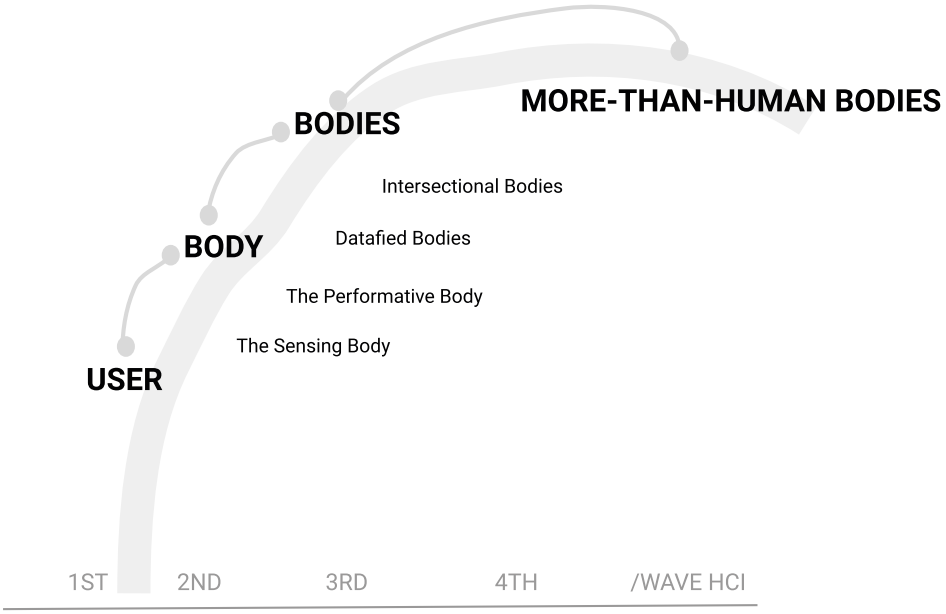


Figure 35. Visualization of the arc and bodily conceptions. Terms adapted from Paper 1 (Homewood et. al.)

Related Phenomenology

Phenomenology has many branches. It is related to senses, experience, objects, tools, time, self, and others. Phenomenology is widely used, re-used, and revised. It appears in social science as a qualitative approach in conducting in-depth interviews (Seidman, 2006). Similar to the new field of Micro-phenomenology, where the focus is on exploring experience through micro-phenomenological interviews and evaluating the quality of the micro-phenomenological research (Valenzuela-Moguillansky & Vásquez-Rosati, 2019). Post-phenomenology focuses on technology as mediators of human experience and technological artifacts, (Idle, 2001; Verbeek, 2016) and analyzes human-technology relations (Hauser et al., 2018). But were post-phenomenology fetish technology. I fetish the body and build my approach entirely on bodily perspectives.

Revised Phenomenology

The phenomenological concepts in this dissertation are inspired by Merleau-Ponty's work in a contemporary revised perspective that acknowledges that bodies are multifaceted and entangled. By adopting the more-than-human bodily view and positioning my research in the transition between the third and fourth wave of HCI, I present a view of

the lived experience of designing as entangled. My understanding of Merleau-Ponty is further refined, informed, and expanded by other people's reading of his work through performative and feminist phenomenology and through new materialism.

New Materialism, Performative & Feminist Phenomenology

Phenomenology, and particularly the work of Merleau-Ponty, has been criticized for the neglect of racial and sexual specificity of the lived body (Diprose & Reynolds, 2011). The lived body is assumed male, privileged, and white. Diprose and Reynolds (2011) present a feminist view of Merleau-Ponty and point to Judith Butler, Moira Gatens, and Elizabeth Grosz as examples of voices in corporeal feminism who use Merleau-Ponty as a resource. Merleau-Ponty's phenomenology and feminism both share an anti-Cartesian perspective – the rejection of separation between mind and body, consciousness, and corporeity (Diprose & Reynolds, 2011, p.201).

New materialism, too, is positioned through critique of Cartesian dualism. New materialist ontology sees the task as one of creating new concepts and affirming matter as *immanent vitality*. "Such thinking is accordingly post- rather than anti-Cartesian. It avoids dualism or dialectical reconciliation by espousing a monological account of emergent, generative material being"(Coole & Frost, 2010, p.8). Furthermore, new materialism erases traditional ontology of, for example, the study of nature, to be entangled with our relationship to ourselves and the world. It goes on to include ethical and political concerns in the exploration of complex issues of modes of matter and living matter: "...explore the significance of complex issues such as climate change or global capital and population flows, the biotechnological engineering of genetically modified organisms, or the saturation of our intimate and physical lives by digital, wireless, and virtual Technologies" (Coole & Frost, 2010, p.5).

In the performing arts there is a rich tradition of turning to phenomenology (Sheets-Johnstone, 1979, 2015; Whatley, 2016; Fraleigh, 2018). Here phenomenology is a method of studying experience – as a first-person voice for the performer or the audience (Fraleigh, 2018). It is understood as a study of experience, hence both descriptive and experiential. And accepted as more than personal: "...what can seem a separate self is already interactive through reciprocities of nature, culture, and consciousness" (Fraleigh, 2018, p.22).

Sondra Fraleigh (2018) describes how performative phenomenology pays attention to embodied actions through behavior. Moreover, she exemplifies this with Simone de Beauvoir's sex and gender phenomenology of becoming a woman, and later how Judith Butler outlined performativity as a feminist and political concept. Karen Barad shows how the entanglement of matter and meaning in performative approaches emerges

through doing and how subjects and objects is intra-actively entangled through performance (Fraleigh, 2018).

"... I propose a specifically post-humanist notion of performativity – one that incorporates important material and discursive, social and scientific, human and nonhuman, and natural and cultural factors" (Barad, 2018, p.226).

Another example of feminist theories is Bardzell's (2018) Feminist Utopia. Positioned within fourth wave theory, she outlines the core values of feminist utopia as accommodating a plurality of voices, resisting relativism, and exploring a radically better future without attempting to define it.

A feminist, new materialism, and performative reading of Merleau-Ponty allow for a pluralist bodily perspective not limited to the individual subject or the universal body but rather as intersectional and actual living material bodies acknowledged as part of the world, influenced by culture, other beings, and materials.

Furthermore, my reading of Merleau-Ponty's phenomenology and the notion of the living body is understood through my own doing and artistic design practice: "In one sense, all phenomenology is a performance; it isn't enough to explain phenomenology, ultimately, it is a *doing*" (Fraleigh, 2018, p.33). I am inspired by Kozel's Merleau-Pontian perspective on the practice of dance and connecting phenomenology to the artistic performative process. She combines performance and phenomenology through the late work of Merleau-Ponty. In relation to Merleau-Ponty's perspective of the dynamics of hyper-reflection and reversibility, she states: "Performance entails a reflective intentionality on the part of the performer herself, a decision to see/feel/hear herself as performing while she is performing, a decision to see/feel/hear others performing while she watches them perform" (Kozel, 2007, p.69).

New Phenomenology

In addition to Merleau-Ponty's phenomenology, in Chapter 9, *Materiality: The Materiality of Bodily Interaction Design* I use elements from Hermann Schmitz's New Phenomenology and his corporeal concepts: *expansion* and *contraction* as notions of how our inner bodily feelings and physical movement are related to both affective involvement, and emotions.

Hermann Schmitz's New Phenomenology nuances the lived experience as a counter to the notion of the mind or soul as subjective experience. He presents the felt body as corporal dynamics, affective involvement and emotions as spatial atmospheres (Schmitz, Müllan, & Slaby, 2011).

Corporal dynamics is the felt body's vital drive between *tightness* and *wideness* by means of *expansion* and *contraction*. They are intertwined, in competition, and in dialogue as a rhythm between expansion, and contraction (Schmitz, 2017). Corporal *expansion* happens as a widening of felt space in one's body, e.g. in the state of relaxation, whereas *contraction* is a narrowing of one's felt body that happens suddenly in states of shock, panic, or concentration (Schmitz et. al., 2011).

"A basic example is the felt intake of breath. It begins with a predominance of expansion in the region of the chest or the abdomen; this predominance gradually phases over into a predominance of contraction, which is released by breathing out before it becomes unbearable " (Schmitz et. al., 2011, p.249).

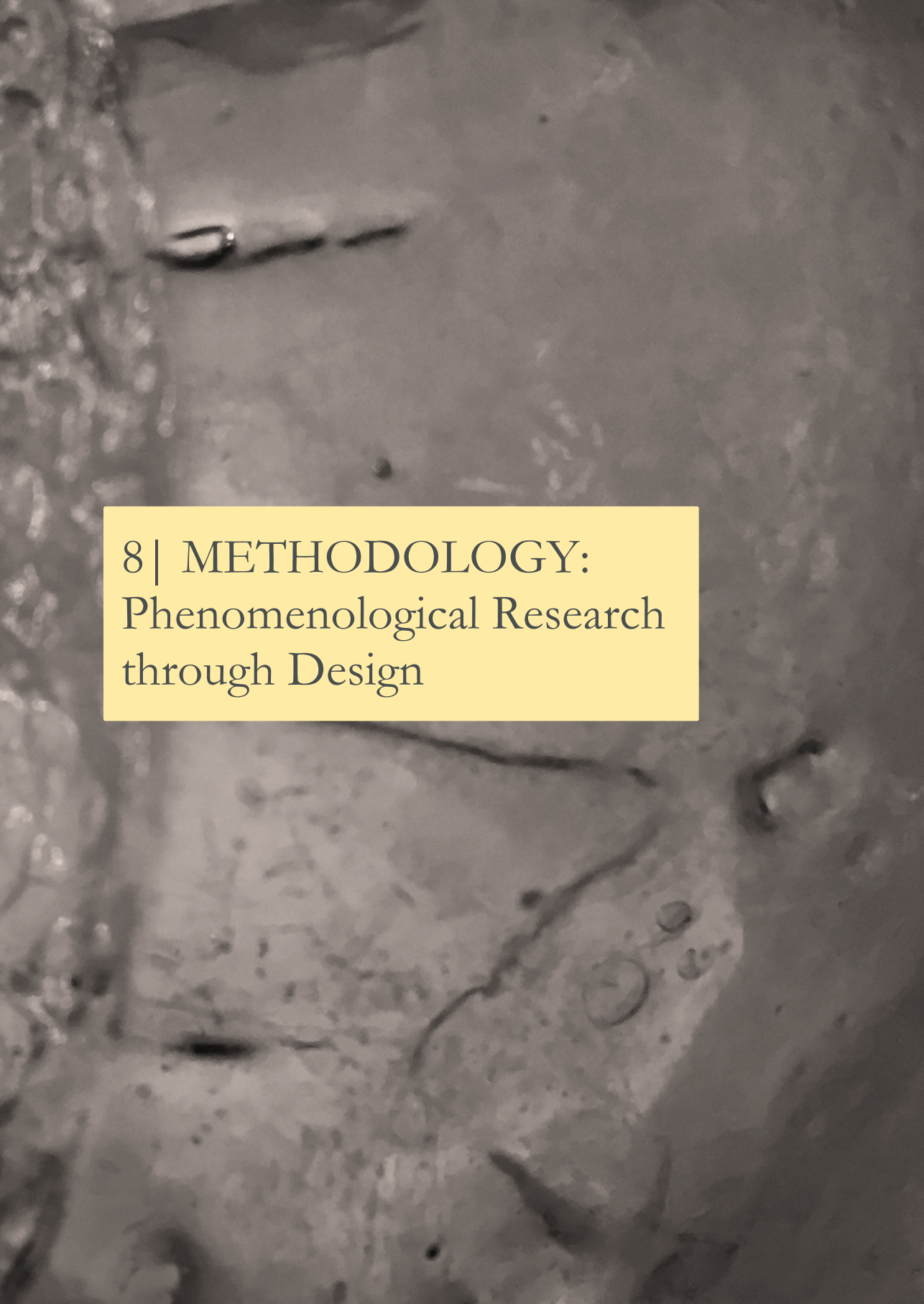
His notion of emotions as atmosphere describes how feelings can be *room-filling*. Exemplified by the atmosphere of grief to be *felt as an authority filling the space* and corporally move, e.g. a joyous person. (Schmitz et. al., 2011, p.258). Hence the *affective involvement* is how corporal feelings are both affected by and involved in what is going on in the environment (Schmitz et. al., 2011).

He distinguishes between two types of corporal emotions – the purely corporeally moving impulses or stirrings felt only by the individual, and the room-filling emotions that affect or "grip" bodies and surroundings. (Schmitz et. al., 2011). In the first category he places hunger, pain, thirst, lust, disgust, freshness, tiredness, and movement kinesthesia like breath, swallowing, running, catching, etc. The second category is anxiety, sadness, shame, cheerfulness, rage, etc. (Schmitz, 2017).

Schmitz's notion of the felt body as an antenna- constantly catching the feelings in the room and in turn filling rooms -recalls Jen-Luc Nancy's description of the body as an echo chamber (through resonance) that responds to music both by inner and outer vibrations (Nancy, 2007).

Furthermore, feelings can appear over time as a process. Here exemplified by shame: "The corporeal dynamic in a state of shame is a process that starts from a corporeal openness towards the social surroundings populated by significant others (domination of expansion) into the contraction of oneself in a submissive movement to hide away from the merciless gaze of those nearby (domination of contraction)" (Schmitz et. al., 2011, p.245).

Another interesting notion is his concept of *half entities* alongside full entities as objects. He includes in this concept: "The wind, the human voice, glances, musical melodies, meteorological atmospheres, and electrical and other forces such as gravity..." (Schmitz et. al., 2011, p.247).



8| METHODOLOGY: Phenomenological Research through Design

8| METHODOLOGY: Phenomenological Research through Design

This chapter introduces the methodology of Bodily Interaction Design as *phenomenological research through design* via the four sub-sections *Research through Design from a phenomenological perspective*, *From Merleau-Ponty's concepts to Phenomenological RtD aspects*, *Material Experiments*, and *Towards performing phenomenological RtD*.

METHODOLOGY	**Phenomenological Research Through Design.** The methodology of the perspective. *What is the lived experience of designing as a methodology?*

Research through Design from a Phenomenological Perspective

Since Frayling (1993) coined the term Research through Design (RtD) in 1993, the term has been challenged, expanded, and criticized for the lack of clear consensus about what the approach implies, and how to turn designerly explorations into rigorous design methods (Höök, Dalsgaard, et al., 2015). Zimmermann, Stolterman, and Forlizzi (2010) discuss the need for a more formal and rigorous research approach, as they find research through design an emerging and unrefined approach and they discuss the need to establish a common ground, an agreed-upon method to document the knowledge that emerges from this type of research. Gaver (2012), on the other hand, considers it a risk to establish standards. Markussen (2017) points out that research through design does not need to match traditional scientific standards and processes, and points to specific forms of theory construction. Höök, Dalsgaard et al. (2015) point to the lack of a shared expression of different forms of intermediary knowledge. Bang and Eriksen define research through design as "…ways in which design examples can contribute to knowledge generation in design research" (Bang & Eriksen 2014, p.4.1). Redström (2018) stresses that the general research through design and a program framing in combination with a set of particular designs creates a meaningful whole in contrast to isolated stand-alone design concepts.

I welcome the continuation of discussions about how to generate knowledge and new theory from research through design (Redström, 2018; Markussen, 2017; Höök, Dalsgaard, et al., 2015). To me, research through design is a generous methodological approach allowing exploratory processes of performing experiments and design in a research context. In line with Redström's program framing – I believe that research should be done from a defined worldview or framing in the field, informed by theoretical concepts and design projects with the possibility of including various specific methods that fit the research program. In this case, the framing is to explore Bodily Interaction Design from a phenomenological perspective.

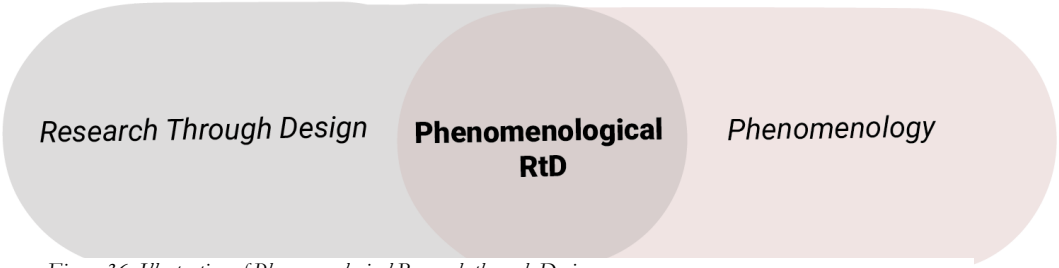


Figure 36. Illustration of Phenomenological Research through Design

To merge Research through Design with a phenomenological perspective (Figure 36) requires new attention to the role of the designer in the development processes, focusing on sensory perceptive presence, memories, and the active participation of the lived body. And furthermore, it stresses that a subjective approach can contribute to knowledge generation in design research. The designer's embodied interaction with material and prototypes when working with materiality can be understood by applying a phenomenological perspective. *I touch, and I am touched back.*

Other scholars in interaction design and HCI have suggested concrete methods to explore the active engagement of the lived body for designers in the design process. Hansen and Kozel (2007) introduced the method of *embodied imagination*, where the body is integrated directly into the loop of design iterations to incorporate personal imagination and daily life into the design process. Loke and Robertson (2011) suggest designers develop *a bodily literacy* to articulate felt experience. Schiphorst (2011) presents the idea of involving *somatic connoisseurship* in the design process. Svænæs' (2013) Merleau-Ponty-inspired term *kinesthetic creativity* describes how the designer uses one's own body to imagine what a product will feel like for the end-user. *Embodied sketching* is grounded in the lived experience, including the social and spatial setting (Segura et al., 2016). *Somatic sensibility* aims to allow designers to better articulate internal felt bodily experiences (Schiphorst & Loke 2018). Lastly, in Höök's (2018) Soma Design program, designers train *aesthetic sensibility* and cultivate aesthetic appreciation.

The bodily aspect of active lived bodily engagement in the design process can be mapped into different categories and methodological traditions, similarly to what we do in Paper 1, "Tracing Conceptions of Bodies in HCI", with the different lenses of bodily conceptions. The body as embedded and contextually situated, as seen for instance with Dourish's (2001) notion of the term *embodied interaction.* The body as performing, where methods inspired by somatic practices such as bodystorming, and performance ethnography (Laurel, 2003) are performed. This includes the concept of the moving body (Kozel, 2007; Loke & Robertson, 2013; Schiphorst, 2009). The body as sensing, affected, and affecting ranging from Höök's (2018) training of the body inspired by Shusterman's term *somaesthetics* (Shusterman, 2008, 2009) to Kozel's (2014) philosophical formulations of a phenomenology of affect. The political body, as explored in feminist HCI by Bardzell (2010), and by Ahmed (2006) in Queer Phenomenology. And the living body as memories, imagination, and traces (Kozel, 2017).

I suggest the term *phenomenological research through design* (Ranten, 2013) as an umbrella methodology to include and mix and match the above body categories and concrete existing methods. By viewing both research through design and phenomenology as an exploratory process of performing, the active participation of the lived body is the foundation of being, meaning, and making for designers. Regardless of whether the body is framed as performing or contextually situated, the phenomenological perspective inspired by Merleau-Ponty (1962, 1968) can be applied to interaction design as a design perspective accounting for the body of the designer(s) in relation to technology, not just the body of the user(s). That designers act and make meaning through bodily relationship with technology: designers perform phenomenology.

The proposal of the umbrella term *phenomenological research through design* will serve as a broad methodological approach for designers to use existing concrete methods, develop new, and re-iterate methods for active engagement of the lived body of designers in the design process. It is a view of designers as phenomenologists in the design process, where designers are invited to acknowledge active use of their lived bodies throughout the design process. This view will include the use of one's own body to be involved in sensing and feeling, exploring, including play, aesthetic issues, involvement, engagement, participation, embodiment, social, and physical elements. It is also to be explored through the inclusion of subjective experience, first-person perspective, autoethnography, and memories as an active part of the design process. Viewing designers as phenomenologists also raises the political issue of what kind of bodies we are designing. Stressing that the way we view our bodies in the design process affects users' bodies when they interact with the final designs. Furthermore, it acknowledges the extent to which designers and their bodies are involved in the process.

A Phenomenological Design Process

The design process developing the project Light Flow.

In my experience, a design process is a complex process that resists easy compartmentalization. However, it is possible to categorize generic phases that we typically go through in the process of making. Each step can entail several iterations. In my work, I divide them into three main sections: one) the exploratory phase, two) production and making, and three) on-location during execution. To me, it is evident that the active participation of my lived body is the foundation in the creative design development process. However, given the collaborative nature of my work, I seldom work alone. Therefore, it is not just my body but also how our bodies are interconnected in the process and form a collective archive of materials. We act and make meaning through our lived bodies – we touch and are touched back. We interpret through our bodies, we sense, we perform, and our bodies and memories influence the process of making.

The installation Light Flow is an UNMAKE project implemented at a large, week-long Danish annual music festival set in the woods. In UNMAKE, Halfdan Hauch Jensen and I organized and developed the installation, later working with a team of eight on-site at the festival to set up, operate, and dismantle the installation. We were assigned a one-hundred-meter-long pathway connecting the festival site and stage areas to an exit/entrance. The aim was to create an embodied experience of the light following your movement on the path, either walking alone or in groups. The main hardware materials in Light Flow included PIR sensors (motion sensors) and DMX-controlled PAR LED lamps. The software is a lengthy list of programs communicating Arduino, Processing, MaxMSP, and MadMapper to cover controlling the sensor system and the light output through mapping of colored videos, resulting in dynamic and fluid light.

1. The Exploratory Phase

In the exploratory phase (Figure 37), we typically prototype and ideate in the lab. We familiarize ourselves with new and old materials. We touch materials and are touched back. Typically, we sketch a simple prototype that we can play around with and conceptualize from. We work with simple technology, here an Arduino-based sensor control that gave us the possibility of scaling. So, the initial digital sketch of a setup with one movement sensor controlling a light change in a single lamp can end up being multiplied and upscaled to a one hundred meters long path in the forest. This phase combines experiments with technology with the bodies' experiences on many levels; we practice, familiarize ourselves with the materials, and improvise and play with the ideas and experiences that arise.

Figure 37. Pictures from the explorative phase: material exploration and site inspection of Light Flow. Photos by UNMAKE

Besides exploring materials, this phase includes the initial creative and practical tasks: sketching, ideating, meetings with the stakeholders, getting materials. Parallel to the practical tasks around researching gear and shopping for materials, we play with the materials and delve into the bodily experience of exploring materials in conjunction with familiarizing ourselves with the technical possibilities.

In the case of the Light Flow project, we held various exploratory experiment sessions in test setups experimenting with fabric, light, and movement. We also made a site visit to get a sense of the physical place, walk along the path in the woods, and experience the length, the trees, the location, and do on-site experiments to solve the technical issues of how many sensors we needed to cover the pathway and from how far away they measure passers-by and map out the trees' position – so we could return to the lab and start sketching the infrastructure of the system.

2. Production and Making

Later in the actual production phase, the hardware is assembled. Our test setup is multiplied as we delve into the calm bodily flux state of repetition, when soldering electronics for hours, gluing plastic drains onto the sensor boxes or reassembling wires for hours and hours. Soldering is a slow state of flux, like a slow dance with the same entwinement of action and awareness but distributed in time differently in different rhythms. We make the software setup, and we test in the lab and try out the installation. We iterate between bodily experience and tweaking and adjusting the system (Figure 38).

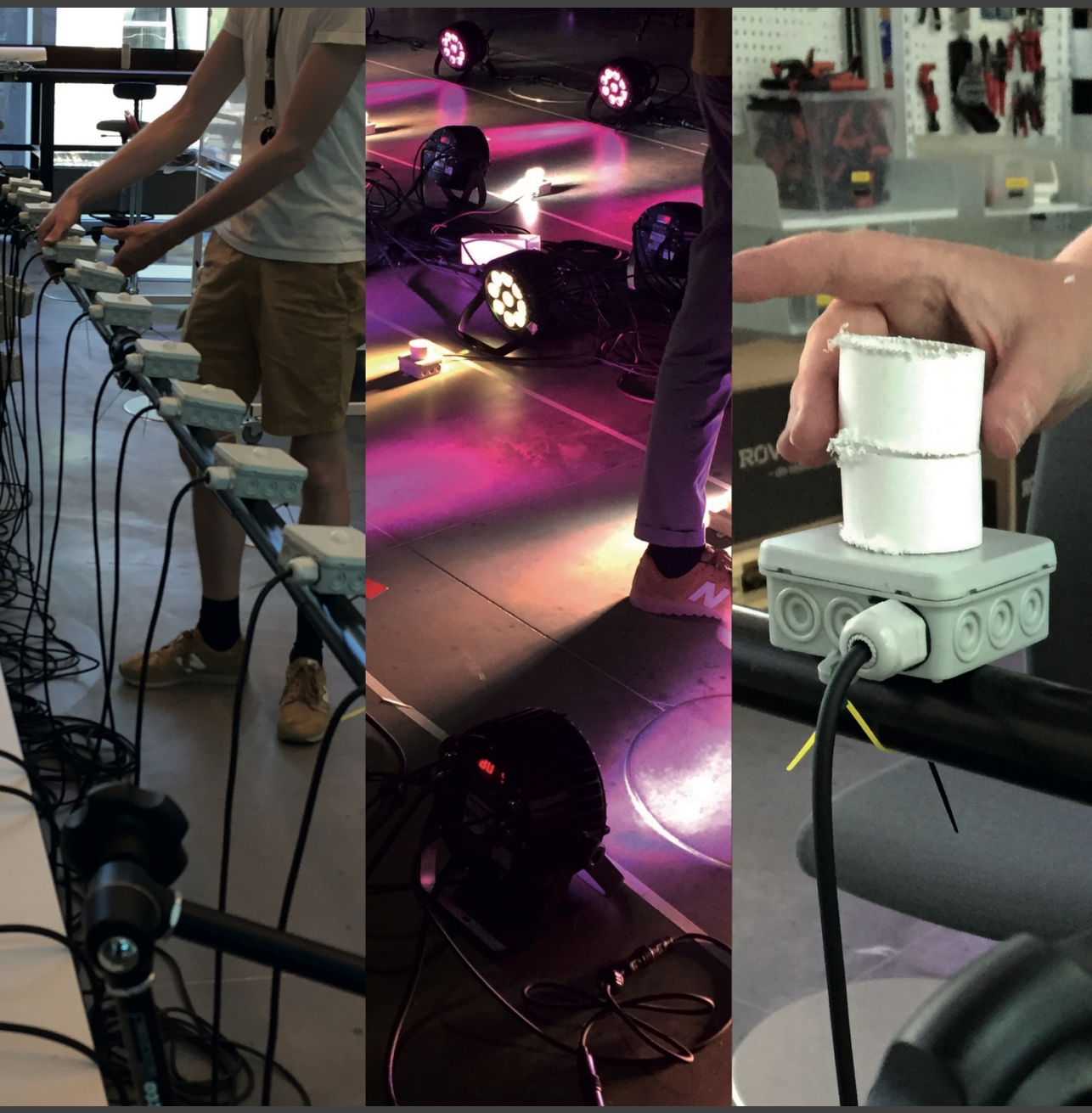


Figure 38. Pictures from the production and making phases of Light Flow. Photos by UNMAKE

Figure 39. Pictures from the location during execution of Light Flow. Photos by Nicolas Padfield & UNMAKE

3. On Location During Execution

On location- we continue to tweak and test – while setting up the installation. During the execution of an installation, we observe and talk to participants in the installation, and we try out the installation ourselves and go back to the engine room and tweak the system according to our bodily experience of the installation (Figure 39).

From Merleau-Ponty's Concepts to Phenomenological RtD Aspects

Within phenomenological research through design, I suggest four provisional methodological aspects of phenomenological research through design inspired by Merleau-Ponty's concepts: aspect (a) *prototyping with the lived body*, aspect (b) *interplay between touch and touchback*, aspect (c) *social interrelation,* and aspect (d) *drifting.*

The Merleau-Ponty concepts are chosen from my empirical subjective experience of designing and transformed into aspects based on experience from my practical collaborations. For an overview of the relation between the methodological aspects and phenomenological approach see Figure 40. The methodological aspects are inspired by Merleau-Ponty's phenomenological concepts and informed by my empirical experience of phenomenological relationship with materials in the design process.

METHODOLOGICAL ASPECTS	PHENOMENOLOGICAL CONCEPTS
Aspect (a) Prototyping with the lived body	The Lived Body + Hyper-reflection
Aspect (b) The interplay between touch and touchback	Reversibility + Flesh
Aspect (c) Social interrelation	Intercorporeality
Aspect (d) Drifting	Reversibility + Intercorporeality + Hyper-reflection

Figure 40. Overview of methodological aspects of phenomenological research through design in relation to Merleau-Ponty's phenomenological concepts

Aspect (a) Prototyping with the Lived Body

Prototyping with the lived body is the foundation of the new field, *phenomenological research through design*, in which the designer acknowledges her own sensory perceptive presence, not just by handling materials and materiality, but also through her own subjective sensory materiality. It is inspired by Merleau-Ponty's concepts of the lived body and hyper-reflections.

Merleau-Ponty. The Lived Body

In *Phenomenology of Perception*, Merleau-Ponty (1962) presents a general method to understand the perceived world as an embodied being-in-the-world and introduces the concept of *the living body* that exceeds the distinction between subjectivity and objectivity as a body with a momentum of existence.

Merleau-Ponty. Hyper-Reflections

Merleau-Ponty's hyper-reflection is described by Kozel (2007) as a partnership between thought and action, exemplified by the act of movement by a dancer, both function through a state of flux. Furthermore, she stresses the importance of not considering it a binary flip between thinking and doing but rather an entwining of action and awareness (Kozel, 2007).

The advancement of technological development tools, such as the Arduino platform in tangible and embedded technology, has opened a new potential of how we consider the digital material as an integrated role in the experimental process of prototyping interactive design. Working in a lab setting offers a space for design exploration where a working prototypical approach allows low threshold and iteration cycles in the design process (Padfield, Haldrup, & Hobye, 2014). In the lab, the relationship with the technical material is a lived, embodied experience. The exploration thus includes a phenomenological perspective on the role of the body when we prototype in a lab setting.

Prototyping with the lived body happens as partnerships of awareness and action throughout the entire design process. In the exploratory phase when we familiarize ourselves with the materials, and in the production phase when we solder for hours in a state of flux entwining action and awareness, and when we test the experience ourselves in the making and execution phase.

Aspect (b) The Interplay Between Touch and Touchback

The interplay between touch and touchback as the designer's tangible and embodied relation with materials can be explored through Merleau-Ponty's concept of reversibility and flesh (Merleau-Ponty, 1962). As designers we act and make meaning through our lived bodies; we touch and are touched back, we interpret through our bodies, we sense, we perform and our bodies and memories influence process of making.

Merleau-Ponty. Reversibility and Flesh

Merleau-Ponty's concept of flesh is an attempt to capture the substance we share with the other beings that make up our surroundings by simultaneously preserving the difference between the two types of flesh: the reversible relation when the body touches a non-human object, the object is regarded a flesh that can reverse the present situation: e.g., of both being touched and touching. "Reversibility: the finger of the glove that is turned inside out – There is no need of a spectator who would be on each side. It suffices that from one side I see the wrong side of the glove that is applied to the right side, that I touch the one through the other (double "representation" of a point or plane of the field) the chiasm is that: the reversibility – " (Merleau-Ponty, 1968, p. 263). The double sensation of touching and being touched is fundamental reversibility as both phenomenal and objectual body, and both subject and object (Grosz, 1994). In total three modalities of touch: "…touching of an object, touching of the properties or qualities of an object, and the touching of being touched…" (Grosz, 1994, p.100).

Kozel's interpretation of Merleau-Ponty's concept of reversibility addresses the convergence between the designer's body and the digital: *"*...I touch the world, certainly I do when I handle materials in the creative process, and these materials touch me back, challenging my autonomous role as creator of knowledge and bestower of meaning" (Kozel, 2015, p.206).

Merleau-Ponty (1968) furthermore describes the concept of flesh as the *"element"* of being: "The flesh is not matter, is not mind, is not substance. To designate it, we should need the old term "element," in the sense it was used to speak of water, air, earth, and fire, that is, in the sense of a general thing, midway between the spatio-temporal individual and the idea, a sort of incarnate principle that brings a style of being wherever there is a fragment of being. The flesh is in this sense an "element" of Being" (Merleau-Ponty, 1968, p. 139).

Thus, *the interplay between touch and touchback* when designers work with materials is also concerned with our living in the world as an element: "When flesh is experienced through our embodied engagement with the world, it exists across senses and across all our connections with people and things" (Kozel, 2007, p.276).

Aspect (c) Social Interrelation

Social interrelation is the phenomenological perspective that our bodies are interconnected in the process in collaborative work. It relates to Merleau-Ponty's concept of intercorporeality, where the role of embodied interactions between the self and the other is stressed.

Designers act and make meaning through lived bodies, in teams, we affect and is affected by each other.

Merleau-Ponty. Intercorporeality

In Merleau-Ponty's concept of intercorporeality, the role of embodied interactions between the self and the other is stressed. In Merleau-Pontian words, my body and the other are two sides of the same phenomenon. In an elaboration of the concept of reversibility he states: "We can only be the 'outside' of each other's 'inside,' and not the inside for each other. But for this reason, we have the richness of our different perspectives upon the same visible, and thus something special to offer one another. Reversibility, the mere imminence of unity, is not a lack but a gift" (Diprose & Reynolds, 2011, p. 192).

Thus, *Social interrelation,* in collaborative work, is how our bodies are interconnected in the process, that we act and make meaning through our lived bodies. We do it in teams, with and without words, we sense, affect, and are affected by each other, and we mix our material repertoire and form a collective archive of materials.

Intercorporeality doesn't appear magically, but builds on synergies between bodies in social interactions, as social aspects of personal experience and relates to the term *participatory sense-making* where sensemaking is performed socially and enacted as a shared practice (Di Paolo, Cuffari, & De Jaegher, 2019).

Aspect (d) Drifting

Drifting is how our body state drift in the process of making. Thus, drifting relates to *intercorporeality* and social relation, as a qualitative example of how our body state is drifting in collaborative work. And it relates to reversibility and hyper-reflection when we shift between thought and action; we affect materials and are affected by them. Bodily affect, sensation, and emotion can vary, change, and drift during the process of time.

Loke and Schiphorst (2013) state a similar point they call the *evaluative dimension* of the body. This elaborates on the changes in the state between our internal and external state, and our ability to evaluate and utilize our experience of both internal and external state when we interact with technology.

Krog, Markussen, and Bang (2015) point to the concept of "drifting" in a research context as a designer capable of adjusting and learning continuously: "Classical processes of research regard "drifting" as a failure since measures and grounds of evaluation can be said to be in flux. In design, however, "drifting" is a quality measure as it tells the story of a designer capable of continuous learning from findings and of adjusting causes of action" (Krogh, Markussen, & Bang, 2015, p.1).

Thus, *drifting* is an overarching concept of phenomenological research through design.

Summarizing the four aspects in relation to the phenomenological design process
The four methodological aspects are present throughout the design process of UN-MAKE and illutron projects. We prototype with the lived body. In *the exploratory phase*, when we start prototyping, ideating, and familiarizing ourselves with materials. And this continues throughout *production and making* when we assemble hardware and test and try out the installation. And *on location during execution* when we try out the installation ourselves and go back to the engine room to tweak the system. So, we consciously prototype with our lived bodies in ongoing partnerships of awareness and action throughout the entire process; we touch materials and are touched back. And our bodies are interconnected through social interrelation as we sense, affect, and are affected by each other throughout the process. And we drift. Our body states drift in the process of making. When we shift between thought and action, our bodily sensations and emotions vary and change. In a more-than-human perspective, we are also affected by the context- the weather when the pouring rain ruins all the sensors -and the culture and politics of the festival organization.

Figure 41. Latex experiment, baked latex. Photo by Maja Fagerberg Ranten

Material Experiments

In relation to programmatic research, experiments can either follow a program to drift or mature and stabilize (Markussen, 2017). The approach in the two material exploration sessions is exploration to expand and probe (Krogh, Markussen, & Bang, 2015) the methodological approach and material considerations.

The two material sessions are part of an expansion of phenomenological research through design, and a bodily material perspective in collaborative work in a lab setting. The following insights are takeaways from my process with the two sessions, they are part of my note-making in relation to the material experiments. I will not go through them exhaustively but will include them in conjunction with short subjective descriptions from the experiment sessions as an insight into my work with note-making and annotations. Some of the aspects overlap with the previous presented phenomenological aspects, and they point forward to the following material chapter.

Series No 1: Sensory Latex Exploration

The sensory latex explorations are various sessions of exploring latex as material. I have worked with the material in liquid form, varying the number of layers and painting it on different structures to dry, baked it in the oven (Figure 41), and conducted experiments involving different ways of turning it into a skin-like structure, doing playful explorative sessions with the skin-like latex wrapping it on my body, and turned it into different objects a mask and a wearable light fixture through collaborative work.

Figure 42. Latex experiments in water. Photo by Maja Fagerberg Ranten

The sessions resulted in the following notes as bodily insights (Figure 43):

BODILY INSIGHTS

Being in the body
(Flesh, lived etc.)

The added body
(Extensions; materials)

Touch/touch back
(Materials + familiarity)

Social interrelation
(The social body vs. the specific body's memories and stories.)

Emotional adaption
(How we affect and are affected by the others)

Context awareness

Figure 43. Bodily insights from the sensory latex exploration sessions

Being in the body | The added body | Touch/touch back
The sensation of *being in the body* is especially present for me when I work alone exploring materials. When I lose myself in the creative process to being through doing. Working with latex became an exploration of the material as second skin. As if it was an extension of my body- *the added body* -when I wrap the stretchy rubbery material around my hand or wear it as mask. I familiarize myself with the material. Notice how it is white and liquid as I paint it on a bubble-form, and it turns darker and dry if I bake it in the oven and slightly lighter if I leave it to dry overnight. I *touch* the material, and the material *touches me back*. It leaves marks on my skin. And under water it is soft and wet like the inside of my body (Figure 42). Attached to my body it is an extension of my skin.

Social interrelation | Emotional adaption | Context awareness
When I work in collaborations, the entwining of thinking and doing is affected by *social interrelation*. There is an inner subjective experience and the outer social body relating and interrelating with the other. When we work in lab settings collaboratively, we do not talk much. We work side by side. And at times it feels like parallel work, but always with a *context awareness* of the other and an awareness of the room where we affect and are affected by the others as *emotional adaption.* We sense and are affected by the little outbursts, the annoyance when a soldering iron slips, or the satisfactory smile from the joy of a material mix or sensation.

Figure 44. Composite material exploration. Photos by Maja Fagerberg Ranten

Series No 2: Composite Materials Exploration

The composite material exploration was executed at Exostudio with my colleague Mads Hobye. Our intention was to explore materials as composites, detached from object meaning (Figure 44). The session resulted in the following notes of tangible insights (Figure 45):

TANGIBLE INSIGHTS

Material repertoire
(A designer's material toolbox/collective archive)

Mixing repertoires
(Composite materials from various designers)

Exploring unknown combinations
(Material exploration)

Memory and resemblance

Experimental interfaces
(Outcome of the unknown)

Figure 45. Tangible insights from the composite material exploration session

Material repertoire | Mixing repertoires

An interaction designer's material repertoire varies. And what we have in our repertoire is challenged, evolved, trained, and broadened through collaborations, education, institutions, doing, and training (Schön, 1983). The three core materials of a bodily interaction designer might be computational, tangible and the body. But our personal repertoire or toolbox can be significantly different. And in collaborations we build and expand our shared repertoires together. Skills are another factor. And then there is actual training (as with dancers and musicians), where we tune, maintain, and broaden our skills when we learn about new materials, or collaborate with new people with different material repertoires.

Mads previously worked with glass through a collaboration with glassblowers (Padfield et al., 2018) and had left-over pieces we put in the potluck of materials together with electronics, LED strips, different glasses like fluent material, fabric, and paper.

Exploring unknown combinations | Memory and resemblance | Experimental interfaces

As we were not making specific objects for a purpose, it was as if we were *exploring unknown combinations,* and there is a satisfaction in playing with the material free of connotations or expectations. Yet at the same time, my experience was that I was searching for *resemblance* to familiar objects or *memories* of materials. One of the glass leftovers had a

phallus shape, or simply it was just a hollow glass tube with a round bottom. But as Mads filled it with epoxy, light, and a vibration motor. It became a dildo. A techno dildo. Or it resembled a dildo. Even the objects with no obvious resemblance became *experiential interfaces* due to new combinations of materials from the shared repertoire of materials available.

Towards Performing Phenomenological RtD

> "Merleau-Ponty writes that "phenomenology is accessible only through phenomenological method" (1989, viii), but he does not inform us explicitly how it is done. It is easy for many to accept the need for a phenomenological approach, and to be seduced by its sensory appeal and embodied relevance, but again there looms the question of how one actually performs a phenomenology. How is a phenomenological epoch́ set in motion?" (Kozel, 2007, p.48).

I suggest a provisional approach to set in motion how to perform phenomenological research through design in a design process. By using the notion of the three-part paradigm: *before, during,* and *after* from experience design. In experience design it is used to follow the experience of an event, e.g.- visiting a museum -and state the relationship between learning (before) experience (during), and memory (after) (Falk & Dierking, 2016).

Design teams, design researchers, art groups, and developers working with Bodily Interaction Design can use the three-part paradigm to divide their phenomenological research through design approach into the three steps: before, during, and after (Figure 46).

From a research point of view, the three steps resemble Bang and Eriksen's (2014) three stages in programmatic design research; Beginnings, Perform, and Intersections (that I have used in my research program process). In their terminology *beginnings* is the initiating, driving and framing stage, *perform* is where the project drifts, is reframed, matured, and stabilized, and *intersections* is theory building, knowledge contribution, closure, and finalizing.

BEFORE. The perspective:	**DURING.** The method:	**AFTER.** The reflection:
Designers as phenomenologists	*Prototyping with the lived body*	*Research evaluation*

Figure 46. Three phases of phenomenological research through design; before, during, and after

Before RtD

Before, represents the prelude or the rehearsal phase. Here designers can familiarize themselves with the perspective, Designing Bodily Interactions, and the aspects of phenomenological research through design. Here they can initiate and formulate the *why* of their research and decide on concrete methods in following process.

Designers, unlike dancers for instance, might not consider the body to be part of their material repertoire. Nor are they trained to use their body. To some designers, this step might entail actual learning and training as suggested within soma design, where there is a focus on the need to train our *aesthetic sensibilities* by repeatedly engaging in different body practices: "This resembles other artistic practices in which artists always start by learning about materials before they can mold into artistic expressions" (Höök, 2018, p.18).

During RtD

During represents the *how* part – the actual prototyping with and through the lived body. Bodily interaction designers will do this through work with the three core materials bodies, computational, and tangible/physical materials.

In this step, designers do iterations of design experiments. Kozel (2007) express: "Revisit, repeat, reiterate your process: the French word for rehearsal is *répétition*, and designers have their own procedural term for the cyclical advancement of projects: iteration. In existential terms, I like to consider the phenomenological process as having a respect for living through, or dwelling within, an experience or set of experiences" (p.55).

After RtD

After, is the reflection step. Where research designers ask *what*? And work towards new theory and knowledge contribution. This can manifest in the form of a paper, a presentation or the actual design work can be part of an annotated portfolio. It can include methodological reflections, a study of the participant's experience or whatever reflection or evaluative perspective makes sense within the specific design research frame.

9| MATERIALITY: The Materiality of Bodily Interaction Design

9| MATERIALITY: The Materiality of Bodily Interaction Design

This chapter presents the material unfolding of the methodology of phenomenological research through design. Across three subsections- *The Materiality of Bodily Interaction Design, Three Core Materials,* and *Designing with Materials* -it unpacks the bodily interaction designer's materiality.

MATERIALITY	**The materiality of Bodily Interaction Design.** Unfolding the materiality of the methodology: *What are the materials of a bodily interaction designer?*

The Materiality of Bodily Interaction Design

> "Interaction design is no longer restricted to organizing things on a virtual screen, representing information, and enabling those sets of information to be manipulated via a keyboard and a mouse. Far beyond that, interaction design is increasingly about designing a wide range of interactive and computational elements to work completely integrated with other physical materials, objects, and even bodies" (Wiberg, 2018, p.11).

In his book *The Materiality of Interaction*, Mikael Wiberg (2018) describes the change from a representation-driven approach to the *material turn* and proposes the new *material-centered* interaction design approach. Representation-driven HCI and interaction design represents the long history of the design profession, where computers process and present models of our world back to us in the form of user interfaces. The shift towards the *material turn* includes terms such as physical user interfaces and tangible user interfaces. Within third-wave interaction design ubiquitous computing and tangible user interfaces lead the field towards *computing in a physical form* (Wiberg, 2018). This marked a shift from traditionally working with representation to making computing about the real integrating computing in our everyday world: "From this viewpoint, the 'material turn' closed the world-representation gap, and it brought computing out of its box and into the physical world" (Wiberg, 2018, p.4). The Internet of Things and maker culture are growing fields that further show a focus that is less about interfaces and increasingly about objects and materiality (Wiberg, 2018).

Material-centered interaction design is a craft-based approach to interaction design where users and designers are closely related to the materials. Wiberg (2018) advocates for the notion of taking a *compositional approach* to interaction design across the digital and the physical towards coming together as a whole. The material-centered approach does not distinguish between digital and physical ontologically. Overall, knowing materials better allows designers to work compositionally across different materials. The material-centered approach is an invitation to see interaction design "...through a material lens" (Wiberg, 2018, p.70).

Similar lines of research within materiality of interaction include Vallgårda's (2014) framework of interaction design as temporal form and as a form-giving practice. Building on Hallnäs' and Redström's (2002a) understanding of computational technology as a design material with temporal gestalts, and the expression of computational things (Hallnäs 2011).

Interaction design as temporal is also emphasized by Löwgren and Stolterman (2004) who address the need to experience digital artifacts as a whole – we need to try it to experience it as it: "...emerges in the interaction with the user over time" (p.137). It is a process to interact with an artifact and experience possibilities and course of event (Löwgren, Jonas & Stolterman, 2004). Giaccardi and Karana (2015) present a framework for material experience in HCI and point to social and cultural practices of materials, as the situated experience of materials.

Another forgiving area within HCI and interaction design is the related *tangible computing* – addressing the combination of physical form and computing as a paradigm of interaction (Baskinger & Gross, 2010), *tangible user interfaces* (Ishii & Ullmer, 1997), and *embodied interaction*, where Dourish (2001) further added phenomenology and situatedness to tangible interaction as moving computation and interaction "...out of the world of abstract cognitive processes and into the same phenomenal world as our other sorts of interactions" (pp.102-103).

Another perspective on materiality and matter is from social science, where post-human and new materialism thinking include a broader perspective of materiality as more than mere matter (Coole & Frost, 2010). New materialist thinking includes complexity, recognizing agency, entanglement, intra-action (Barad, 1996), nature, affect, and ethics (Bennett, 2010).

The Iceberg Model from Paper 2

My initial framework for this dissertation was based on the idea that there is a close connection between how we develop and how we experience. And that we- as designers - can choreograph the internal software and code in relation to external experience in a use situation. In paper 2, "Behavioral Complexity as a Computational Material Strategy," we present how computational material and complexity in code is part of interaction design as a form-giving practice between the two parts: physical form and computational form. With an iceberg analogy, we present a model of the relationship between physical form and computational form (Figure 47). Above the surface is the *expression,* physical form, the tangible part that participants can interact with, and below the *behavior,* the computational form, software, and code that only presents itself through interaction with the system – that the participants cannot see or touch. We distinguish between the general code in the computational form and the code that intentionally affects the expression of the interaction, which we term *behavioral complexity*: "Behavioral complexity is the underlying algorithms in the computational code created to enable the computational form to come alive through the physical form" (Paper 2, Hobye & Ranten, p.42). The model is illustrated as a feedback loop showing how expression is experienced through the physical form, and physical form is formed by behavioral complexity. Hence *expressive complexity* is the combination of behavioral complexity in the computational form combined with the physical form experienced by the participants.

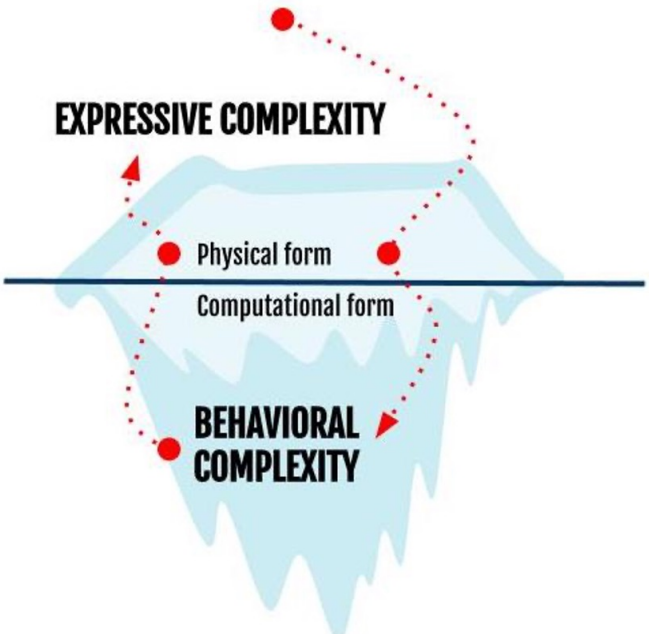


Figure 47. The iceberg model. Reprinted from Paper 2, Hobye & Ranten, p. 41

The paper does not fully unfold materials, as it only handles the two overall material components, i.e., the tangible and computational components. The body as material is only represented as the expressive part experienced by participants.

Wiberg Model

Wiberg (2018) drafts a similar model (Figure 48) to illustrate thinking about materiality and form of interaction through two entangled processes: *threads of interaction* (use) and *threads of computing* (processing). The thread of interaction connects the user with the materiality of the interactive artifact, and that thread also adds to the changes. He also refers to this part as the *concrete expression* – the user interface of the interactive artifact and stresses that concrete expression might change over time due to interaction being an ongoing dynamic process.

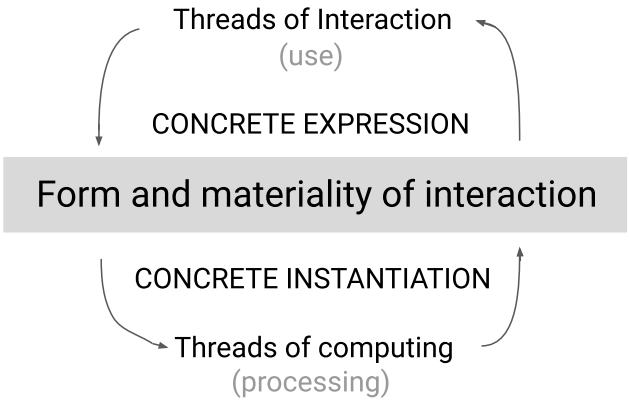


Figure 48. Wiberg's model of form and materiality of interaction. Adapted from Wiberg (2018, p. 133)

"In fact, a core character of the materiality of interaction is its ever-changing state and form, its dynamics, and how it performs – both in relation to its user and in relation to the composition that defines the concrete instantiation of the interaction in computational form" (Wiberg, 2018, p.135).

The other part is the *threads of computing* that take place in parallel with the first part, concrete expression. This part handles user input to the interactive system to monitor the interaction with the system and process and store data information. He refers to the threads of computing together with the set of materials as *concrete instantiation*. In this context, material is anything a microprocessor can read and write, register, sense, monitor, or process, not just digital and physical material, but also properties such as pace and

location. (Wiberg, 2018). In total, the model consists of three intertwined processes: (a) processes of interaction (threads of interaction); (b) processes of computing (threads of computing); and (c) the materiality of interaction "....as an ever-changing process that reflects the entanglement of the other two processes" (Wiberg, 2018, p.135).

Bodily Interaction Design Model

Both Wiberg's model and that of Hobye & Ranten's (from paper 2) show the materiality of interaction as a feedback loop between expression and computation, but neither of them specifies bodies as part of this material. They focus on the user side of the interaction: "...the materiality of interaction is inseparably related to a person *using* an interactive artifact" (Wiberg, 2018, p.58).

In my *Feedback Loop of Bodily Interaction Design* model (Figure 49), the interaction design loop is presented from a bodily perspective, rather than from a use or participant perspective. The model is built around the three core material types: bodily, tangible, and computational. The bodily material represents a designer's body in the making of interaction design, and it represents the user's bodies when interacting with an interactive installation.

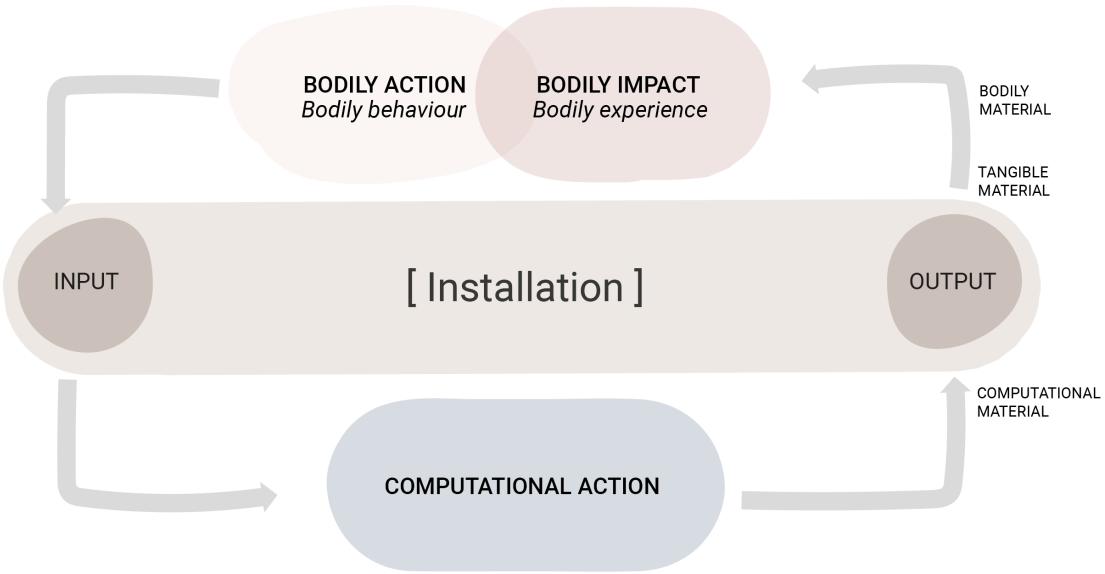


Figure 49. Model: Feedback Loop of Bodily Interaction Design

In the model, the two parts from the iceberg model- tangible material and computational material -are accompanied by a mobius strip-like addition of the bodily material as *Bodily Action* – the bodily behavior and *Bodily Impact* – the bodily experience (Figure 49).

The mobius strip-like form is to illustrate the constituting relationship between bodily action and bodily impact. The model is sketched as a feedback loop from the initial bodily behavior to the final bodily experience to illustrate the bodily perspective in the feedback loop. The body as material in the top of the model represents the initial bodily action (through behavior) one performs to interact with an installation (or system) as an input and the bodily impact (as experience) one receives in turn from the output of the installation. The middle part is the physical/tangible part of the installation initiated by an input, e.g., a funnel the participant blows air into (Figure 50), and the output, e.g., a visual change in a light sculpture (in the case of Water Illumina that follows the velocity of the participant's breath into the funnel). And at the bottom of the model is the computational action. The code that- in the case of Water Illumina -reads velocity and speed of breath from a microphone and "translates" it into a light output.

The model can still be understood as a feedback loop, similar to Wiberg's threads of interaction and threads of processing and the feedback loop in the iceberg model. Following the arrows from bodily action through an input towards the installation, and output and back to the body as impact is comparable to the threads of interaction part of the loop, and threads of processing from input to computational action and output. Wiberg illustrates the more general *form* and *materiality* to represent the changing form of interaction. My model is specifically about interactive installations within Bodily Interaction Design, where the simple logic of input/output represents the initiation of the installation performed by bodies and the changing form illustrated as an output. The significant difference between the three models is that I specify and add bodies as materials to the process of interacting with interactive installations. Wiberg identifies this gap as users. And, in paper 2, "Behavioral Complexity as a Computational Material Strategy," is identified as participants interacting with the physical material to access an installation. Another distinction between Wiberg's model and my Bodily Interaction Design model is directly showing the feedback loop, whereas the iceberg model's agenda was specifically to communicate the metaphor of below and above the water as what is concealed from the participants and introduce the notion of computational behavior. Additionally, it is important to stress that my model is outlined as a simple version of a feedback loop inspired by the installations of my engagements to illustrate a bodily perspective on interaction design. Many of the installations would require a more complex route through the feedback loop model, e.g., to illustrate when tangible and computational material cannot be separated or how different input variations create several output variations.

Figure 50. Water Illumina. Blowing air into funnel. Photo by UNMAKE

Three Core Materials

"Existence: bodies are existence, the very act of ex-istence, being" (Nancy, 2008, p.19).

It is the ontological being of a designer to materialize through the notion of the lived body. Designer's experience, develop, touch, see, feel, sense, and make meaning through bodily relation with the material. Our being-in-the-world is embodied. For designers, materiality is the act of being and doing.

From a development point of view, the three core types of material we mix when we develop interactive systems include the tangible (physical), computational, and the body as material. See Figure 51. Dividing the materials into the three core types could be considered too reductionist in the fourth wave entanglement perspective. Note that the categories overlap and relate to each other. There are numerous examples of design work where materials overlap, merge and are entangled. My material view is closely tied to our work in illutron and UNMAKE, where simple tangible and embedded technology has been the base of our installations and can be discussed using the three categories: tangible, computational and bodily materials.

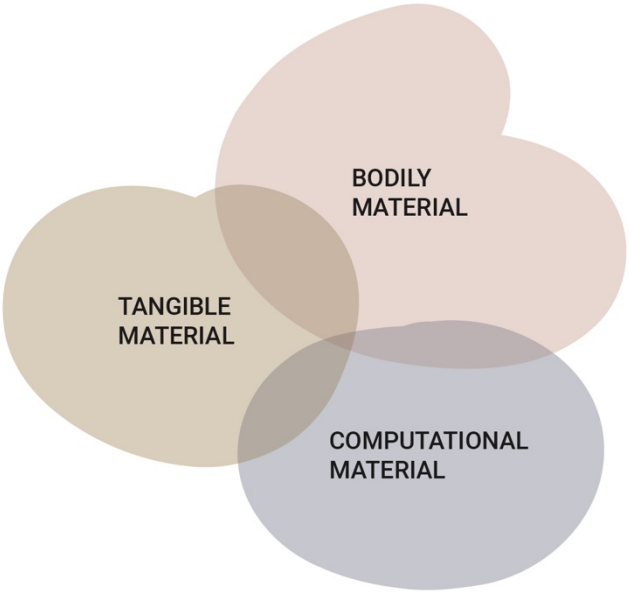


Figure 51. Illustration of the three core materials of Bodily Interaction Design: bodily, tangible, and computational material

Vallgårda's (2014) trinity model of physical form, temporal form, and interaction gestalt cover comparable materials in her framework of interaction design as temporal form elements. The physical form is things in the environment, the temporal form is the state changes produced by a computer, and interaction gestalt "... is the performance of movements that a user(s) will do in relation to the thing or the environment" (Vallgårda, 2014, p.4). Using that terminology, my framework unfolds the interaction gestalt from a phenomenological bodily perspective rather than in line with concepts from tangible interaction and affordance (Gibson, 1986; Norman, 1999). Wiberg uses the abstract: the visual, the temporal, and the functional elements as the three elements of material interaction (Wiberg, 2018).

Tangible Material

In UNMAKE and illutron installations, there is typically a tangible representation of an input and a tangible representation (and/or change) of an output. Together they make up the physical installation. A tangible output can be represented physically and tangibly in the sense that you can touch and see them as an object. An output can also be physical phenomena like light or sound that might be experienced as non-tangible and immaterial. Yet, from a development point of view, it is still represented by physical materials such as speakers and LED light; the technical setup consisting of the hardware of the installation including the software and computer or embedded computers controlling and enabling the interaction.

In paper 2, "Behavioral Complexity as a Computational Material Strategy," we define tangible material as "...actual spatial dimension of the tangible object that participants can interact with..." (Paper 2, Hobye & Ranten, p.41), but also include electronics and embedded computers: "The physical materials commonly wrap the electronics and a computational system into a physical form. The electronics consist of the gateways between the computational system and the physical world. Inputs are sensors, buttons, touch sensors, cameras, etc. Outputs are actuators, speakers, LEDs, etc." (Paper 2, Hobye & Ranten, p.41).

Material Properties

Wiberg (2014) makes a methodology for materiality outlining materials, details, texture, and wholeness as the overall steps through different lenses, such as material properties, quality, aesthetics, composition, and meaning. Materials have properties, functionalities, and temporalities. For example, how plastic can melt, wood can bend, and smart materials can remember (Wiberg, 2018). Karana et al. (2016) express how materials can act as performers embodied into a product when designers create user experiences. How *sensorial* is related to soft and round materials, *interpretive* to natural, elegant, and calm, *performative* to exploring, caressing, and *affective* to nostalgia, desire, and lingering.

Example, Annotated Portfolio of Tangible Interfaces

In the following, I will revisit the annotated portfolio *Tangible Interfaces* introduced in chapter 5, *Portfolio of Engagements*. The three installations- Laser Tennis, Collaborative Drumming, and Tangible Data -all have a tangible interface as the initiator of the installation. The annotations revolve around the connection between the computational material and the bodily experience both from a development point of view and a user experience point of view: *#1 Computational material serves as a significant mediator in the bodily experience*. The bodily experience of touching tangible material: *#2 Tangible interfaces create bodily interplay between touch and touchback*. And sensory perception when we touch materials: *#3 We experience sensory perception through tangible interfaces* (Figure 52).

#1 Computational material serves as a significant mediator in the bodily experience.

This annotation is based around the argument that there is a connection between how we develop and how we experience. The interface of an interactive installation is typically based on an input and an output and between these two we can play, tweak, and choreograph the computational material to create an embodied experience.

This was later formulated in paper 2 as the behavioral part of the code- what we termed behavioral complexity -that intentionally affects the whole (physical form and expression): "The combination of the physical form and the computational form provides the basis for the overarching expression of the thing or the material" (Paper 2, Hobye & Ranten, p.41).

#2 Tangible interfaces create bodily interplay between touch and touchback.

This annotation is inspired by Merleau-Ponty's concept of flesh touch and touchback – that when we touch materials (e.g., tangible interfaces) we are also touched back. In chapter 8, *Methodology: Phenomenological Research through Design*, interplay between touch and touchback was suggested as an aspect of *phenomenological research through design*, exemplified as the designer's relationship with materials. In this annotation the focus is from an experiential point of view. The interplay between touch and touchback is the double sensation of feeling when your hand touches a smooth surface (as in Laser Tennis) and feeling the surface touching your hand. An additional factor is the action of how you interact with the surface. Whether the action is to caress or exploratively perform (Karana et al., 2016). In Laser Tennis, you hit a button quickly while in motion as part of a lifesize game with a a competitive social aspect (Figure 52), and in Collaborative Drumming, you beat a drum to 'catch' the light in eager collaboration to get the final reward of the fire cannon explosion (Figure 52). In Tangible Data you can lead the movement of boxes calmly to identify the meaning of data in the light sculpture (Figure 52).

Figure 52. Tangible Interfaces, annotated portfolio of the three installations Laser tennis, Collaborative Drumming, and Tangible Data

#3 We experience sensory perception through tangible interfaces.
Related to both Karana et al. (2016) and Wiberg (2014) the properties, texture and quality of the materials can be interpreted as sensual, soft, or smooth. There is an obvious difference between a smooth plastic button (as in Laser Tennis) and a rough rusty oil barrel (in Collaborative Drumming) as a tangible input surface (Figure 52). Furthermore, sensory perception is influenced by whether we use our full body or primarily our hands as in a classical computer interface (as in the case of Tangible Data).

Svanæs (2013) connects the sensory apparatus to the necessity of rapid coupling between user actions and system feedback: "...the action-reaction coupling should be one that is easily "understood" by the body" (p.8:26).

When considering sensory perception, we need to include the entire feedback loop – and consider both tangible and computational material in conjunction with the bodily experience.

Half Entities
In paper 4, Sound as Material for Eco-technogenesis, we describe sound as material. Sound can be experienced as immaterial and ephemeral, as between a sonic object and interpreters, and it is both spatial and occurs among bodies (Paper 4, Hines, et. al.). This relates to Schmitz's concept of *half entities* where he places musical melodies, the wind and atmosphere as half entity objects (Schmitz, Müllan, & Slaby, 2011, p.247). And it is related to new materialisms' inclusion of external force and agency "In sum, new materialists are rediscovering a materiality that materializes, evincing immanent modes of self-transformation that compel us to think of causation in far more complex terms; to recognize that phenomena are caught in a multitude of interlocking systems and forces and to consider anew the location and nature of capacities for agency" (Coole & Frost, 2010, p.9).

Example: Half Entities in Dream Forest & Light Flow
The design setting and the design use setting are also populated by a variety of different materials. The woods in the case of Dream Forest and Light Flow, the trees, the air etc. (Figure 53). It all becomes factors in what is experienced by the living body. The other bodies. Nature, smell, and time of day serve as external material entities not necessarily part of the intended choreographed experience. But still factors in the interpretation from a user perspective. And factors to consider in the development phase.

Figure 53. Dream Forest. Walking in the woods by night with eyes closed. Photo by Mai Vanilli

Bodily Material

> "The best way to design *for* the lived body is to design *with* the lived body" (Svanæs 2013, p.8:27).

Unfolding Bodily Action/Impact

As an unfolding of bodily material, I divide the mobius strip like relation between bodily action and bodily impact from my model of Bodily Interaction Design into the two sub sections: Bodily actions, and Bodily impact (Figure 55). Isolated from the *Feedback Loop of Bodily Interaction Design* model, the mobius strip-like form illustrates the constituting relationship between bodily action and bodily impact in a constant exchange (Figure 54). The three overall types of Bodily actions – are *performing*, *sensing,* and (*bio)feeling*. And the three overall bodily impacts are *physical reaction*, *sensory perception,* and *affect response*.

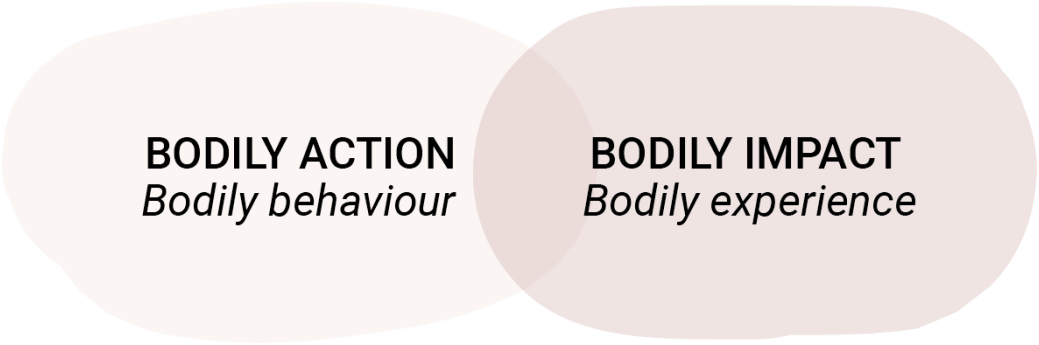


Figure 54: Bodily action and bodily impact isolated from the model Feedback Loop of Bodily Interaction Design

Performing as an action is a moving body – actual motor skills through a body that function as the input to the installation by being read by a sensor, camera etc. Included here is also the body performing sound – noise – voice through movement or shouting, whispering, or singing. Typically read by a microphone or a sensor. The impact in return, the *physical reaction* can be either concrete such as chills or jumping or abstract impact notions from body movement such as *tightness* or *widening* (from Schmitz et. al., 2011).

The sensing actions are touch, taste, and aura typically read by a sensor or a button and *sensory perception* in return can concretely be seeing, hearing, or remembering, or the abstract stimulated or deprived.

The (*bio)feeling* actions are meant as internal either voluntary or involuntary actions such as breath and pulse – typically read through biometric sensors, and the *impact* is various emotional body states such as excitement, avoidance, or affective qualities like goosebumps or shivering.

BODILY ACTION		BODILY IMPACT	
Performing		**Physical reaction**	
The moving body	Catch/run	*Concrete*	Jump up
	Jump		Move away
	Balance		Chills
	Gestures	*Internally*	High/low pulse
The body making sound	Sound		Nausea
	Voice	*Abstract*	Tightness/wideness
	Noise		
Sensing		**Sensory perception**	
The internal inner	Touch	*Concrete senses*	See
	Taste		Hear
The external outer	Aura		Smell
	Kinesthetics/proprio-ception		Remember
			Temperature
			Touch
		Abstract	Deprivation
			Stimulation
(Bio)feeling		**Affect response**	
Measurable 'emotions'	Breath	*Emotional body states*	Fear
	Pulse		Excitement
	Temperature		Avoidance
	Brain (EEG)		Nothing
Abstract	Voluntary vs. unvolun-tary		Disappointment
			Disgust
		Affective qualities	Expansion/contrac-tion
			Tension
			Resonance
			Shivering

Figure 55. Unfolding of the bodily material; bodily action and bodily impact into the subsections performing/physical reaction, sensing/sensory perception, (bio)feeling/affect response

Outlining the terms into a table is meant to be read as relating to each other – reading from left to right. One) How *performing* with the body is related to *physical impact* of the body. Two) That s*ensing* with the body is related to *sensory perception*, and three) how *(bio)feeling* is related to an *affect response*. But it is also important to stress that the table can be mixed and matched. Furthermore, *bodily actions* are concrete bodily actions you need to perform to instantiate the interactive installation (the input), but the *bodily impact* is not a fixed output, but rather the subjective impact of the body. Also, since it happens throughout the duration of time in an encounter with an interactive installation it can consist of multiple actions and effects during the time spent in an installation from a user experience point of view. Both actions and affect are temporal, and on a subjective level many complex actions are at play when the body performs.

In reality, it is impossible to isolate the overall bodily action and impact when participating in an installation. Bodily action and impact are in a constant exchange - our living bodies both perform, sense, and feel without separating between the internal or external body. The bodily impact is never a fixed output but rather a subjective impact of the body. Furthermore, the overall bodily material is entangled with other materials, bodies, context etc. Hence the table should include this complex entanglement (Figure 56). The table is meant as a design companion to think with and through in the design development process: dismantling the bodily perspective as embodied and entangled to reassemble again.

Note that I use the term (Bio)feelings solely to point to sensor technology that can "read emotions" in line with Picard's (1997) notion of *affective computing* where affect and emotions are attempted to be measured through technology. The much broader *affect response* is divided into emotional body states and affective qualities inspired by Schmitz's distinguishment between two types of corporal emotions – the purely corporeally moving impulses or stirrings, and the room-filling emotions. Similar notions are seen in affect theory, e.g., by Brian Massumi (2021), who differentiate between affect and emotion. Massumi adapts Spinoza's (1985)- via Deleuze's (1985) interpretation -concept of affect as the body's capacity for affecting and being affected. Affecting and being affected go together as a *continuous bodying*: "When you affect something, you are opening yourself up to being affected in turn and in a slightly different way than you might have been the moment before" (Massumi, 2002, p.34).

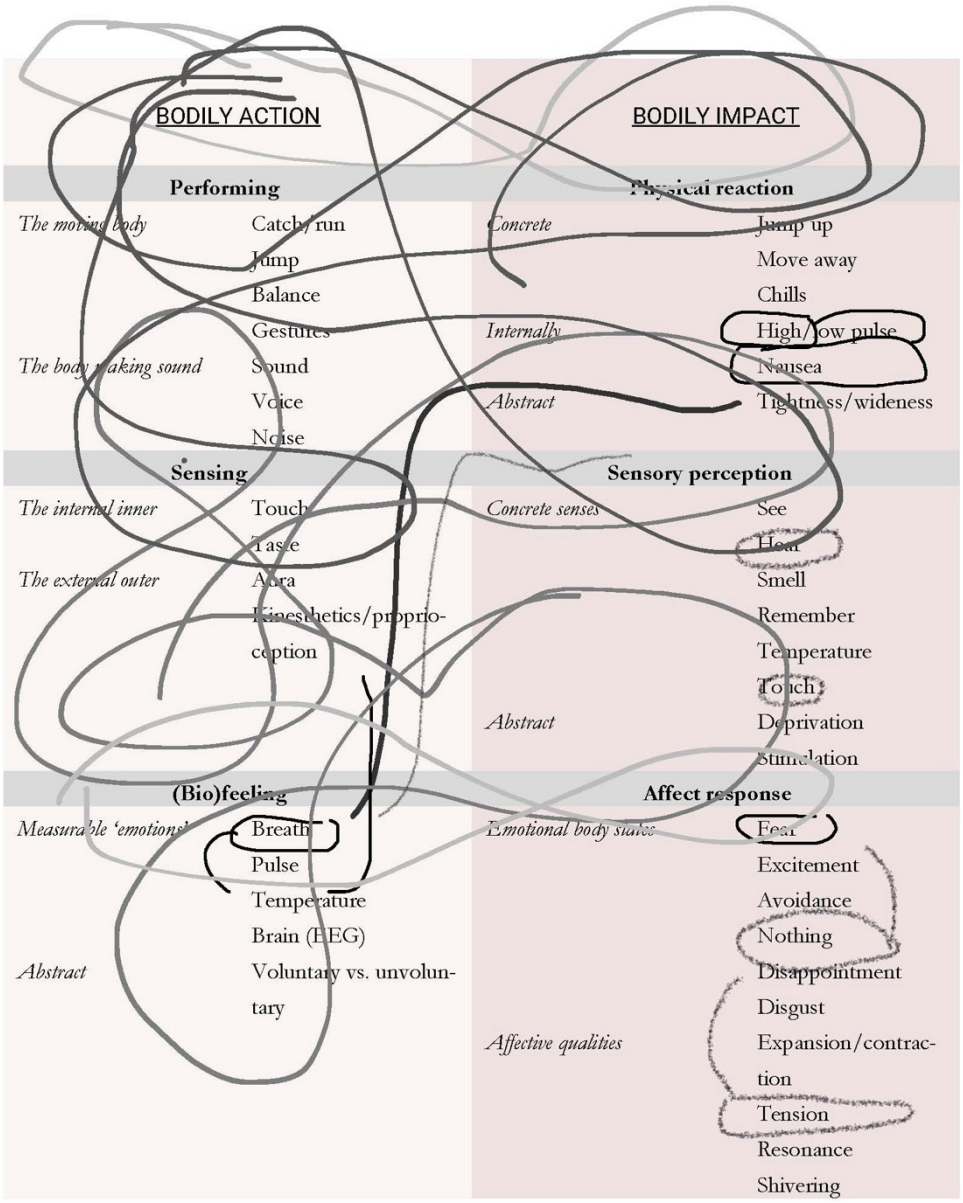


Figure 56. Bodily action and impact as entangled

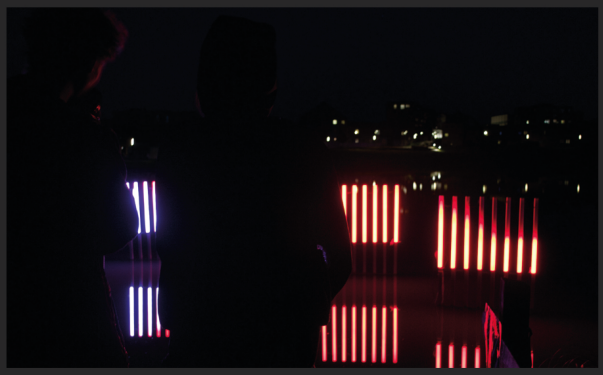
Examples: Annotated Portfolio of Bodily Actions

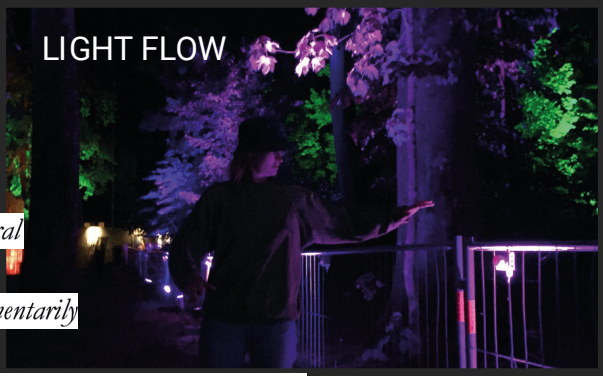
In the following I will return the annotated portfolio *Bodily Actions* (introduced in chapter 5, *Portfolio of Engagements*). The three cases Water Illumina, Light Flow, and Interactive Water form a collection of installations where the body serves as the input of the installation (Figure 57). The annotated portfolio will concretize and unpack the terms from Figure 55.

#1 The states of bodily action and impact are temporal.

In Water Illumina (Figure 57) the action of the installation is to blow air into a funnel. The action is temporal and can be explored and adjusted; the power of air you blow with, and the duration. This can cause immediate sensations, affects or physical reactions, and it can also change over time. Blowing air might make you feel lightheaded and even lead to nausea over time, or it can make your body feel wider as your stomach and breast enlarge when you breath in air to blow out.

Sheet-Johnstone's (2015) phenomenological analysis of movement include a similar point – that "…distinctively different kinesthetically-felt spatial dynamics in stretching and contracting, and in fact, distinctively different overall dynamics that include temporal and intensity differences between the two kinds of movement, i.e., stretching and contracting..." (p.33).

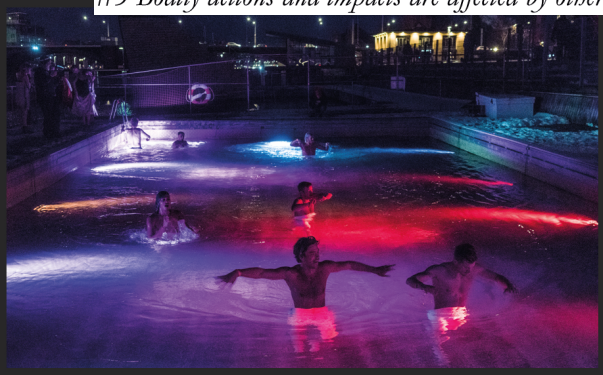




#1 The states of bodily action and impact are temporal

#2 Bodily impacts are, subjective, multiple, and momentarily

#3 Bodily actions and impacts are affected by other bodies, context, and half entities



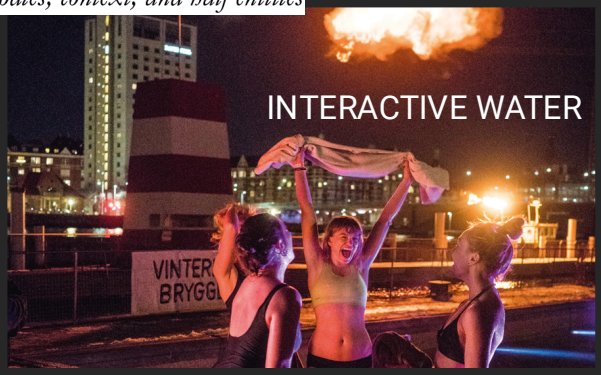


Figure 57. Bodily Actions, annotated portfolio of the three installations Water Illumina, Light Flow, and Interactive Water

#2 Bodily impacts are, subjective, multiple, and momentarily.
In the installation Interactive Water (Figure 58), the intended experience is built around the experience of bathing in cold water during the wintertime. The primary bodily action is movement as you jump in the water, but secondary you touch the cold water, and experience the changes of the colors in the water, followed by the high-volume bang from the cannon and the warmth from the fire. Multiple senses and possible impacts are at play here.

This also relates to the aspect in the methodological approach of phenomenological research through design that stress how our bodily state is *drifting*.

Furthermore, the impacts of bodily actions are subjective. One person's bodily experience of jumping into cold water could be one's body *tightening* up in discomfort whereas for another it could mean an endorphin experience of *widening*, or even both and over time multiple sensations, physical reactions and affect responses (in relation to Schmitz notion of the felt body as dynamics between *tightness* and *wideness* (Schmitz et. al., 2011).

Figure 58: Interactive Water. The fire cannon goes off. Photo by Mathias Vejerslev

The following table (Figure 59) show how the three installations have multiple possible impacts (marked with an "X"), a primary action (marked with an underlined "Y"), and secondary actions (marked with an "Y").

	WATER ILLUMINA	LIGHT FLOW	INTERACTIVE WATER
PERFORMING	Y (touch)	Y (movement)	Y (jump)
PHYSICAL REACTION	X (pulse change)	X (move away)	X (chills)
	X (lightheaded)		X (tightness)
	X (nausea)		X (wideness)
SENSING			
SENSORY PERCEPTION	X (touch)	X (see)	X (see)
	X (see)	X (stimulated)	X (touch)
			X (cold/warm)
(BIO)FEELING	Y (breath)		
AFFECT RESPONSE	X (excitement)	X (nothing)	X (fear)
	X (expansion)	X (avoidance)	X (tension)
	X (disappointment)	X (excitement)	X (shivering)

Figure 59. Mapping out the bodily actions and possible impacts of the three installations, Water Illumina, Light Flow, and Interactive Water

#3 Bodily actions and impacts are affected by other bodies, context, and half entities.
The experience of the action is not purely reserved to the installation and the isolated impacts from performing/sensing, sensing/physical or as feeling/affect response. But can also be impact from other people's bodies or *half entities* (Schmitz et. al., 2011).

"Affect is reduced frequently to emotions, but is more than "feelings." Further, it bleeds across the borders of a single body. Affect is more like a cloud: it is as likely to be creepy as euphoric and it does not just come from bodies, but encompasses objects, structures, animals, systems, and all things environmental" (Kozel, 2013, p.158).

Light Flow (Figure 57) takes place in the woods and is situated at a noisy festival – those factors play into and possible affect the bodily experience. The subjective experience can be affected by the wind in your hair. The alcohol you might have consumed. The dinner you had earlier. The way your breath is visible in the cold night. The temperature during the night in the woods, all play a part in the bodily experience and alert the bodily senses. Light flow could also be categorized as an example of failure or a disembodied experience in terms of bodily impact. Participants do not enter a visible interaction design area; some participants do not sense they are in an interaction space, and the reactiveness is unclear

when many participants occupy the path. Hence, the bodily impact can be experienced as "nothing" (Figure 59).

Unfolding bodily actions/impact into a table is meant as a design companion to think *with* and *through* for designers. It is not meant as a taxonomy of finished general framework to follow. It can be expanded, challenged, and evolved when designers work with shaping the materials in relation to each other and choreographing the flow of the intended experience. And should be understood in a complex entanglement perspective where bodily action and impact are in a constant exchange.

Computational Material

Computational material is code. As we point out in Paper 2, "Behavioral Complexity as a Computational Material Strategy," code enables physical material to come alive and be interactive and is connected to the tangible material through computer/system and electronics to input and output. With the introduction of the concept of behavioral code we distinguish between general and behavioral code, i.e., code that affects the expression intentionally. And we propose strategies for the behavioral part of the code to be *reactiveness*, *multiple modes*, *non-linearity*, *multiple layers,* and *alive connotations* (Paper 2, Hobye & Ranten). See the full description of five computational strategies in the following (Figure 60):

COMPUTATIONAL STRATEGIES

Create Reactiveness: To create interfaces that react in real time with the interaction.

Create Multiple Modes: To create multiple modes in the system that invites diverse kinds of interaction.

Create Non-linearity: To create internal logic without linear causality.

Create Multiple Layers: To combine multiple non-linear parameters into a multidimensional interaction space for participants to explore.

Create Aliveness: To create computational patterns with anthropomorphic expressions.

Figure 60. Computational strategies. The full description of the strategies from Paper 2, Hobye & Ranten, p. 40-41

Vallgårda defines computational composite properties as *reversibility and accumulation* to be shaped into material expression (through loops in programming), *computed causality*, controlling property as cause/effect-events (if-else-functions), and *connectability* (network technology) (Vallgårda, 2014). Wiberg introduces the following six dimensions of interactivity as *change of state*, *speed of change*, *request input*, *responsiveness*, *single/multi treaded*, and *direct or agent based,* and their properties: *dynamics*, *pace*, *turn-talking* and *receptiveness* (Wiberg, 2018).

In my model *Feedback Loop of Bodily Interaction Design*, I have named the computational material *computational action* and within the computational action we can place the different aspects; dimensions of interactivity, characteristics of properties, composite properties, and behavioral strategies as the part of the code specifically used to create an interactive experience with. In the following table, I have initiated an overview of the four aspects of computational material. Wiberg's (2018) interactions are the overall interactivity dimensions for interactive systems and their properties. Vallgårda's (2014) composite properties are general computation terms we use to compose interactivity, and the behavioral strategies from Paper 2 are computational composite properties realized as specific constructions to create a certain expression to the installation. Together they serve as inspiration for working with the form-giving part of computational material. The table shows that even though they present different aspects of computational material, there are similarities (Figure 61). The first row shows that all the aspects point to responsiveness/reactiveness as a core property in the different aspects of computational material. Svanæs (2013) too points to the importance of reactiveness as rapid coupling between user actions and the systems feedback: "When designing technology to support embodied perception, it is important to ensure that there is a good match between hardware and software and our sensory apparatus with regard to speed, feedback, mapping, and coupling" (p.8:20). Wiberg's (2018) notion of interaction design as being either single or multithreaded is meant as an overall description of interaction design as either linearly step by step interaction or as multithreaded as not restrained to one specific path, multithreaded relates to Vallgårda's (2014) specific composite property of causality and Paper 2's multiple modes and multiple layers.

DIMENSIONS OF INTERACTIVITY (Wiberg 2018)	CHARACTERISTICS OF PROPERTIES (Wiberg 2018)	COMPOSITE PROPERTIES (Vallgårda 2014)	BEHAVIORAL STRATEGIES (Paper 2, Hobye & Ranten)
Responsiveness	(Receptiveness)		Reactiveness
Change of state Speed of change	(Dynamics) (Pace)	Reversibility and Accumulation	Non-Linearity Multiple modes
Single-threaded			
Multi-threaded		Computed causality	Multiple modes Multiple layers
Request input	(Turn-talking)	(All of the above)	(All of the above)
		Connectability	
			Alive annotations
Direct or agent based		(All above direct)	(All above direct)

Figure 61. Aspects of computational material; dimensions of interactivity, characteristics of properties, composite properties, and behavioral strategies

From a developer point of view the computational material is general code and various aspects designers can use as a form-giving practice. From an experience point of view, the general part of the computational material might be invisible, but the aspects realized as properties or behavior can be experienced as expressions of being live, slow, simple, complex etc.

Example: Technical Setup of Light Flow

The technical set up in Light Flow consists of the two overall parts: hardware and software. To enable those two parts to function, it is connected through a computer, ethernet, power and electronics. The computational material is the general code and various aspects of the code- the properties and behavior -that form the experience (in conjunction with bodily material and tangible material). The properties and behavioral part of the computational material are reactiveness, dynamics, and pace which can be experienced as light changing that follows your movement. The general code enables the system to function and the various software to communicate.

Computational Material as Intangible Matter with Agency

In paper 4, "Sound as Material for Eco-technogenesis" we describe sound as material and how sound resembles computational material (and can be computational material when algorithmically generated) as they are both intangible matter with agency. Through Hayles' (2012) definition of technogenesis we investigate her posthuman perspective of how human and technology co-evolve: "We are bodily affected through, with, and by computational material, and no longer differentiate between the subjective inside and technology from the outside. Rather than dividing the human-technology relation into a matter of a foreground and a background we can unpack Hayles' (2012) claims that digital media and the actions of computers are embodied, that technical objects have agency..." (Paper 4, Hines et. al., p. 197).

Visual Summary of the Materials

To visually sum up the materials, I present a visual illustration of the materials with insights, concepts and aspects presented so far. See Figure 62. The bodily and tangible insights from the experiments. The annotations from the two portfolios tangible interfaces and bodily materials. Unfolding the bodily material and the computation action as aspects. And from a more-than-human bodily perspective, I have added Hermann Schmitz's concept of half entities to the three core materials: tangible, bodily and computational. The colored dots indicate the amount and types of materials the different insights, aspects, and concepts have covered.

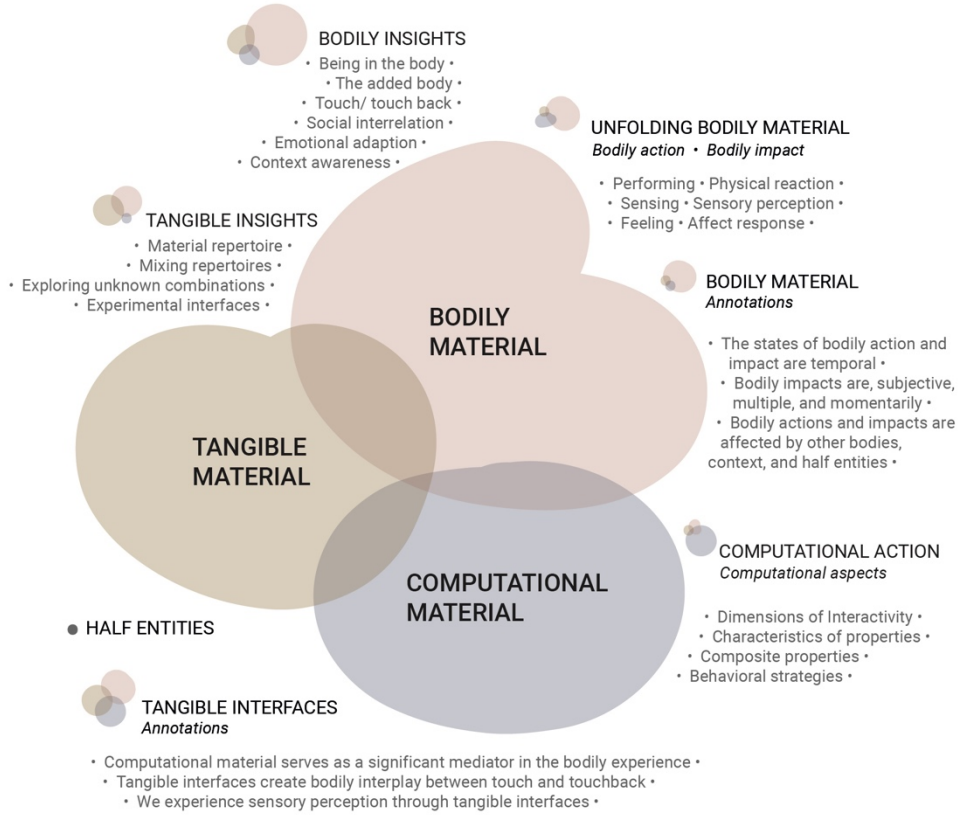


Figure 62. Visual illustration of three core materials with material aspects and insights, and the overall methodological approach phenomenological research through design

Designing with Materials

In this section, I move from the materials into reflections about designing with the materials and how that requires us to create a *choreography of the material into "compositions"*. Furthermore, three considerations are added to the material framework: *context* – where are we designing from and to, *intention* – what are we designing for, and finally, *entanglement* – who and why are we designing for; an intersectional view of how the design process is entangled with society, culture, politics, and ethics. Hence, returning to the visual overview of the materials, the *choreography of the material into compositions* and the three considerations *the context*, *the intention*, and *entanglement* are added to the model (Figure 63).

The following includes the four subsections: *The Choreography of Material Compositions*, *The Context*, *The Intention*, and *Entanglement*.

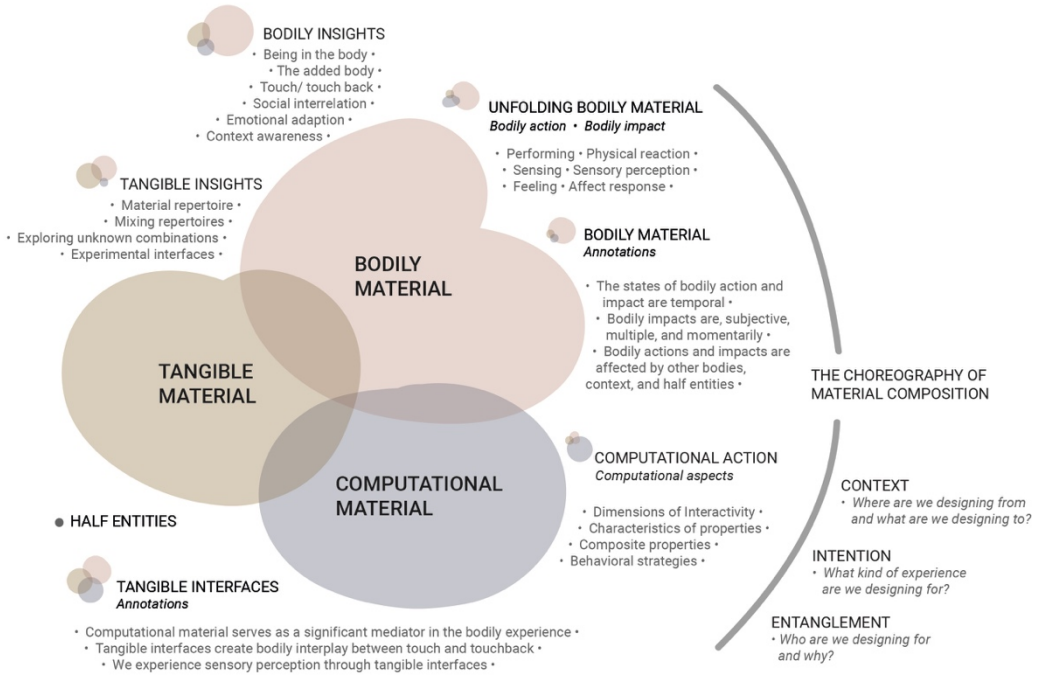


Figure 63. Visual illustration of three core materials with material aspects and insights, and the overall methodological approach phenomenological research through design. Additionally, "the choreography of material compositions", and the considerations about context, intention, and entanglement

The Choreography of Material Compositions

As an overall way to describe how to shape and choreograph materials into an interactive experience, design, or interactive installation, I use the term *choreography of material composition* to illustrate the resemblance between design development and theatre and music production: that designers can choreograph and compose with materials, based on knowledge about the materials properties, aspects, and insights.

Vallgårda (2014) considers computation and programming a form-giving practice inseparable from the interaction gestalt and the physical form-giving. Höök (2018) too defines interaction design as *form-giving* engagements with sociodigital materials. She stresses that "...our digital and technological materials are only half of our design material: the other half consists of our own soma and those of our users" (p.127). Furthermore, Höök (2018) articulates the creative process of shaping the materials into experiences as orchestrated dynamic gestalts: "In summary, our soma design theory must speak of the aesthetic potential of the sociodigital materials and the creative process of shaping these into dynamic gestalts, orchestrated experiences" (p.127). This aligns with Wiberg's (2018) and Vallgårda's (2014) notion of bringing different materials into a composition. And Hallnäs and Redström (2002a), who relate temporal gestalts of design materials to temporal structures generated when musicians perform music. In the case of music manifested as sound and in the case of computational things temporal structures "... by means of executing programs, and ii) some other material(s) to manifest these structures in space" (p.106).

Kozel's (2007) phenomenological term *data choreography* shows how performance qualities such as ephemerality, expressivity, physicality, and poetry can be used in design to disrupt and challenge conventional design use. Choreographing data entails being aware of what it is, who receives it, the form, the rhythm, and whether it has a narrative or an affective quality.

From a new materialist perspective Coole and Frost (2010) use the term *choreographies of becoming* about matter becoming and constantly forming and reforming: "Matter is no longer imagined here as a massive, opaque plenitude but is recognized instead as indeterminate, constantly forming and reforming in unexpected ways. One could conclude, accordingly, that "matter becomes" rather than that "matter is." It is in these choreographies of becoming that we find cosmic forces assembling.." (p.10).

Löwgren and Stolterman (2004) call it a dramatic structure through a dynamic process that can be inspiring, boring, or repetitive. Specific properties in creating the choreography of an installation can be- as suggested by Vallgårda (2014) -temporal elements such as rhythm, randomness, and synchronicity, and physical elements like durability, scale, texture, and compression.

Example of Choreography of Material Composition. Dream Forest

If we take the core interaction from Dream Forest. It is a simple input/output setup of a movement sensor as an input and a LED-light strip changing color. If we unfold this as choreographing the materials into a composition we can play with the length and rhythm of the light, we can multiply the set-up and fill a huge area of the woods into an embodied walking experience. We can explore the set-up in relation to the physical setting – the noisy festival and add multiple layers – a soundscape as a contrast to the noise to create the intended calm experience of leaving the festival and entrancing a magic place. In this way it is possible to choreograph the materials in relation to the setting (Figure 64), intention, and to the entanglement of politics, ethics, and society (or organizational requirements from the festival).

Figure 64. The setting in the woods of the installation Dream Forest. Photo by Nicolas Padfield

The Context

Consideration: *Where are we designing from and what are we designing to?*

The context as the actual place we design *from* is relevant on three levels, the personal context, the physical, and the social. And finally, the context we design *to*, is the intended performance context.

The first three: personal, physical, and social are presented by Falk and Dierking (2016) as constructed by the visitor of a museum and collectively makes up the total experience. Transferred to a design development perspective the personal context is how we arrive, our actual living body and our prior knowledge, attitude, interest, and motivation. The physical context is the physical setting of our design process. Typically, a lab setting, and how we encounter materials and objects and are affected by the feeling of the building. The social context is our encounter with collaborators or other people in the physical. And the performance setting is the physical intended context of the interactive installation.

In Paper 3, "The Implications of Using Interactive Artifacts to Bridge the Divide Between Audience and Stage in a Conventional Hall Setting" we suggest the two proposed strategies for working in a specific intended performance context: "1) to work across disciplines and stakeholders to custom design mediated experiences for a particular production, and 2) the possibility to think in terms of designing artifacts that can be integrated into different plays without larger interference with the overall experience" (Paper 3, Ranten et. al., p. 19).

The projects in the paper evolve around hall setting performances- where the audience conventionally is passive -and investigate what happens when we bring interactive technologies into this setting. Meaning-making in relation to the specific context and art form is relevant: "...we suggest that the embodied experience of interacting with technological artifacts – besides relating a physical embodied and sensory experience – also relates to whether the object affects the meaning-making in the specific context and to the specific art form" (Paper 3, Ranten et. al., p. 16). And technological artifacts should make sense in relation to both embodied experience, art from and the context: "...the need to materialize the use of digital technology as objects that make sense in relation to the embodied experience, the art form, and the context. In other words, objects that support the communication and experience of what is happening on stage without disrupting the overarching context" (Paper 3, p. 17, Ranten et. al.).

The Intention

Consideration: *What kind of experience are we designing for?*

Intention identifies what kind of experience we are designing for. This can include different field categories in combination with a physical context. Like an embodied interaction design experience for a festival setting. Or it can include specific qualities designers work with to create an intended experience.

Löwgren and Stolterman (2004) list qualities related to the user's motivation to interact with interaction design, *playability*, *seductively*, *anticipation*, *relevance*, and *usefulness*. And qualities related to our immediate experience and perception of a design, *pliability*, *control/autonomy*, and *immersion*. As well as qualities that relate to the users meaning making in relation to an artifact: *ambiguity* and *surprise*.

All these qualities and more can add to a growing framework of interaction dynamics, levels and meaning/making interpretation designers can work with as intentions when creating the choreography of materials. Do we want to create an experience that can be interpreted by the participants as curiosity, confusion, or provocation? Do we want the participants to play, be seduced, move, stumble, perform, explore, or be immersed?

The Entanglement

Consideration: *Who are we designing for and why?*

Who we are designing for and why is meant as an intersectional consideration of how the design process is entangled with society, culture, politics, and ethics.

On a concrete level there is an obvious difference to either designing for a Danish music festival, a research conference, or a cultural institution. But as designers we also need to navigate different societal, cultural, political, and ethical considerations in our work and-collaborations. From a development point of view, we need to consider norms, discrimination, and privileges in the experiences we create.

This places the model of Bodily Interaction Design loop within the three perspectives: (a) the overall entanglement with society, culture, politics, and ethics. (b) the experience from a user-perspective. (c) the development perspective of a Bodily Interaction Designer designing an interactive installation (Figure 65).

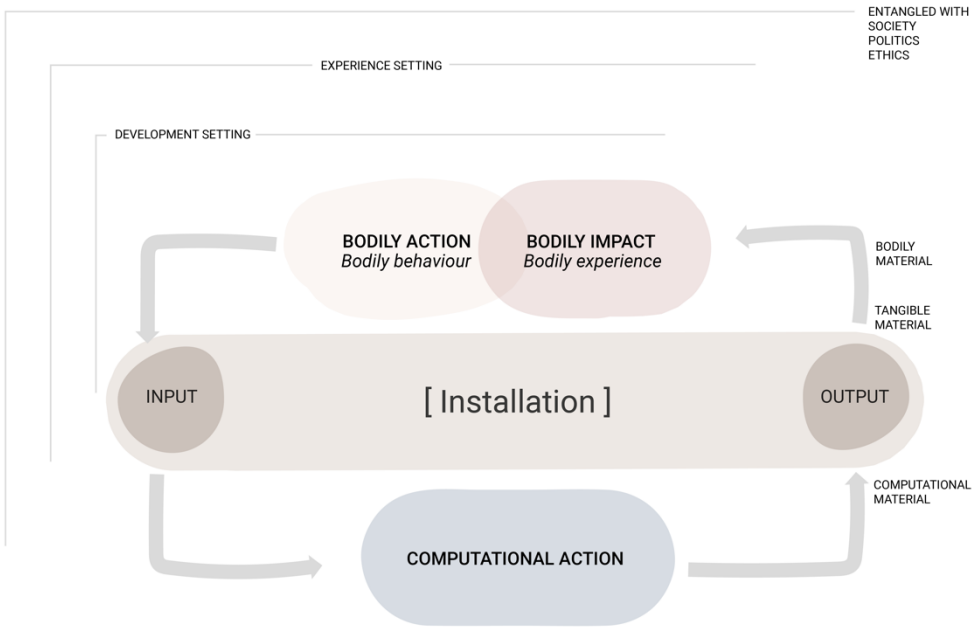
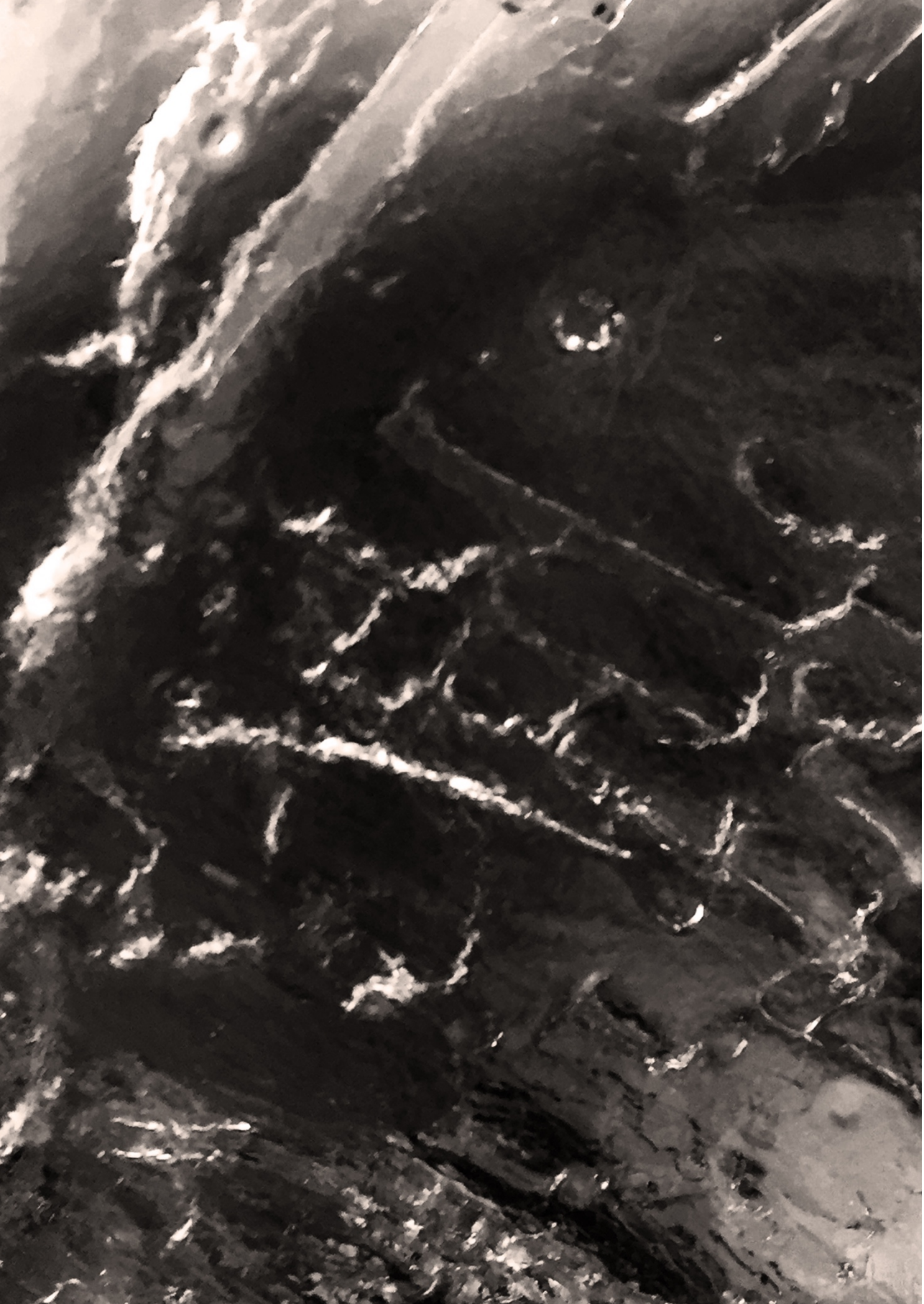


Figure 65. Model: Feedback Loop of Bodily Interaction Design including the three perspectives: development, experience, and entangled with society, politics, and ethics

PART THREE | FORWARDING



10| Case Interview

Figure 66. memoryMechanics, performance at CLICK AI days in Elsinore. Photo By Mads Hobye

10| Case Interview

Finally, I will present memoryMechanics as an example of a case outside of the scope of the previous UNMAKE and illutron projects. memoryMechanics was executed as a collaborative project between performers and designers/developers. It was executed during the COVID-19 pandemic, and originally initiated to combine performing arts with artificial intelligence (AI).

Through an interview with the two performers (and co-creators) of the installation, to explore their bodily experience of performing, I will shift from my phenomenological first-person perspective to focus on their bodily experience. The interview stresses the subjectivity at play, the temporality, and multiple actions and impact during bodily performance in an installation. Furthermore, the case is an example of a project entangled with a complex real world where different settings, versions, and people, affect the process.

memoryMechanics (2019-2021)

memoryMechanics is an interactive installation that explores artificial intelligence in relation to storing and evoking embodied memories. The project is a cross-disciplinary process between performers (Lise Aagaard Knudsen & Karen Eide Bøen), and computer scientists and interaction design artists (myself, Troels Andreasen, & Mads Høbye) and have been under development and exploration since 2019. A virtual early version of the work was part of the Ars Electronica program in 2020. And the physical version has been showcased in three different festival settings in 2021.

The virtual version allowed participants to enter the installation through a website and use their webcam to turn their living room into an interactive space for exploration and contribution of memories through performed bodily postures guided by an AI voice.

Figure 67. memoryMechanics, performance at NOVA festival, Bucharest. Photo by Maja Fagerberg Ranten

In the physical version, participants are led by a performer into a bodily posture and are invited to recount a recollected memory out loud. The computer tracks the specific posture in the space and relates it to the recorded memory. In this way, the collection of memories grows, and the space that is used to record memories from postures is also an exploration space to find previous participants' bodily postures and memories. The work has three modes: one) a workshop part where participants join the performers in the installation for a memory session in which they record their body posture memories to grow the AI stored "bank" of memories, two) the installation itself, where participants can move around in the space and find other people's memories through postures, and three) a performance created and performed by Lise Aagaard Knudsen and Karen Eide Bøen in the installation.

The physical version was originally intended for the CLICK festival, an annual tech and music festival in Elsinore. But due to the COVID-19 pandemic, the project was delayed and extended over a two-year period until new venue possibilities arose, which have so far included two performances at CLICK AI days in Elsinore, taking place in an old shipyard venue (Figure 66). The NOVA festival in Bucharest offered a neat gallery experience organized around the three modes during four days at the festival – workshops, open installation, and a performance (Figure 67). And finally, the HAUT works in process festival in Copenhagen provided a traditional theatre black box, allowing for a performance followed by a talk (Figure 68).

The execution at the three festivals was conducted by Mads Hobye, Lise Aagaard Knudsen, and Karen Eide Bøen. I attended the showings as an inside biased participant/audience member.

The interview

The interview (Figure 69) took place via Teams on the 15th of November 2021 as a conversational interview between me (Maja), Lise Aagaard Knudsen (Lise), and Karen Eide Bøen (Karen). The intention was to explore the experience of being performers in the installation, and thus test the phenomenological concepts and insights from working with Bodily Interaction Design in this dissertation. The interview is divided into the following themes: Memories as bodily experience, the material collaboration, the bodily experience, experience of the different modes, and the different settings. Lise is an actor and MSc in Theater & Performance Studies. Karen is a dancer and choreographer.

Figure 68. memoryMechanics, performance at HAUT works in process festival. Photo by Maja Fagerberg Ranten

MEMORIES AS BODILY EXPERIENCE

MAJA: For me, the thematic interest is bodily experience. And, within that, memories, and your experience as performers in the three modes; workshop to grow the memory bank, and installation to try out the memories, and the performance in the installation. I know you worked with memories in an analog context earlier... What's the difference for you between the analog version and bringing in technology?

KAREN: Actually, it's interesting that it becomes even more tangible in a way- more available or more present than physical -when it's sound. The way sound moves... you don't have to go find paper and read this memory...You can be in it in a physical way. Even though it's technology.

LISE: Yeah, there is some kind of landscape to move in. And, for me, it's a way to reconnect with the stories and the people every time we go back into the archive. It's kind of like meeting these people again, and their stories. I don't think they talk about us, but we talk about them and have very vivid images of them doing positions and how they were when they were sharing the story. I haven't thought about that very much before, but there's this feeling of connection to someone that we don't actually really know.

KAREN: I think that comes both from the recorded voice, but also because sound is a very connective thing. But I guess it's also the fact that it's being triggered by what we do and that it has a mind of its own. In a way it's the computer… but it [also] feels like these people are taking the choice to speak.

MAJA: It reminds me of something mentioned at the talk afterwards [at the HAUT performance], that you somehow perform other people's memories. I've tried being guided, and I've observed you guide other people. And there's something about the way you slowly and gently move people around and talk to them. As if you transfer an energy to the sessions that makes people connect to the memories. Is it a method for you, that you've worked on, consciously?

KAREN: How did it become like that?

LISE: I think it was about creating a kind of space where people would feel comfortable. And a way of conveying that there is no right or wrong. Like, if you don't remember anything, or if you remember something more recent. It's okay. It's not about doing the right thing or hitting a jackpot. It is about participating and sharing. We always focused a lot on sharing. What people share with us; we share with them. And I don't think it has to be memories. But the way we set it up, there is some kind of soft energy around us participating that sets a tone.

KAREN: Because we are always- in the workshops -also sharing something. I guess it's also a practical thing. When you find out that it is better if the eyes are closed, that it triggers the memories if someone else manipulates or moves your body. And also, we wanted them to move around, so they did not know where they were, somehow you get in a different space. People might find that a bit uncomfortable, so we had to be... to not scare them because we really wanted them to reach their memories.

THE MATERIAL COLLABORATION

MAJA: I would like to talk about the collaboration in terms of materials, because I have this thought that we bring a different material toolbox to a collaboration. For instance, in your toolbox, is the fact that you worked with memories for a long time. So, you might have bodily experienced knowledge about memories and how to work with people to make them calm. So, I wonder what is in your toolbox, as a performer or a dancer, an actor, a choreographer?

[silence...] To me, as an interaction designer, it's as practical as thinking about the core materials for me as an interaction designer is computational material, tangible material, and the body as material. And I can

put those three together in a million various ways and choreograph an interactive installation, for instance.

KAREN: It is nice to think about what is in our common toolbox, because doing this, maybe it is possible because we come from different backgrounds, but when we work together, we both work with texts, like speaking and moving.

LISE: I think in this project, we have of course, a toolbox of memories in different formats. We have positional material, we have sounds, we have written texts. We have memories of people, positions of people, and people sharing. And, we have made different small performative things around this material. And then text, working with text and working with the body with movement.

KAREN: Maybe, also physical tasks. Like movement tasks. We have a set of materials, but we also used movement materials that are based on rules or tasks. It's improvisation, I guess, it's an important thing in our toolbox in the performances, and in interaction with someone who comes for the installation, and in the workshop.

MAJA: It's interesting, the materials you mention are all in the performance. Within the performance, you shift between different modes: there is a part where you speak out loud, one where you move in unison as twins, and you move around at a fast pace. All these shifts are then presenting some of your shared toolbox.

THE BODILY EXPERIENCE

MAJA: These shifts in the performance. I wonder what they are like for you in a bodily sense. Do you get sensations or feelings while doing the performance?

LISE: Yes, and no. I don't think I feel – like feelings. I mean, I don't think I get emotions. But I get feelings like sometimes you hit a text, or you come to a position and the text just fits in a good way. Or you hear something that's a funny moment because it's a certain snippet that's done or with a sensation of accomplishment that you end up in the right position or take it to the edge of something where you can get a feeling that it works or that we are having a moment of flow.

KAREN: Do you mean when the audience is there specifically, or? I'm asking both of you...

MAJA: I was thinking in the performance situation, but...

LISE: Yeah, I think so. But I also think that sometimes when we rehearse, it can also happen.
Especially with twins, both in performance and rehearsals, I feel like you can get that feeling of a better flow or a good flow. But I mostly hear the sound and I feel oh, that was a good moment in the performance.

KAREN: So, in a way, then you kind of experience what they experienced. You don't really... but you know...

LISE: ...you get a sense that you do, or that you know what you're giving them.

KAREN: I really like performing because I get all this adrenaline, so it's very different when you're performing... but in bodily experiences. Being in the sensations...?

[pause]

MAJA: For me as an audience, there are points where I get special sensations or a feeling. When it's attached to the words in a certain way, or when you just move beautifully together, I get a tiny feeling of joy or endorphins... There's this special place in the performance after you move around in high

pace, where you stand together and move your hands on your thighs. Every time I get a bodily reaction of, you know, that feeling in your stomach that something is up here. It's either a little bit dangerous, or is it sensual? And I wonder whether you have those moments...?

KAREN: I guess. Also, every time is different a little bit. How long we stay with that depends a bit on when it feels right to move on.

MAJA: And when you move in unison. Are you aware of each other? Is it a bodily connection that makes you move so well together? Or is it training?

KAREN: It's very funny, because I think we have tried it and then we talk about it, and then try it again and say, ah, this didn't work. And there's so many dos and don'ts or rules, but then I guess at some point you get this feeling of how it is, kind of. Maybe, I don't know, can you take away all those rules and then just know how it feels?

LISE: Yeah, we've set some rules and we've tried it a lot. So, it's practice and rules and of course also knowing each other somehow or having done it together. So, we're moving within a certain movement language. We kind of recognize or follow some patterns. And then we do that for a bit and then we try to challenge that a little bit or see like, okay, now, it doesn't feel quite right this time or…

KAREN: ...or when we watch it on video, and we think we're going slow but we're not really going slow [ha ha].

MAJA: There was another a moment in Romania. The snow-white thing [one of the memories spoken in Romanian- we were told -included the word Snow White]. You mentioned you move to a certain match in a memory. But then in this instance, you didn't know the word. So, do you move to the words, the sounds, or to the memories?

LISE: I mean, it was very different. Not knowing exactly what they were saying, we were more using our experience of telling the stories we knew. We knew the positions they were in, and we knew something about rhythm. And then just hoping that they would get a similar feeling. But of course, it really lost a lot of intention or timing, because we couldn't really know what was being said. But you can still hear when people are finishing a sentence or, you can listen to the rhythm of them speaking.

KAREN: And I guess we don't always allow people to tell the whole story, anyway, so in a way, it's not right or wrong. But it was very difficult.

EXPERIENCE OF THE DIFFERENT MODES

MAJA: What about the different modes? You have the bodily experience of both being performers, guides in the workshops, and even being participants in the installation. Are there any obvious differences?

KAREN: I would say it is three quite different modes. I guess what we're doing when we're performing is a lot like composing in the moment. How long do we do something? When do we switch? For how long? But then when you are in the installation… I don't have those thoughts, I guess.

LISE: ... it's more for- I mean, the performance is also for -someone else. But when you're guiding it's, about listening to that person, you're guiding and being a helper for them; like facilitating their experience of it.

MAJA: And what about being in the installation? Without the performance? What has your experience been listening to the memories?

LISE: Just exploring the space. I'm trying not to be like married to them. The actual positions. How far does it spread, is something everywhere in the space, does it change depending on how I move? Because we work- in the performance -with set places that we go, but then what if you use the other spaces more intentionally? And how far does – how do the stories stretch?

KAREN: And also, it's nice to try to… I've tried a few times to see if it is possible to make a story that is made of the different words? I feel like it could be words popping up a fun history…

MAJA: That gives the part in the performance where you have the high pace running around a totally different perspective!

THE DIFFERENT SETTINGS

MAJA: Finally. It's been three different settings. What is your experience from the settings, what were your favorites or what was the differences?

LISE: I think it was very nice that the first one was in Elsinore in the space where we originally wanted to make the piece. There was something about the aesthetics that I enjoy. And I felt it was very satisfying with this big, big space and this raw energy of the room. And then I think in Romania, it was aesthetically less pleasing. But it was very interesting to experience how people would engage with the installation and see different people use it and see the quality of listening and of exploration.

MAJA: What happened there [the special quality of listening and exploration] Is it a cultural thing? Or is it the gallery setting? Or what was at play here?

KAREN: Well, it was just something about…It was not closed off, but it was a little bit secluded in the room, and they had the headphones on. So that they didn't, perform. I think in Elsinore, the installation was also open afterwards, but with speakers.

LISE: And, because this space is so open [in Elsinore], you're so exposed.

KAREN: And then we didn't really try it with the headphones in Copenhagen.

LISE: No. I think in Copenhagen it was nice too. I think it was nice to do the performance in a performance space [black box]. And it was satisfying for us to get the feedback. And think about where the project should go next. At the same time, it was not very satisfying that we didn't activate the installation for more people to experience it.

MAJA: And that worked great at the NOVA festival, the intended idea to mix workshops, open installation, and performance.

KAREN: …maybe the different modes fit better in different contexts? I don't know. The installation seems to fit quite well in this case. That it is open for a longer time…

LISE: …they sent a lot of pictures and videos [after we went home] so you can see that there was a lot of people trying it out afterwards.

MAJA: Oh, nice they kept it going. Thank you very much. I will stop the recording.

Figure 69. Transcript of the interview with Lise & Karen

Interview extracts

Memories as bodily experience

Memories play a lead role in the installation. Participants can search for other people's memories in the space, they can contribute to the installation with their own memory, and in the performance Lise and Karen reconnect with the participants through their memories: "…it's a way to reconnect with the stories and the people every time we go back into the archive. […] there's this feeling of connection to someone that we don't actually really know" (Lise).

Karen points out how they trigger memories as sound when they are performing in the installation, and at the same time the computer (the AI) has a *mind of its own*: "…sound is a very connective thing. But I guess it's also the fact that it's being triggered by what we do and that it has a mind of its own. In a way it's the computer… but it [also] feels like these people are taking the choice to speak" (Karen).

For me as an observer of the workshops, seeing Lise and Karen guide participants into postures that lead to spoken out memories, it is remarkable that their calmness becomes a room-filling energy: "…there's something about the way you slowly and gently move people around and talk to them. As if you transform an energy to the sessions that makes people connect to the memories…" (Maja). Lise and Karen stress the importance of the fact that they share, too, and the memory impact is higher if the participants close their eyes and are touched and manipulated or guided into postures: "…you find out that it is better if the eyes are closed, that it triggers the memories if someone else manipulates or moves your body" (Karen).

The material collaboration

Karen and Lise share a repertoire- a collective material toolbox -from working together throughout several years. They list the shared material: "We have positional material, we have sounds, we have written texts. We have memories of people, positions of people, and people sharing" (Lise). And include their methods from rule-based posture tasks and improvisation: "We have a set of materials, but we also used movement materials that are based on rules or tasks. It's improvisation, I guess, it's an important thing in our toolbox in the performances…" (Karen).

The bodily experience

The interview confirms many of my bodily notions. It shows that bodily actions and impacts are highly subjective and multiple sensations, feelings, and affect are at play.
Karen is full of adrenalin when performing and Lise gets sensations of accomplishment: "…I don't think I get emotions. But I get feelings like sometimes you hit a text, or you come to a position and the text just fits in a good way […] a sensation of accomplishment…" (Lise).

There is a hyper-reflection between action and reflection from a performer's point of view, combining moments of flow with considerations about rules: "…there's so many dos and don'ts or rules, but then I guess at some point you get this feeling of how it is…" (Karen), "…you can get a feeling that it works or that we are having a moment of flow" (Lise). And movement becomes their language between flow and rules: "…we're moving within a certain movement language. We kind of recognize or follow some patterns…" (Lise).

There is a shift in the sensations when they move to memories spoken in languages they cannot understand "…it really lost a lot of intention or timing, because we couldn't really know what was being said. But you can still hear when people are finishing a sentence, or you can listen to the rhythm of them speaking." (Lise).

Experience of the different modes

The experience of the three different modes is very different. Performing is like composing in the moment: "I guess what we're doing when we're performing is a lot like composing in the moment" (Karen). Whereas guiding is about facilitating the participant's experience: "But when you're guiding it's about listening to that person, you're guiding and being a helper for them; like facilitating their experience of it" (Lise). And being in the installation is pure exploration. Lise is "Just exploring the space" and Karen makes playful experiments: "I've tried a few times to see if it is possible to make a story that is made of the different words? I feel like it could be words popping up a fun history…".

The different settings

The three settings and contexts were quite different: One night with performances in Elsinore in the old shipyard venue Hal 14, four days at a festival in the gallery in Romania with workshops, open installation, and a performance. And one night with a performance followed by an open talk at HAUT works in process festival in Copenhagen in a black box.

Hall 14 at the Culture Yard in Elsinore was the originally intended location for the installation. And here Lise enjoys the aesthetics from the raw room: "There was something about the aesthetics that I enjoy. And I felt it was very satisfying with this big, big space and this raw energy of the room" (Lise).

The gallery setting in Romania omit this was "…was aesthetically less pleasing" (Lise), but the engagement from participants was quite interesting, as participants seemed to really engage and spend a lot of time in the installation: "…it was very interesting to experience how people would engage with the installation and see different people use

it and see the quality of listening and of exploration" (Lise). Maybe due to the intimate, secluded space, and the fact that they had headphones on "So that they didn't perform…" (Karen).

From my perspective in the audience, the traditional stage room of the black box meant that the work-in-progress was experienced as finished work, which was appreciated by Lise: "…it was nice to do the performance in a performance space….".

Final Comment

Overall, the interview overlaps with aspects of my methodology and insights. In particular, how they relate to memory through bodily gestures. That sound was a strong medium for connecting with memories. How they too experience creating a collaborative material repertoire, that their bodily actions and impact are subjective and how hyper-reflection between action and reflection is present throughout their performance. Furthermore, it is an interesting, complex case with different modes, settings, and roles. From a performer's perspective, although the designer's role is blended in a cross-disciplinary collaboration of performers, developers, and designers. The memoryMechanics project also brings forward the necessity of constantly evolving, expanding, and challenging the program to test and try out the dissertation's various aspects, models, and methodology in new real-world contexts and include complex technology such as AI and machine learning.

11 | Original Contribution

11 | Original Contribution

Where do we go from here? First, I again wish to stress that my proposed perspective, methodology, models, insight, and aspects are merely suggestions to be further evolved, elaborated, or challenged. They are meant for interaction designers working with Bodily Interaction Design to think *into, through,* and *with*.

Second, this is an example. It is a subjective first-person interpretation of concepts, methodology, and practice through lived experience with developing interactive installations that elicit bodily behavior. To paraphrase Redström (2018): This dissertation is an example of a programmatic design research. With examples of designing for, with and through Bodily Interaction Design. "The conclusion is inevitable. *This* is an example" (p.142).

Third, I want to point to the focus of this dissertation as the development point of view of creating Bodily Interaction Design. If we move the focus from development to user experience, a different methodological approach is required, where standardized rigorous methods such as empirical data can be useful in understanding the lived experience of the participants.

Fourth, not all developers/designers/artists have a bodily approach to interaction design. The research is situated within a research through design approach to creating Bodily Interaction Design that elicits embodied action and impact. The attention is not on the outcome of the design, but rather a particular bodily perspective in the development process and the methodological phenomenological research through design approach.

Contribution to Whom?
The contribution is directed to the academic community and field of Interaction Design, and HCI, and it is aimed at designers working in these fields. And within a more traditional technical approach, it serves as a suggestion to broaden the approach towards a new ontology.

Within the evolving focus and maturing program of design from a lived body perspective within HCI my contribution is an attempt to communicate a revised phenomenological approach to Bodily Interaction Design, a suggestion of an umbrella methodology of phenomenological research through design, and an unfolding of the materiality of the methodology into a framework on the materials of Bodily Interaction Design.

Programmatic Research "Question"
Returning to my programmatic research question/curiosity/provocation/investigation/exploration/what if... *the materiality of interaction design was considered from a phenomenological perspective. How can we design bodily interaction design as a way of doing phenomenology for practitioners of interaction design?*

The knowledge contribution is constituted in an assemblage of program (Bodily Interaction Design) and experiments (all the practical designs from my portfolio of engagements). The program has been explored and unfolded throughout the dissertation as a research program of Bodily Interaction Design through the three angles and sub explorations:

Perspective: Bodily Interaction Design: A revised phenomenological perspective.
What is the worldview of Bodily Interaction Design?

Methodology: Phenomenological Research Through Design. The methodology of the perspective. *What is the lived experience of designing as a methodology?*

Materiality: The materiality of a Bodily Interaction Designer. Unfolding the materiality of the methodology: *What are the materials of a bodily interaction designer?*

The Perspective: Bodily Interaction Design

PERSPECTIVE	**Bodily Interaction Design.** A revised phenomenological perspective. *What is the worldview of Bodily Interaction Design?*

Bodily Interaction Design is a phenomenological perspective- a *worldview* -where the lived body plays a significant role in design development. It is a contemporary revised phenomenological perspective that acknowledges that bodies are multifaceted and socio-culturally entangled. And it is a phenomenological and new materialist more-than-human perspective of the designer's bodily relationship with materials.

The lived experience of designing includes object/subject exchanges, subject/subject exchanges, and nature/subject exchanges. It has a feel dimension that can be physical, functional, and biological. The lived experience of designing is a state of flux and includes the notion of being changeable and in relation to other beings, objects, and elements. Bodies are social, biological, situated, political, and cultural. Hence the lived experience is entangled with culture, politics, biology, and the socio-cultural.

The Methodology: Phenomenological Research through Design

METHODOLOGY	**Phenomenological Research Through Design.** The methodology of the perspective. *What is the lived experience of designing as a methodology?*

The methodology is phenomenological research through design. It has been explored as *the lived experience of designing as a methodology*. With the broad term phenomenological research through design, the intention is to allow for a broader interpretation of the use of the lived body in the design process as opposed to fixed solutions and concepts where the focus is on one specific method or bodily conception. Furthermore, it overcomes the continual hesitation to acknowledge the significance of the designer's body in the design process. This is an invitation for an ongoing interpretation of a methodological exploration of phenomenological research through design, where a phenomenological perspective in the design process is continuously evolved, adapted, and adjusted to explore the lived body of the design process. Viewing designers as phenomenologists also raises the political issue of what kind of bodies we are designing.

Additionally, I state that phenomenological research through design as a methodology can include entanglement, interrelatedness, feminism, social, political, and culturally shaped perspectives. As well as several different conceptions of the body. Phenomenological Research through Design is thus a broadly embracing umbrella term.

Specifically, in chapter 8, *Methodology: Phenomenological Research through Design*, I suggest four methodological aspects of phenomenological research through design; (a) *prototyping with the lived body*, (b) *the interplay between touch and touchback*, (c) *social interrelation*, and (d) *drifting*. I further suggest dividing the practical phases of phenomenological research through design into the three phases: before, during and after.

The Materials: The Materiality of a Bodily Interaction Designer

MATERIALITY	**The materiality of Bodily Interaction Design.** Unfolding the materiality of the methodology: *What are the materials of a Bodily Interaction Designer?*

The material contribution is an unfolding of *the materials of Bodily Interaction Design.* Materials in interaction design is a form-giving practice designers can choreograph into "compositions". It includes the three main materials: tangible materials, computational material, and the body as material. The three materials illustrate the core elements of bodily interaction design, they overlap merge and relative to each other. And it is further entangled with half entities and affect and is affected by context, intention, society, politics, and ethics.

Specifically, I present the model *Feedback Loop of Bodily Interaction Design* where the focus is on the constituting relationship between bodily action and bodily impact, thus positioning a phenomenologically informed perspective to the definitions of materiality in HCI and interaction design as a form-giving practice. I further initiate an unfolding of the different types of bodily actions and bodily impact as performing/physical reaction, sensing/sensory perception, and bio-feeling/affect response.

Performing Bodily Interaction Design

The knowledge contribution is the program. Well, a suggestion of a program: Bodily Interaction Design. With the worldview of a revised phenomenological approach. A suggestion of an umbrella methodology: phenomenological research through design. And an unfolding of the materiality of the methodology into a framework of the materials of Bodily Interaction Design. This is the parameter of the work so far.

The program is not value-based like the Soma Design program is built on pragmatic perspectives to live better lives (Höök, 2018). And the program's attention is not on the design outcome but on a particular bodily perspective in the development process that can lead to attention to the future bodies we design.

The benefits of the program (Figure 70) it that it is grounded in materials and practice, and it can help overcome the hesitation to acknowledge the designer's bodies in the design process. It is not enforcing any rules or strict guidelines but is instead related to opening the research area as a broad, generous bodily perspective and methodology.

THE BENEFITS OF THE PROGRAM BODILY INTERACTION DESIGN

- The program is for interaction designers working with Bodily Interaction Design to think into, though, and with.

- The program is expanding the repertoire of exemplars and research in phenomenology in the fields of HCI and interaction design.

- The program can help overcome the continual hesitation to acknowledge the significance of designers' bodies in the design process.

- The program is related to opening the research area - as a broad, generous bodily perspective and methodology (rather than being prescriptive).

- The program's attention is on a particular bodily perspective in the development process that can lead to attention to the future bodies we design (rather than on the outcome of the design).

Figure 70. Summarizing the benefits of the program: Bodily Interaction Design

For the program to mature, it will be necessary to revisit what we can expect from the program continuously. To keep exploring how the program affects, improves, and changes design processes and the design exemplars made through the program.

For now, I propose and return to dividing performing phenomenological research through design into three parts – before, during, and after. Here to act as a placeholder for the contributions presented throughout the dissertation as inspiration for designers to think through and with the program and the various takeaways presented: the perspective, the design exemplars, the feedback loop of bodily interaction, the methodology, methodological aspects, the material framework, and the bodily feedback loop entangled with society, politics, and ethics (Figure 71). All as inspiration for future research, experiments, and design development.

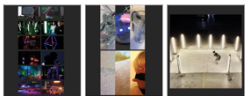
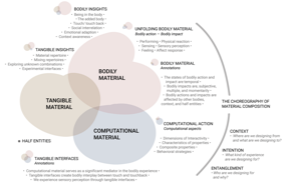
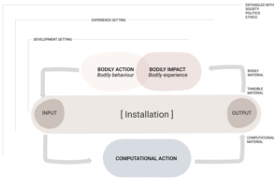
BEFORE. The perspective:	DURING. The method:	AFTER. The reflection:
Designers as phenomenologists	*Prototyping with the lived body*	*Research evaluation*
A revised phenomenological perspective *Design exemplars:*  *The feedback loop of Bodily Interaction Design:*  *(Figure 48)*	*A broad umbrella methodology: Phenomenological Research through Design* *Methodological aspects* *Material framework:*  *(Figure 62)*	*The Bodily Interaction Design feedback loop entangled with society, politics, and ethics:*  *(Figure 40)*

Figure 71. The takeaways of the program Bodily Interaction Design placed in the three parts of performing phenomenological research through design: before, during, and after

12| Re-Program

12| Re-Program

In returning to my methodological approach, programmatic research: the program drifts and needs re-visiting. Design research naturally drifts. "Traditionally, in science literature, drifting is regarded as bearing the touch of randomness, the uncontrolled, illogical and inconsistent. However, in design research and in particular the professional practice of design, drifting or pursuing alternative opportunities in the vicinity of one's work is an embedded way of arriving at relevant and high quality work" (Krogh, Markussen, & Bang 2015, p.4).

I suggest four main themes for a possible re-program and future work direction for Bodily Interaction Design.

i) Explore the user experience side of the development focus from the dissertation.
Exploring Bodily Interaction Design from a user experience point of view would require a different methodological approach e.g., with a focus on validation and reliability. The same could be said about the development focus – that an obvious next step would be to test and try out the methodology in new design collaborations, as well as discuss the reliability of first-person accounts of experience. A similar statement has recently been pointed out by Höök et al. (2021) in relation to the Soma Design program: "Soma Design methods should be validated by criteria such as whether they are *generative* to design; whether the resulting designs reliably sustain the somaesthetic user experience sought; and so on" (p.40:31).

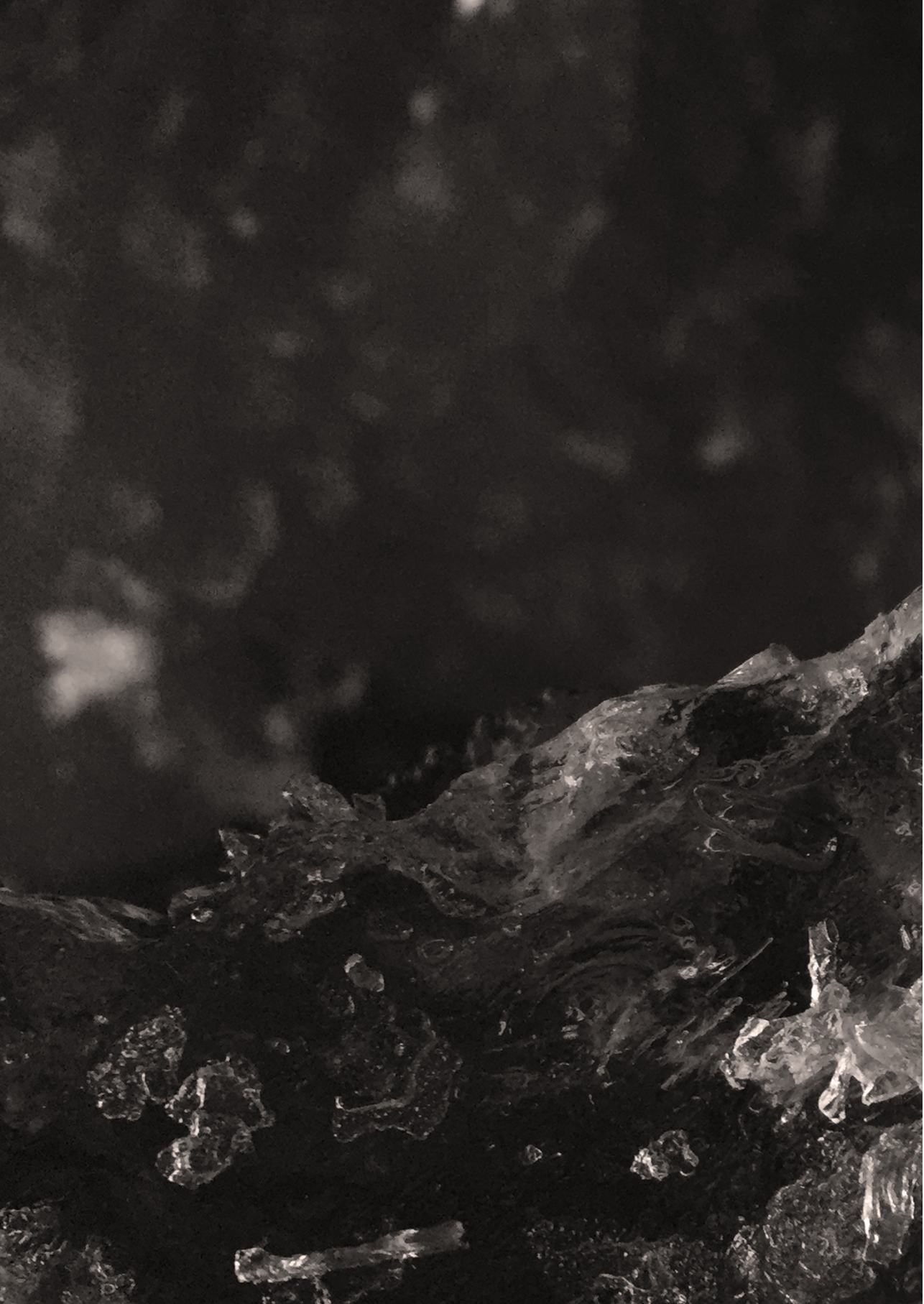
ii) A closer view on more-than-human perspective.
An area I would like to unpack further is the entanglement of bodies as political, socially, and culturally in a more than-human perspective with new installations and performance contexts. My research echoes the notion of the need to understand bodies in a more-than-human perspective, we present in Paper 1, "Tracing Conceptions of Bodies in HCI". Touring with the memoryMechanics project in different settings, locations, and organizational structures has been a gentle reminder to incorporate entanglement considerations into the design process actively. It would also be interesting to unpack the perspective to include all the more-than-human bodies we encounter, intersect with and affect. And broaden the material perspective with exemplars of design that work with more-than-human species.

iii) Exploring complex technology in the Bodily Interaction Design perspective.

Another area inspired by the memoryMechanics case is to explore more complex technology within the Bodily Interaction Design perspective and methodology. Such as artificial intelligence, machine learning, and big data. The practical engagements of my portfolio are primarily based on computing in physical form based on embedded platforms. Frauenberger (2019) argues that relationship with complex technology require updating research paradigms: "Our relationships to virtual realities, artificial intelligence, neuroimplants or pervasive, cyberphysical systems generate ontological uncertainties, epistemological diffusion and ethical conundrums that require us to consider evolving the current research paradigm"(p.1).

iv) Re-visiting the role of the designer in a broader sense.

Finally, doing Bodily Interaction Design raises questions about the future role of the designer. When the body is entangled with society, culture, politics, ethics, and norms about the body, how do we ascertain what kind of bodies we design for? This creates a need for designers be aware of intersectionality and to "…acknowledge the interconnectedness of social categorizations such as race, class, gender, ability, sexual orientation, ethnicity, geographical location, and age" (Paper 1, Homewood et. al., p. 9). As we point out in Paper 1, "Tracing Conceptions of Bodies in HCI," designers design more-than-human bodies. Furthermore, it may require the designer to take a humble stand, in line with Wakkary (2021), who states that the human designer should not be the privileged force in design, but rather the designer should be understood as an assembly of the non-human and humans.



13| Closing

13| Closing

Bodily Interaction Design has been explored as a research program based on practice-based engagements with interactive installations that elicit embodied behavior and through a first-person experience of attention to the lived body in the design development process. The program is informed by a contemporary reading of Merleau-Ponty's phenomenology in a new materialist bodily more-than-human perspective, and a phenomenological material view of interaction design as a form-giving practice.

The knowledge contribution includes exploring and expanding the three angles of the research program into firstly, a bodily perspective from a phenomenological perspective: *Bodily Interaction Design*; secondly, a suggestion of a new field within research through design: *phenomenological research through design*; thirdly, a material unfolding of the methodology as *the materiality of Bodily Interaction Design.*

The research is a contribution to the ongoing and expansive area of scholars within HCI working with bodily conceptions and the lived body in the design process. Furthermore, the unfolding and positioning of the body as material into the materiality of interaction design contributes to ongoing work around interaction design as a form-giving practice in HCI.

The perspective, methodology, and materiality, as well as the specific models, insights, and aspects presented throughout the dissertation is a suggestion for designers to work with particular attention to a bodily perspective in the design development process as a way of doing phenomenology and Bodily Interaction Design for practitioners of interaction design.

As a program, Bodily Interaction Design is still under development. Likewise, I only highlight the potential of exploring a Phenomenology of Research through Design. As stated by Fallman (2003): "Phenomenology is an attitude to research – not a recipe" (p. 365). For the program to mature and phenomenological research through design to evolve as a methodological approach in interaction design and HCI, we need to continuously view and develop particular attention to the lived body in the design process. And we must continue to discuss, explore, and pay attention to what kinds of bodies we create through our designs.

References

References

Ahmed, S. (2006). *Queer Phenomenology Orientations, Objects, Others*. Duke University Press.

Bang, A. L., & Eriksen M. A. (2014). Experiments All the Way in Programmatic Design Research. *Artifact Journal* III (2), 4.1-4.14. https://doi.org/10.14434/artifact.v3i2.3976.

Barad K. (1996) Meeting the Universe Halfway: Realism and Social Constructivism without Contradiction. In: Nelson L.H., Nelson J. (eds) *Feminism, Science, and the Philosophy of Science*. Synthese Library (Studies in Epistemology, Logic, Methodology, and Philosophy of Science), vol 256. Springer, Dordrecht. https://doi.org/10.1007/978-3-319-62140-1

Barad, K. (2018). Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter. In: Åsberg C., Braidotti, R. (eds) *A Feminist Companion to the Posthumnaities*. https://doi.org/10.4324/9780203427415-41.

Bardzell, S. (2010). Feminist HCI: taking stock and outlining an agenda for design. *Proceedings of the 28th International Conference on Human Factors in Computing Systems - CHI '10*, 1301. New York, New York, USA: ACM Press. https://doi.org/10.1145/1753326.1753521.

Bardzell, S. (2018). Utopias of Participation: Feminism, Design, and the Futures. ACM *Transactions on Computer-Human Interaction*. 25. 1-24. 10.1145/3127359.)

Baskinger, M., & Gross M. (2010). Tangible Interaction = Form + Computing. *Interactions* 17 (1): 6. https://doi.org/10.1145/1649475.1649477.

Bennett, J. (2010). *Vibrant Matter: A Political Ecology of Things*. Durham : Duke University Press.

Bochner, A. P. (2017). Heart of the Matter: A Mini-Manifesto for Autoethnography. *International Review of Qualitative Research* 10 (1). https://doi.org/10.1525/irqr.2017.10.1.67.

Bochner, A. P., & Ellis, C. (2016). *Evocative Autoethnography: Writing Lives and Telling Stories*. *Evocative Autoethnography: Writing Lives and Telling Stories*. Routledge. https://doi.org/10.4324/9781315545417.

Bødker, S. (2006). When Second Wave HCI Meets Third Wave Challenges. *ACM International Conference Proceeding Series*, 189:1–8. New York, New York, USA: ACM Press. https://doi.org/10.1145/1182475.1182476.

Bødker, S. (2015). Third-Wave HCI, 10 Years Later - Participation and Sharing. *Interactions*. https://doi.org/10.1145/2804405.

Brandt, E., & Binder T. (2007). Experimental Design Research: Genealogy Intervention–Argument. *International Association of Societies of Design Research, Hong Kong.*

Brandt, E, Redström, J., Erikssen, M. A., & Binder. T. (2011). *XLAB*. The Danish Design School Press.

Buxton, B. (2010). Sketching User Experience: *Getting the Design Right and the Right Design*. Morgan Kaufmann

Coole, D., & Frost, S. (2010). *New Materialisms. Ontology, Agency, and Politics*. Duke University Press.

Deleuze, G. (1988). *Spinoza: Practical Philosophy*. San Francisco: City Lights.

Diprose, R., & Reynolds, J. (2011). *Merleau-Ponty: Key Concepts*. *Merleau-Ponty: Key Concepts*. Routledge. https://doi.org/10.1017/UPO9781844654024.

Dourish, P. (2001). *Where the Action Is the Foundations of Embodied Interaction*. MIT Press.

Dunne, A., & Raby F. (2013). *Speculative Everything: Design, Fiction, and Social Dreaming. Speculative Everything: Design, Fiction, and Social Dreaming*. MIT Press.

Ehn, P., Nilsson, E. M., & Topgaard, R. (2014). *Making Futures: Marginal Notes on Innovation, Design, and Democracy. Making Futures*. MIT Press.

Falk, J.H., & Dierking L. D. (2016). *The Museum Experience Revisited. The Museum Experience Revisited*. Routledge. https://doi.org/10.4324/9781315417851.

Fallman, D. (2003). *In Romance with the Materials of Mobile Interaction: A Phenomenological Approach to the Design of Mobile Information Technology*. Umeå University.

Fallman, D. (2008). The Interaction Design Research Triangle of Design Practice, Design Studies, and Design Exploration. *Design Issues*. 24(3): 4-18. https://doi.org/10.1162/desi.2008.24.3.4.

Fraleigh, S. (2018). *Back to the Dance Itself. Back to the Dance Itself*. University of Illinois Press. https://doi.org/10.5406/j.ctv80cb20.

Frauenberger, C. (2019). Entanglement HCI the next Wave? *ACM Transactions on Computer-Human Interaction. Vol.27, No. 1*. https://doi.org/10.1145/3364998.

Frayling, C. (1993). Research in Art and Design. *Royal College Research Papers*.

Frost, S. (2011). The Implications of the New Materialisms for Feminist Epistemology. In: Grasswick H. (eds) *Feminist Epistemology and Philosophy of Science*. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-6835-5_4

Gaver, B, & Bowers J. (2012). Annotated Portfolios. *Interactions*. https://doi.org/10.1145/2212877.2212889.

Gaver, W. (2012). What Should We Expect from Research through Design? *Conference on Human Factors in Computing Systems - Proceedings*. https://doi.org/10.1145/2207676.2208538.

Gaver, W. (2012). What Should We Expect from Research through Design? *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems - CHI '12*, 937. New York, New York, USA: ACM Press. https://doi.org/10.1145/2207676.2208538.

Giaccardi, E., & Karana E. (2015). Foundations of Materials Experience: An Approach for HCI. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. https://doi.org/10.1145/2702123.2702337.

Gibson, J. J. (1986). *The Ecological Approach to Visual Perception. Lawrence Erlbaum Associates. Hillsdale, New Jersey*.

Grosz, E. (1994). *Volatile Bodies: Toward a Corporeal Feminism*. Indiana University Press.

Hallnäs, L. (2011). On the Foundations of Interaction Design Aesthetics: Revisiting the Notions of Form and Expression. *International Journal of Design* 5 (1): 73–84.

Hallnäs, L., & Redström J. (2002a). Abstract Information Appliances: Methodological Exercises in Conceptual Design of Computational Things. In *Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, DIS*. https://doi.org/10.1145/778712.778730.

Hallnäs, L., & Redström J. (2002b). From Use to Presence: On the Expressions and Aesthetics of Everyday Computational Things. *ACM Transactions on Computer-Human Interaction*. https://doi.org/10.1145/513665.513668.

Hansen, L. K., & Kozel, S. (2007). Embodied Imagination: A Hybrid Method of Designing for Intimacy. *Digital Creativity*. https://doi.org/10.1080/14626260701743200.

Hauser, S., Oogjes, D., Wakkary, R., & Verbeek, P. P. (2018). An Annotated Portfolio on Doing Postphenomenology through Research Products. *DIS 2018 - Proceedings of the 2018 Designing Interactive Systems Conference*. https://doi.org/10.1145/3196709.3196745.

Hayles, N. K. (2012). *How We Think. Digital Media and Contemporary Technogenesis*. University of Chicago Press.

Hobye, M. (2014). Playing with Fire: Collaborating through Digital Sketching in a Creative Community. *Making Futures*. https://doi.org/10.7551/MITPRESS/9874.003.0009.

Höök, K. (2010). Transferring Qualities from Horseback Riding to Design. *NordiCHI 2010: Extending Boundaries - Proceedings of the 6th Nordic Conference on Human-Computer Interaction*. https://doi.org/10.1145/1868914.1868943.

Höök, K. (2018). *Designing with the Body - Somaesthetic Interaction Design*. MIT Press.

Höök, K., Benford, S., Tennent, P., Tsaknaki, V., Alfaras, M., Avila, J. M., Li, C. et al. (2021). Unpacking Non-Dualistic Design: The Soma Design Case. *ACM Transactions on Computer-Human Interaction* 28 (6): 1–36. https://doi.org/10.1145/3462448.

Höök, K., Caramiaux, B., Erkut, C., Forlizzi, J., Hajinejad, N., Haller, M., Hummels, C.C.M. et al. (2018). Embracing First-Person Perspectives in Soma-Based Design. *Informatics*. https://doi.org/10.3390/informatics5010008.

Höök, K., Dalsgaard, P., Reeves, S., Bardzell, J., Löwgren, J., Stolterman, E., & Rogers, Y. (2015). Knowledge Production in Interaction Design. *CHI EA '15: Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*. https://doi.org/10.1145/2702613.2702653.

Höök, K., Eriksson, S., Søndergaard, M.L.J., Felice, M.C., Woytuk, N. C., Afsar, O.K., Tsaknaki, V., & Ståhl, A. (2019). Soma Design and Politics of the Body Addressing Conceptual Dichotomies through Somatic Engagement. *Proceedings of the Halfway to the Future Symposium 2019 (HTTF 2019)*. https://doi.org/10.1145/3363384.3363385.

Höök, K., Jonsson, M. P., Ståhl, A. & Mercurio, J. (2016). Somaesthetic Appreciation Design. *Conference on Human Factors in Computing Systems - Proceedings*. https://doi.org/10.1145/2858036.2858583.

Höök, K., Jonsson, M., Ståhl, A., Tholander, J., Robertson, T., Marti, P. , Svanæs, D. et al. (2016). Move to Be Moved. *Conference on Human Factors in Computing Systems - Proceedings*. https://doi.org/10.1145/2851581.2856470.

Höök, K., & Löwgren, J. (2012). Strong Concepts. *ACM Transactions on Computer-Human Interaction*. https://doi.org/10.1145/2362364.2362371.

Höök, K., Ståhl, A., Jonsson, M., Mercurio, J., Karlsson, A., & Johnson, E.C.B. (2015). Somaesthetic Design. *Interactions* 22 (4): 26–33. https://doi.org/10.1145/2770888.

Ihde, D. (2001). *The Technological Lifeworld: From Garden to Earth*. Indiana University Press.

Ishii, H., & Ullmer, B. (1997). Tangible Bits : Towards Seamless Interfaces between People , Bits and Atoms, *CHI '97: Proceedings of the ACM SIGCHI Conference on Human factors in computing systems*. https://dl.acm.org/doi/10.1145/258549.258715

Karana, E., Giaccardi, E., Stamhuis, N., & Goossensen, J. (2016). The Tuning of Materials: A Designer's Journey. *DIS 2016 - Proceedings of the 2016 ACM Conference on Designing Interactive Systems: Fuse*. https://doi.org/10.1145/2901790.2901909.

Koskinen, I., Zimmerman, J., Binder, T., Redstrom, J., & Wensveen, S. (2012). *Design Research Through Practice - From the Lab, Field, and Showroom. Design Research Through Practice*. Morgan Kaufmann. https://doi.org/10.1016/C2010-0-65896-2.

Kozel, S. (2007). *Closer: Performance, Technologies, Phenomenology*. MIT Press.

Kozel, S. (2010). The Virtual and the Physical: A Phenomenological Approach to Performance Research. In: Biggs, M., Karlsson, H. (eds) *The Routledge Companion to Research in the Arts*. Routledge.

Kozel, S. (2013). Somatic Materialism: Or 'Is It Possible to Do a Phenomenology of Affect? *Site*, no. 33. 153–167.

Kozel, S. (2017). The Archival Body: Re-Enactments, Affective Doubling and Surrogacy. *The New Human*. Medea. https://medium.com/the-new-human/the-archival-body-re-enactments-affective-doubling-and-surrogacy-448815d62c07.

Kozel, Susan, Ruth Gibson, and Bruno Martelli. (2018). The Weird Giggle : Attending to Affect in Virtual Reality. *Transformations*, *31*(31), 1-24. http://www.transformationsjournal.org/wp-content/uploads/2018/06/Trans31_01_kozel.pdf

Krogh, P.G., Markussen, T., & Bang, A.L. (2015). Ways of Drifting – 5 Methods of Experimentation in Research through Design. In: Chakrabarti A. (eds) *ICoRD'15 – Research into Design Across Boundaries Volume 1. Smart Innovation, Systems and Technologies*, vol 34. Springer, New Delhi. https://doi.org/10.1007/978-81-322-2232-3_4

Latour, B. (1986). Visualisation and Cognition: Drawing Things Together. *Knowledge and Society Studies in the Sociology of Culture Past and Present. Jai Press* 6: 1–40.

Laurel, B. (2003). *Design Research: Methods and Perspectives*. MIT Press.

Loke, L., & Robertson, T. (2010). Studies of Dancers: Moving from Experience to Interaction Design. *International Journal of Design* 4(2).

Loke, L., & Robertson, T. (2011). The Lived Body in Design: Mapping the Terrain. *Proceedings of the 23rd Australian Computer-Human Interaction Conference, OzCHI 2011*. https://doi.org/10.1145/2071536.2071565.

Loke, L., & Robertson, T. (2013). Moving and Making Strange: An Embodied Approach to Movement-Based Interaction Design. *ACM Transactions on Computer-Human Interaction*. https://doi.org/10.1145/2442106.2442113.

Loke, Lian, and Thecla Schiphorst. (2018). The Somatic Turn in Human-Computer Interaction. *Interactions* 25 (5): 54–5863. https://doi.org/10.1145/3236675.

Löwgren, J. & Stolterman, E. (2004). *Thoughtful Interaction Design: A Design Perspective on Information Technology*. MIT Press.

Löwgren, J., & Reimer, B. (2012). Designing Collaborative Media: A Challenge for CHI? *Conference on Human Factors in Computing Systems - Proceedings*. https://doi.org/10.1145/2212776.2212781.

Löwgren, J., Svarrer Larsen, H. & Hobye, M. (2013). Towards Programmatic Design Research. *Designs for Learning*, *6*(1-2), 80–101. https://doi.org/10.2478/dfl-2014-0017.

Manen, M.V. (1984). Practicing Phenomenological Writing. *Phenomenology and Pedagogy* 2 (1). https://doi.org/10.29173/pandp14931

Markussen, T. (2017). Building Theory through Design. In Vaughan, L. *(eds) Practice Based Design Research*. Bloomsbury Publishing, 87–98.

Markussen, T., Bang, A.L., Knutz, E. & Pedersen, P. (2012). Dynamic Research Sketching: A New Explanatory Tool for Understanding Theory Construction in Design Research. *Proceedings of the 8th International Design Research Society Conference.*

Massumi, B. (2002). *Parables for the Virtual: Movement, Affect, Sensation*, Duke University Press.

Merleau-Ponty, M. (1962). *Phenomenology of Perception. Phenomenology of Perception*. London: Routledge. https://doi.org/10.4324/9780203720714.

Merleau-Ponty, M. (1968). *The Visible and the Invisible: Followed by Working Notes*. Northwestern University Press.

Nancy, J. (2008). *Corpus*. Fordham University Press.

Nancy, J. (2007). *Listening*. Fordham University Press.

Neustaedter, C., & Sengers, P. (2012). Autobiographical Design: What You Can Learn from Designing for Yourself. *Interactions* 19 (6). https://doi.org/10.1145/2377783.2377791.

Norman, D. (1999). Affordance, Conventions, and Design. *Interactions* 6: 38–42. https://doi.org/10.1145/301153.301168.

Padfield, N., Haldrup, M., & Hobye, M. (2014). *Empowering Academia through Modern Fabrication Practices*. Fablearn Europe, Aarhus, Denmark.

Padfield, N., Hobye, M., Haldrup, M., Knight, J. & Ranten, M.F. (2018). Creating Synergies between Traditional Crafts and Fablab Making Exploring Digital Mold-Making for Glassblowing. *FabLearn Europe'18: Proceedings of the Conference on Creativity and Making in Education*. https://doi.org/10.1145/3213818.3213821.

Paolo, E.A. Di, Cuffari, E.C. & De Jaegher, H. (2019). *Linguistic Bodies. Linguistic Bodies*. The MIT Press. https://doi.org/10.7551/mitpress/11244.001.0001.

Picard, R. (1997). Affective Computing. Int. J. Human-Computer Studies 59 (2003) 55–64. MIT Press, Cambridge.

Ranten, M.F. (2013). *Wearables as Medium of Expression*. Malmö University. Master Thesis.

Ranten, M.F. (2018). *Everything I Touch Touches Me: Phenomenological Qualities of Tangible Interactive Interfaces within Interaction Design*. Abstract presentation at Affects, Interfaces, Events, Aarhus, Danmark.

Ranten, M.F. (2020). Interaktion: Krop Og Teknologi Som Materiale. In Lindelof, A.M, (eds) *Performance Design: 15 Års Alfabet*, 56–61, Roskilde University.

Redström, J. (2011). Some Notes on Program/Experiment Dialectics. *Proceedings of Nordes'11 the 4th Nordic Design Research Conference, Making Design Matter!*

Redström, J. (2018). *Making Design Theory. Making Design Theory*. MIT Press. https://doi.org/10.7551/mitpress/11160.001.0001.

Schiphorst, T. (2009). Soft(n): Toward a Somaesthetics of Touch. *Conference on Human Factors in Computing Systems - Proceedings*. https://doi.org/10.1145/1520340.1520345.

Schiphorst, T. (2011). "Self-Evidence: Applying Somatic Connoisseurship to Experience Design." In *Conference on Human Factors in Computing Systems - Proceedings*. https://doi.org/10.1145/1979742.1979640.

Schiphorst, T., & Loke, L. (2018). The Somatic Turn in Human-Computer Interaction. *Interactions*. https://doi.org/10.1145/3236675.

Schmitz, H. (2017a). *Kort Indføring i Den Nye Fænomenologi*. Aalborg Universitetsforlag.

Schmitz, H. (2017b). *Kroppen*. Aalborg Universitetsforlag.

Schmitz, H., Müllan, R.O., & Slaby, J. (2011). Emotions Outside the Box-the New Phenomenology of Feeling and Corporeality. *Phenomenology and the Cognitive Sciences*. https://doi.org/10.1007/s11097-011-9195-1.

Schön, D. (1983). *The Reflective Practitioner: How Professionals Think in Action*. New York: Basic Books.

Segura, E.M., Vidal, L.T., Rostami, A., & Waern, A. (2016). Embodied Sketching. *Conference on Human Factors in Computing Systems - Proceedings*. https://doi.org/10.1145/2858036.2858486.

Seidman, I. (2006). *Interviewing as Qualitative Research : A Guide for Researchers in Education and The Social Sciences*. New York: Teachers College Press.

Sheets-Johnstone, M. (1979). On Movement and Objects in Motion: The Phenomenology of the Visible in Dance. *Journal of Aesthetic Education* 13 (2). https://doi.org/10.2307/3331927.

Sheets-Johnstone, M. (2008). *The Phenomenology of Dance*. Temple University Press.

Shusterman, R. (2012). *Body Consciousness: A Philosophy of Mindfulness and Somaesthetics. Body Consciousness: A Philosophy of Mindfulness and Somaesthetics*. Cambridge University Press.

Shusterman, R. (2009). *Thinking through the Body: Essays in Somaesthetics. Thinking through the Body: Essays in Somaesthetics*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139094030.

Spiel, K. (2021). The Bodies of TEI – Investigating Norms and Assumptions in the Design of Embodied Interaction. *Association for Computing Machinery (ACM)*. https://doi.org/10.1145/3430524.3440651.

Spinoza, B. (1985) *The Ethics. The Collected Works of Spinoza*. Edwin Curley (ed). Princeton: Princeton University Press.

Svanæs, D. (2013). Interaction Design for and with the Lived Body: Some Implications of Merleau-Ponty's Phenomenology. *ACM Transactions on Computer-Human Interaction* 20 (1): 1–30. https://doi.org/10.1145/2442106.2442114.

Telier, A. (2012). Drawing Things Together. *Interactions* 19 (2). https://doi.org/10.1145/2090150.2090160.

Valenzuela-Moguillansky, C., & Vásquez-Rosati, A. (2019). An Analysis Procedure for the Micro-Phenomenological Interview. *Constructivist Foundations*, 14. 123-145.

Vallgårda, A. (2014). "Giving Form to Computational Things: Developing a Practice of Interaction Design." *Personal and Ubiquitous Computing* 18 (3): 577–92. https://doi.org/10.1007/s00779-013-0685-8.

Vallgårda, A., Winther, M., Mørch, N., & Vizer, E.E. (2015). Temporal Form in Interaction Design. *International Journal of Design, 9*(3), 1-15.

Vaughan, L. (2017). Introducing Practice-Based Design Research. In Practice-Based Design Research. In *Practice Based Design Research. Bloomsbury Publishing*, 1–6.

Vellodi, K. (2014). Diagrammatic Thought: Two Forms of Constructivism in C.S Peirce and Gilles Deleuze. *Parrhesia*, no. 19: 79–95.

Verbeek, P. (2016). Toward a Theory of Technological Mediation: A Program for Postphenomenological Research. In: Friis, J.K.B.O. & Crease, R. C. *Technoscience and Postphenomenology: The Manhattan Papers*. London: Lexington Books

Wakkary, R. (2021). *Things We Could Design: for more than human-centered worlds*. MIT Press.

Whatley, S. (2016). Sondra Fraleigh, Moving Consciously: Somatic Transformations through Dance, Yoga, and Touch. *Dance Research* 34 (1). https://doi.org/10.3366/drs.2016.0154.

Wiberg, M. (2014). Methodology for Materiality: Interaction Design Research through a Material Lens. *Personal and Ubiquitous Computing* 18 (3). https://doi.org/10.1007/s00779-013-0686-7.

Wiberg, M. (2018). *The Materiality of Interaction. Notes on the Materials of Interaction Design*. The MIT Press.

Wiberg, M., Ishii, H., Dourish, P., Vallgårda, A., Kerridge, T., Sundström, P., Rosner, D., & Rolston, M. (2013). Materiality Matters - Experience Materials. *Interactions*. https://doi.org/10.1145/2427076.2427087.

Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research through Design as a Method for Interaction Design Research in HCI. *Conference on Human Factors in Computing Systems - Proceedings*, 493–502. https://doi.org/10.1145/1240624.1240704.

Zimmerman, J., Stolterman, E. & Forlizzi, J. (2010). An Analysis and Critique of Research through Design: towards a formalization of a research approach. *Proceedings of the 8th ACM Conference on Designing Interactive Systems - DIS '10*, 310. New York, New York, USA: ACM Press. https://doi.org/10.1145/1858171.1858228.

AND | PAPERS

Paper 1 | Homewood, S., Hedemyr, M., Ranten, M.F., Kozel, S. Tracing Different Concepts of the Body in HCI: From User to More-Than-Human. In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21). Association for Computing Machinery, New York, NY, USA, Article 258, 1–12. Honorable Mention Award

Originally published in: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. https://doi.org/10.1145/3411764.3445656

Joint work with: Sarah Homewood, Marika Hedemyr, and Susan Kozel

Tracing Conceptions of the Body in HCI: From User to More-Than-Human

Sarah Homewood
IxD Lab, IT University of Copenhagen, Copenhagen, Denmark

Marika Hedemyr
School of Arts and Communication, Malmö University, Malmö, Sweden

Maja Fagerberg Ranten
Roskilde University, Dept. of People and Technology, Roskilde, Denmark

Susan Kozel
School of Arts and Communication, Malmö University, Malmö, Sweden

ABSTRACT

This paper traces different conceptions of the body in HCI and identifies a narrative from user to body, body to bodies, and bodies to more-than-human bodies. Firstly, this paper aims to present a broader, updated, survey of work around the body in HCI. The overview shows how bodies are conceptualized as performative, sensing, datafied, intersectional and more-than-human. This paper then diverges from similar surveys of research addressing the body in HCI in that it is more disruptive and offers a critique of these approaches and pointers for where HCI might go next. We end our paper with recommendations drawn from across the different approaches to the body in HCI. In particular, that researchers working with the body have much to gain from the 4th wave HCI approach when designing with and for the body, where our relationships with technologies are understood as entangled and the body is always more-than-human.

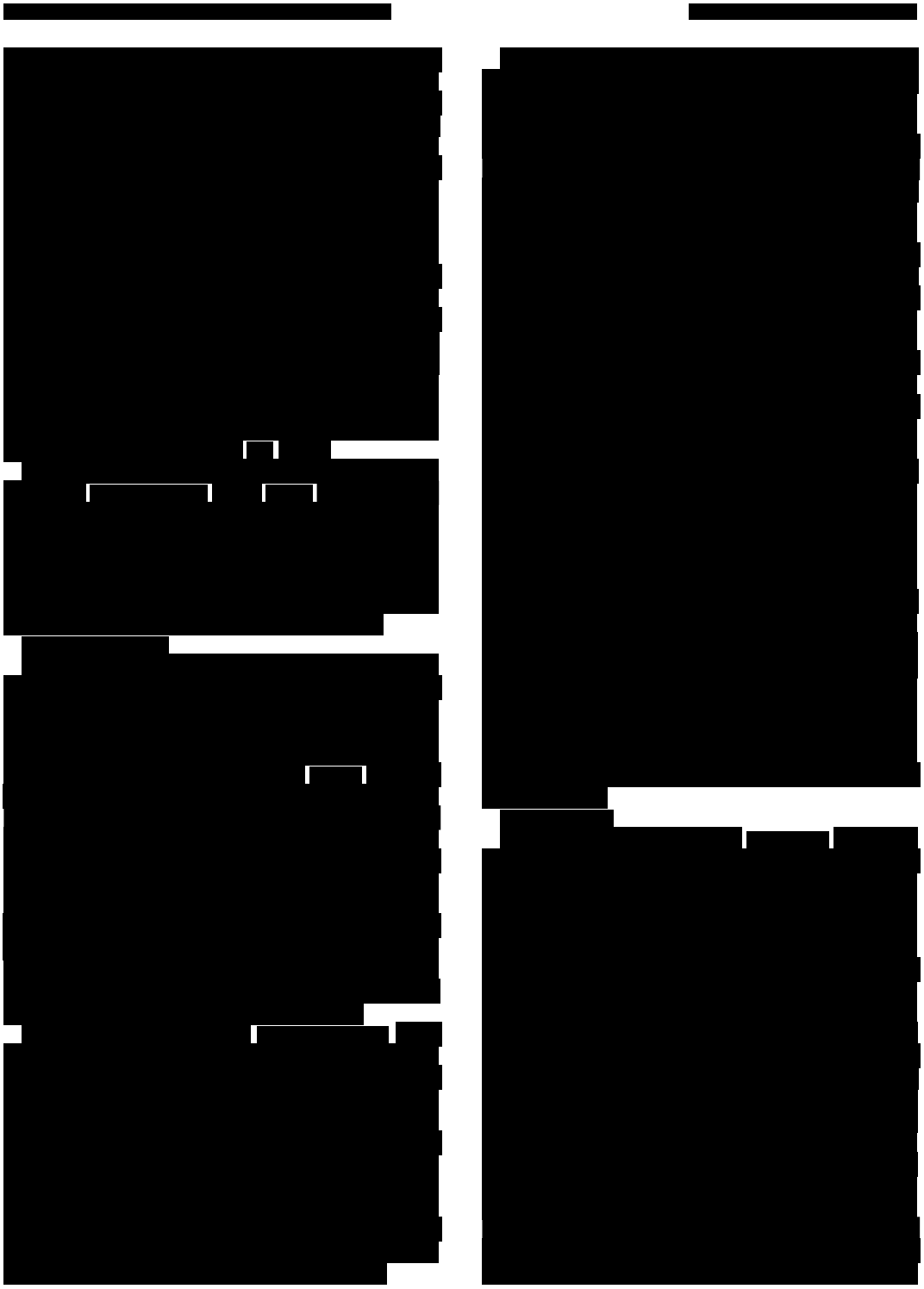
CCS CONCEPTS

• **Human-centered computing** → Interaction design; Interaction design theory, concepts and paradigms.

KEYWORDS

Embodied interaction design, body, embodiment, phenomenology, more-than-human, posthuman, intersectionality, sensing, performance, entanglement theories, feminism, fourth wave HCI

ACM Reference Format:
Sarah Homewood, Marika Hedemyr, Maja Fagerberg Ranten, and Susan Kozel. 2021. Tracing Conceptions of the Body in HCI: From User to More-Than-Human. In *CHI Conference on Human Factors in Computing Systems (CHI '21), May 08–13, 2021, Yokohama, Japan.* ACM, New York, NY, USA, 12 pages. https://doi.org/10.1145/3411764.3445656



[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Paper 2| Hobye, M. & Ranten, M. F., 2019. Behavioral Complexity as a Computational Material Strategy. International Journal of Design. 13, 2, s. 39-53 35 s. & Ranten, M. F., 2019. *Behavioral Complexity as a Computational Material Strategy*. International Journal of Design. 13, 2, s. 39-53 35 s.

Originally published in: International Journal of Design. Special Issue on Material and Design. http://www.ijdesign.org/index.php/IJDesign/article/view/3263/861

Joint work with: Mads Hobye

Behavioral Complexity as a Computational Material Strategy

Mads Hobye * and Maja Fagerberg Ranten

Computer Science, Department of People and Technology, Roskilde University, Denmark

This paper presents the concept of behavioral complexity as a computational material strategy. The materiality of the designed interaction is a relatively new perspective on interaction design. From this perspective, the behavioral complexity should be understood as the underlying algorithms in the computational code. Complexity in the code enables multiple unique material qualities of computational materials to adapt and come to life through interaction. We propose that behavioral complexity contributes to creating expressive complexity and then present strategies of behavioral complexity as annotations in an annotated portfolio of design examples. For each annotation, simple computational programming patterns are included to illustrate practical implementations. The strategies are to create: *reactiveness*, *multiple modes*, *non-linearity*, *multiple layers* and *alive connotations*. Finally, we point towards the potential of mixing the strategies to expand the complexity of alive and adaptive expressions and discuss strategies for preserving coupling.

Keywords – Material Expressions, Behavioral Complexity, Interaction Design, Annotated Portfolio.

Relevance to Design Practice – This paper presents a set of strategies for interaction designers when working with behavioral complexity within tangible and physical computing in relationship to computational technology in order to elicit expressive complexity.

Citation: Hobye, M., & Ranten, M. (2019). Behavioral complexity as a computational material strategy. *International Journal of Design, 13*(2), 39-53.

Introduction

Our intention in this paper is threefold. Firstly, we argue for a shared agenda around the computational complexity in a computational material. We frame this shared interest in *behavioral complexity* as a way to create *expressive complexity*. Secondly, using five design examples in an annotated portfolio, we present a set of strategies that can be used in designing alive and adaptive expressions based on behavioral complexity as inspirational building blocks. Thirdly, we discuss the potential for a strategy in mixing the strategies.

We position our work within the field of interaction design (Bødker, 2006; Fallmann, 2008; Löwgren, 2007). We focus on the computational material and how complexity in the code is part of the form-giving practice in interaction design within tangible and physical computing. We use the concept of behavioral complexity to distinguish between general code and the part of the code that intentionally affects the expression. From a designerly point of view, we are interested in how the designer/developer can explore the complexity of the computational material as a resource to create alive and adaptive designs.

Within the field of interaction design, a selection of scholars has discussed computational complexity within computational, alive and adaptive materials. These are typically presented as an element in an overarching design strategy with multiple elements at play. Gaver, Beaver, and Benford (2003) use the concept of ambiguity as a design strategy to open up the curiosity space of the participants. Through ambiguity, the interactions can be "intriguing, mysterious, and delightful" (p. 233). One way to create ambiguity is through misinformation or ambiguous responses from the system. Similarly, Tieben, Bekker, and Schouten (2011) argue for the complexity of the system as one of multiple strategies to prolong the discovery of an installation. Hobye (2014) argues for designing for *homo explorens* as an extension of Gaver's (2009) designing for *homo ludens* as a way to create socially playful explorations with internal complexity. From a computational composite perspective, Vallgårda and Sokoler (2010) argue for composite materials that play with our expectations of what we consider *natural*. One overlapping aspect is using computational complexity to expand the interaction space of the exploration. Larsen (2015) introduces the concept of *væsen*, a Danish word that can be loosely translated as *essence* or *animism*. His intentions are "about *actual* interactive behavior in relation to the character and role of tangible artifacts as entities with some rudimentary agency" (Larsen, 2015, p. 41). Levillain and Zibetti (2017) examine the psychological properties a behavioral object evokes in an observer. They talk about three levels of perceived complexity: *animacy, agency* and *mental agency*. In the simplest form, animacy is the ability to initiate and change movements spontaneously. In the most complex form, *mental agency* is the ability to display attitudes with respect to other agents (Levillain & Zibetti, 2017).

Expanding the interaction space with computational complexity seems to be challenging. Gaver, Bowers, Kerridge, Boucher, and Jarvis (2009) share their frustration about finding

Received March 28, 2018; **Accepted** May 1, 2019; **Published** August 31, 2019.

***Corresponding Author:** mads@hobye.dk

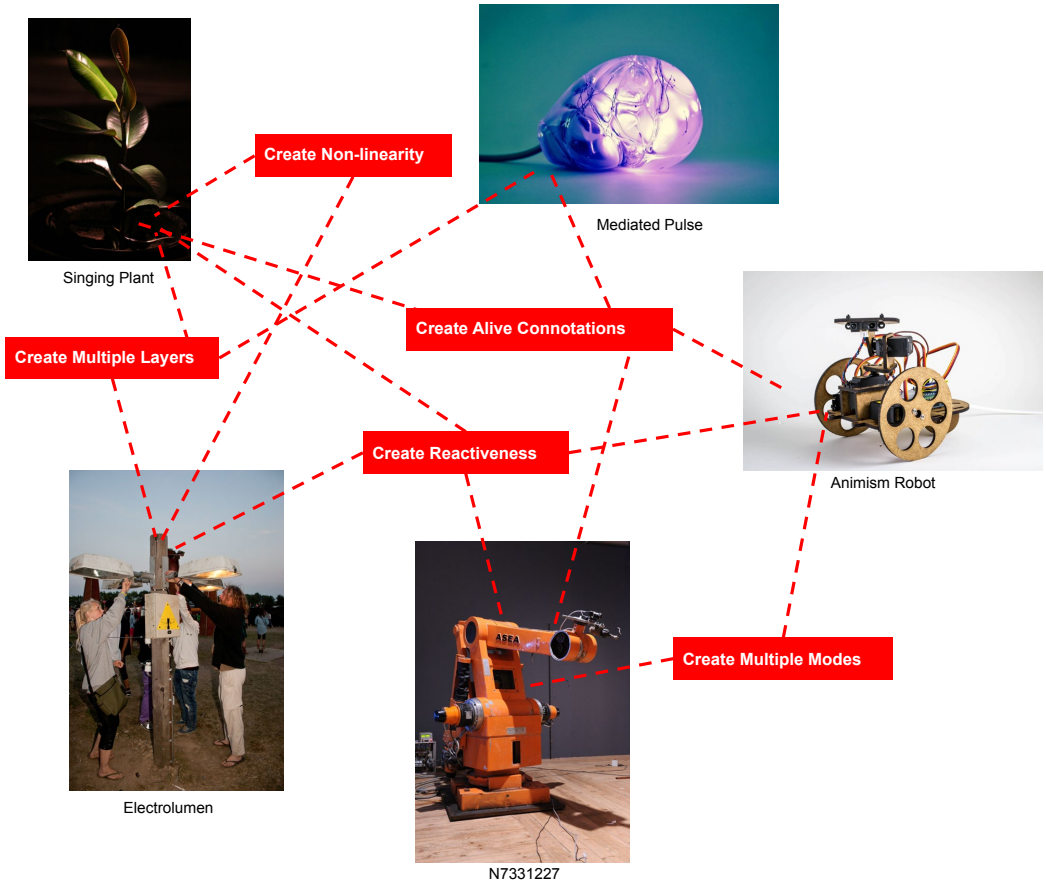


Figure 1. Annotated portfolio of examples of behavioral complexity.

the *sweet spot* between effective randomness and total accuracy in the Home Health Monitor system. Tieben et al. (2011) reflect on the limits of out-of-context disruptions and wonder if some level of complexity could elicit interactions beyond "a short spur of curiosity and exploration before the student would be satisfied and walk on" (p. 365). With Mediated Body, Hobye (2014) presents accounts of challenging work with internal complexity for eliciting certain types of interaction.

One could see the above views as separate. However, from the perspective of computational complexity, they all point to designing code with some level of complexity in relation to evoking similar kinds of alive and adaptive expressions. We posit that there is a need to conceptually ground computational complexity for adaptive and alive expressions within the field of interaction design. We do this by presenting a model of the relationship between behavioral complexity and expressive complexity. We then suggest a set of strategies that designers can use as a starting point for exploring this practice. The strategies are presented as annotations in the portfolio and introduce the following concepts:

- **Create Reactiveness:** To create interfaces that react in real time with the interaction.

Mads Hobye holds a PhD in interaction design from Medea, Malmö University and is a co-founder of illutron collaborative interactive art studio. He conducts research into the potential of digital material exploration within art and technology. He has a keen interest in maker hacktivism and experimental electronic upcycling. As an Assistant Professor at Computer Science RUC, he has co-created Exocollective and Exostudio to create cross-pollination between artist, scientists, innovators, and makers in general.

Maja Fagerberg Ranten is an Interaction Designer and PhD Fellow at Computer Science, Roskilde University, Denmark. She is part of the Copenhagen art and technology scene and has a wide repertoire of interactive art installations from the design collaboration UNMAKE and as a member of the art collective illutron. At Roskilde University, she is co-creator of the research collective Exocollective and Exostudio, where the research focus is on digital material exploration in interactive design, art, and technology. Her PhD Designing for Bodies with Bodies is a practice-based investigation of the designers' bodily interaction with materials when designing artistic interactive systems with a focus on an expansion of a material framework that considers both physical, computational and the body as material.

- **Create Multiple Modes:** To create multiple modes in the system that invites for different kinds of interaction.
- **Create Non-linearity:** To create internal logic without linear causality.
- **Create Multiple Layers:** To combine multiple non-linear parameters into a multidimensional interaction space for participants to explore.
- **Create Alive Connotations:** To create computational patterns with anthropomorphic, zoomorphic and/or animistic expressions.

Before we dig into the different strategies, it is necessary to ground computational complexity. In the following section, we examine in detail the interplay between behavioral complexity, physical form, computational form and expressive complexity.

Behavioral Complexity for Complex Expressions

As presented in the introduction, multiple scholars have an overlapping interest in exploring computational complexity in relation to interaction. We term this *behavioral complexity*. For us to understand the properties that are at play, we posit that it is necessary to create a conceptual model of the elements. In the following, we use the iceberg metaphor as a way to talk about the internal computational system, the physical form and the expressions as a whole.

Vallgårda (2014) makes a distinction between physical form and temporal form. The physical form combined with the temporal form is what Vallgårda considers the computational composite. Since the temporality of the computer and physical form "determine the temporal expression of any computational thing" (Vallgårda, Winther, Mørch, & Vizer, 2015, p. 2), the internal complexity relates to the expression of the thing. Similarly, Hallnäs and Redström (2002) turn the classic Bauhaus concept of *form follows function* around and argue for the concept that *function resides in the expression* of things to revitalize the importance of the materiality of interaction design as computational things with expressions. As Hallnäs (2011) later formulates it: "As the computer disappears in the background, computational technology reappears as a new expressive design material. We build things with a new material when we build computational things, their behavior in use depending on the execution of given programs" (p. 76). This means that within computational materials, expressions have behavior and that the internal computational logic in the system plays a significant part in this.

Inspired by Vallgårda's (2014) distinction between physical and temporal form and Hallnäs and Redström's (2002) argument for the expression of things, we introduce the visual model: Model of the relationship between behavioral complexity and expressive complexity (see Figure 2). We use the iceberg metaphor as a basis for our model. The part of the iceberg that is above the water surface represents what is visually and physically present; what is below the water surface represents what is initially hidden. What is below, only presents itself indirectly, through interacting with the system.

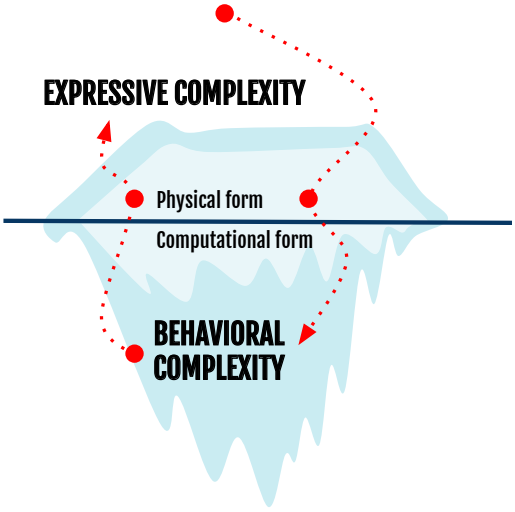


Figure 2. Model of the relationship between behavioral complexity and expressive complexity. The two arrows illustrate the dynamic feedback loop between the interactions as input that goes through the behavioral complexity to become expressive complexity.

Above is the *physical form*. This is the actual spatial dimension of the tangible object that participants can interact with, 'participant' referring to a user interacting with an interactive system. The tangible object consists of multiple elements: physical materials, electronics and embedded computers. The physical materials commonly wrap the electronics and a computational system into a physical form. The electronics consists of the gateways between the computational system and the physical world. Inputs are sensors: buttons, touch sensors, cameras, etc. Outputs are actuators, speakers, LEDs, etc.

Beneath the surface resides the *computational form* in the form of code. This enables the material to be alive and adaptive. This typically presents itself temporally through interaction. The combination of the physical form and the computational form provides the basis for the overarching expression of the thing or the material. From a behavioral complexity perspective, we consider the expressions as *expressive complexity*. The expressive complexity is a product of the behavioral complexity in the computational form combined with the physical form.

We are only using experiential anecdotes as a foundation for exemplifying the expressive realism of the object itself. As Hallnäs (2011) phrases it: "Expression is what makes experience possible, which is why concepts and theories of experience can never provide a logical foundation for design aesthetics" (p. 75). By using the perspective of expression instead of more experience-oriented perspectives (see e.g., Löwgren, 2002), we align ourselves with Hallnäs' distinction of aesthetic realism as a frame to discuss the expressional logic of designed things themselves as a design perspective when creating strategies for behavioral complexity.

We argue for the concept of *behavioral complexity* to distinguish between general code in the computational form and the code that intentionally affects the expressive complexity of the computational material. Behavioral complexity is the underlying algorithms in the computational code created to enable the computational form to come alive through the physical form. We consider behavioral complexity to have the following properties:

- **Does not have simple deterministic linear temporality:** The behavioral complexity affects the expressive complexity in such a way that it cannot be considered a predefined sequence of events (like a musical score), but instead consists of internal logic that reacts to its environment.
- **Adds to the complexity of the expression:** Behavioral complexity consists of code that deliberately intends to create complex expressions. One could easily think of complex code with a rather simple expression. For example, when using artificial intelligence to detect a smile the code is complex, but the output only amounts to a binary response.
- **Has non-trivial internal complexity:** A behavior becomes non-trivial (Hobye & Löwgren, 2011) by having an internal logic that creates a set of expressions not easily apprehensible in a predictable way. As Hobye and Löwgren discuss in relationship to non-trivial internal complexity: "[I]f it is perceived as mastered easily and not complex at all, boredom will rapidly set in" (p. 46). In this sense, whether something is non-trivial ultimately resides in the experience of the participant interacting with it. However, with the concept of non-trivial internal complexity, we want to emphasize the *designerly intentions* behind the code as a part of the behavioral complexity.

The properties are intended to identify a set of prevailing strands that can enable designers to have a generative concept for considering computational form as behavioral complexity.

Annotations as Generative Definitions

Our intention is to convey a set of strategies for behavioral complexity as computational form. We do not intend to create an encompassing taxonomy, but merely to create a generative (Gaver, 2012) starting point for designers to explore behavioral complexity. We do this by presenting five technical design examples that encompass some level of behavioral complexity. This allows us to look at how the complexity of the internal code, and thus the expression of the system, can be used as a design strategy for alive and adaptive materials.

The five examples are presented as an annotated portfolio (see Figure 1). The concept of an annotated portfolio was coined by Gaver and Bowers (2012) as a designerly way to present a spatial map to exemplify a design potential and as a way to communicate design research as a form of theory formation. An annotated portfolio is, in its simplest form, a collection of design objects with textural annotations to exemplify topics or themes, indicated by the annotations where the annotations and the designs are mutually informing (Gaver & Bowers, 2012). Gaver (2012) points to a single design as a point in design space whereas a collection—a portfolio—establishes an area in that space. The role of theory should be to annotate those examples rather than replace them.

Similarly, Redström (2017) articulates a notion of assemblages (in relation to defining researchers work with examples; a set of particular designs in combination with an overall program framing) as a meaningful whole: "It is an assemblage of definitions that aims towards a meaningful whole, not towards isolated and contained concepts. It is a hands-on way of working with, and explicitly addressing, the tension between the making of the particular and an overall orientation toward the more general through design" (p. 115).

The design examples for the annotated portfolio are a selection of pieces produced over an extended period of research. The examples vary significantly in form, size, material selection and context of use. However, they all have elements of behavioral complexity in them. Furthermore, all of them have been explored in different contexts through multiple iterations of the code. A relatively large amount of knowledge has been gained about their expressive qualities. They have been consciously selected to create a wide space for which the annotations can exemplify a more general understanding of what constitutes behavioral complexity.

We posit that the knowledge contribution of communicating design exemplars as an annotated portfolio is beneficial as it allows us to look across different experiments and projects. It allows us to take a bird's eye view and compare, reflect on and differentiate design examples. Additionally, it allows us to generate multiple perspectives on behavioral complexity so that the following discussion can result in knowledge production with various possible actions as opposed to one particular action.

Portfolio: *Design Examples for Behavioral Complexity*

The following is the portfolio of the five design examples. The five examples explore different levels of behavioral complexity. We intend the examples to show the diversity of the relationship between behavioral complexity and expressive complexity. For example, Mediated Pulse's organ-like shape gives a clear expression of organic qualities even though the code itself has a relatively simple rhythmic logic.

Electrolumen

Physical Form

Electrolumen (presented by Hobye, 2014; Hobye, Padfield, & Löwgren, 2013) consists of telephone poles, two meters tall, with four street lamps mounted just above head height (see Figure 3). Four wires, looking exactly like standard aerial high voltage electrical cables, are mounted on real ceramic insulators and go off at chest height to another telephone pole several meters away. Electrolumen gives the impression of something both well-known and very dangerous that we are used to seeing far overhead, bringing it suddenly and disconcertingly within easy reach.

Behavioral Complexity

The four lamps are touch connection sensitive, that is, touching one will not elicit any response, but touching any two simultaneously will cause the lamps to light up and the installation to generate sound. The texture of the sound is affected by how firm the touch is. The sensor electronics derive an analog input variable by whether your hand is a half centimetre away, lightly touching, or firmly gripping the lamp. Holding more than two lamps gives more light. Each different combination of four lamps gives a different set of sounds. There are six sound channels, which can be combined. Three behavioral complexity strategies have been used: Reactiveness, Non-linearity, and Multiple Layers (see Table 1).

Expressive Complexity

Electrolumen facilitates social exploration in which the participants make contact with each other. In order to light all four lamps and to play with different sound ambiences, participants need extra hands to help them. A connection can also be made through a friend, a human chain or by kissing a stranger. The design was exhibited in a festival context in which we explored how to make ambiguous interfaces (Gaver et al., 2003) elicit socially playful (Gaver, 2009) and exploratory (Hobye, 2014) interaction between the participants.

Animism Robot

Physical Form

The Animism Robot is an explorative learning platform for creating animatronic behavior and physical expressions (Padfield, Haldrup, & Hobye, 2014). The robot consists of an Arduino microcontroller, four servos, a distance sensor and physical shapes cut out of HDF wood (see Figure 4). The motors allow the robot to drive around on a flat surface and tilt and rotate its head.

Behavioral Complexity

As a part of the kit, a few code pieces were included, which would introduce different aspects of animating the robot. One would make the head shake. Another would make the robot move forward if there were no obstacles in front of it. A vast number of extensive hacks have been done to the platform both physically and computationally. From a behavioral complexity perspective, the computational logic would be extended to create more complex patterns. For example, the robot would move forward and stop if an object were close to it. If the object started to move towards the robot, the robot would try to run away, thus creating the illusion of an optimal distance between the interactors and the robot coming from the robot itself. Three behavioral complexity strategies have been used: Reactiveness, Multiple Modes, and Alive Connotations (see Table 2).

Figure 3. Participant engaging with the Electrolumen installation at Roskilde Festival.

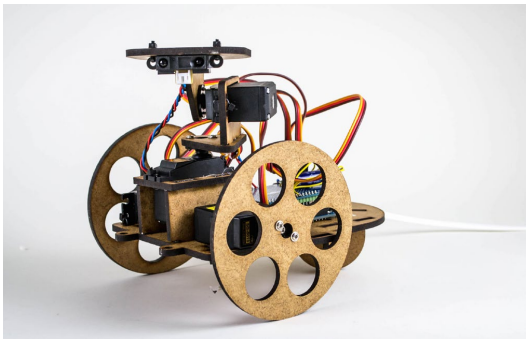


Figure 4. The Animism Robot kit presented in its assembled form.

Table 1. Three behavioral complexity strategies have been used for Electrolumen.

Reactiveness	Non-linearity	Multiple Layers
The installation uses a responsive action<>reaction pattern to enable participants to play and explore the interaction dynamics in real time.	Nonlinear algorithms give a more complex and dynamic feel to the interaction, compared to the relatively simple touch interface.	Amount of touch, length of touch, pull on wires, change in touch and change in pull are all measured and converted to an *energy level*, enabling more complex patterns to emerge than a simple on/off touch interaction.

Table 2. Three behavioral complexity strategies have been used for the Animism Robot.

Reactiveness	Multiple Modes	Alive Connotations
The platform uses a responsive action<>reaction pattern to enable participants to play and explore the interaction dynamics in real time.	The robot has multiple moods. It can be programmed to be happy, curious, scared, bored, etc. These different modes allow for a prolonged interaction where new dimensions of the *personality* of the robot are explored.	The code plays heavily on the social connotations of body movement and facial expressions to give the impression of the robot being *alive*.

Expressive Complexity

The robot provides the participants with the possibility to think, experiment and express themselves through the material, the media of the behaviors, the look, feel and interaction of a robot (Hobye, 2014). Through the many hacks of the code and the physical configuration of the robot, many different behavioral qualities have been designed. They have explored different abbreviations of animism (Larsen, 2015) and how we as humans start to relate to mechanical objects as having an embedded personality or a soul. For example, setting the motors to backwards when an object was in front of it became a way to play with the feeling of fear. Likewise, a fast forward motion when an object was in front gave a sense of an intentional aggressive attack.

Mediated Pulse

Physical Form

The piece is a composite prototype, combining hand blown glass with behavioral complexity. It is an exploratory sketch (Buxton, 2007) to research the combination of computational elements with a three-dimensional shape. The shape and the computational form are designed to give associations to an abstract, organ-like object (see Figure 5).

Technically Mediated Pulse consists of a microcontroller, battery, a vibration motor and an individually addressable *neopixel* light RGB string. The WIFI module in the microcontroller enables it to connect wirelessly to other inputs such as a pulse sensor. Furthermore, the wireless connection and battery allow the heart to be passed around in an audience context without being constrained by cables.

Behavioral Complexity

The behavioral complexity consists of expressing a sensed pulse of a dancer with a vibration motor and an animation on a LED string. The simple mediation of a dancer's pulse can hardly be considered non-trivial complexity. Thus, the design example is somewhat an outlier to the core ideas of behavioral complexity presented in this paper. Its purpose is mainly to illustrate that the physical form, the organ-like shape combined with the pulse animation, creates expressive complexity with minimal non-trivial complexity. Two behavioral complexity strategies have somewhat been used: Multiple Layers and Alive Connotations (see Table 3).

Expressive Complexity

Mediated Pulse is intended as a platform to explore the potential of interactive audience experience. It has been used to visualize the pulse of a ballet dancer for the audience in a performance at the Royal Danish Theatre (see Figure 6). By attaching a wireless pulse sensor to the ballet dancer, it is possible to produce a representation of the pulse in the glass heart. This is done by making the heart vibrate in sync with the heartbeat and producing a synchronised red expressive animation in the string of light to give associations of blood running through the veins.

N7331227

Physical Form

N7331227 is an old industrial toilet seat grinder robot. Compared to the standards of modern robot technology, it is outdated in lacking

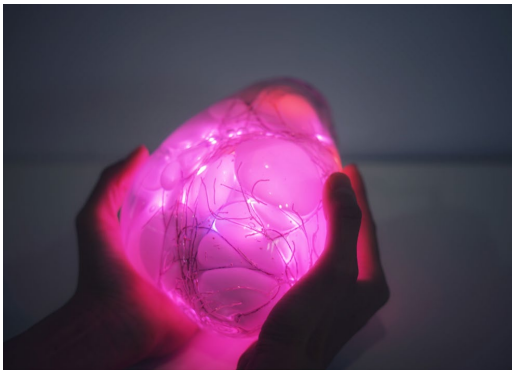


Figure 5. The organ-like glass heart which can vibrate and light up.

Figure 6. Ballet dancers exploring the Mediated Pulse. A pulse sensor is strapped to the arm of the dancer. The two seated dancers sense his pulse wirelessly through the heart-shaped object.

Table 3. Two behavioral complexity strategies have been used for Mediated Pulse.

Multiple Layers	Alive Connotations
The heart has both a light animation and a vibration pulse. Both adjust linearly to the dancer's pulse, but with different animated timing sequences. The light animates as if red blood flows through the veins, while the motor spins up and down in sync with the pulse.	The combination of the physical form *a heart like shaped organ* and the pulsating light rhythm creates the expression of the object having an organ/heart aliveness.

the dynamic and flexible joints expected of a modern robot and the internal computer was only able to navigate a set of fixed points. Age became apparent in its aesthetic appearance (see Figure 7).

Behavioral Complexity

The robot was modified with open-source microcontrollers to control the joints and two cameras were mounted. One on its nose for computer vision tracking of passers-by and one from above to get an overall sense of movement in the space. When people approached the robot, it would detect them in its vicinity and start to *look* at them. When the robot had locked onto a passer-by, it would visually follow them through the room for a little while. Multiple modes were programmed into the robot. For instance, the robot would idle around when nobody was there and interact when somebody approached it. These modes gave the robot multiple moods to perform in the exhibition space. Three behavioral complexity strategies have been used: Reactiveness, Multiple Modes, and Alive Connotations (see Table 4).

Expressive Complexity

N7331227 is the serial number of the old industrial robot used. The interest was to reanimate the robot with an ingrained personality, for example, through its jerky and squeaky movements and an interest in creating an emotional relationship with people. Academically, N7331227 has been presented as a way to discuss the potential of animating non-living objects and how participants are able to create meaning around this (Hobye, 2014).

Singing Plant

Physical Form

The Singing Plant is an interactive sound and light installation using a living greenhouse plant as the sole interactive interface element (see Figure 8). It is based upon one of the first electronic musical instruments, the Theremin, named after its inventor, the Russian professor Léon Theremin.

Behavioral Complexity

The Theremin works by sending an AC signal to an antenna and measuring the attenuation and distortion of the signal by the watery capacitance of a human body nearby.

Normally, the antenna is metal, but in the Singing Plant, a plant is used as the antenna. The water in the plant conducts well enough to make this possible, however great care in calibration is required as the electrical characteristics of the plant and its soil change with varying wetness. When properly calibrated, the Theremin-plant acts as a touch and proximity sensor, which controls pitch and volume. When the plant is touched, it gives feedback in the form of sound and light. The more participants touch it, the more energetically it responds. The sound is modulated through several filters to give a richer and more variable soundscape. Three behavioral complexity strategies have been used: Reactiveness, Multiple Layers, and Non-linearity (see Table 5).

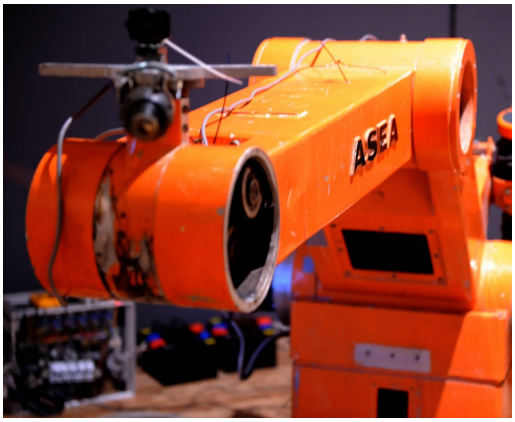


Figure 7. The industrial robot with a computer vision camera mounted on top to detect participants as they move closer.

Figure 8. Participants touching the Singing Plant to explore its soundscape.

Table 4. Three behavioral complexity strategies have been used for N7331227.

Reactiveness	Multiple Modes	Alive Connotations
The robots detect and tracks participant's faces in real time as they move around in the space. This creates a reactive system where the bodily movement of the participants produces a reaction in the movement of the robot.	The robot had five modes it could choose to use depending on the contextual situations. Idling around and looking for people, track people around in the space, look for a new drawing, interact with a light panel.	Many computational elements have been introduced for the robot to appear alive. Most prominently is the face detection and tracking system, which gives the impression of the robot being aware of people around it.

Table 5. Three behavioral complexity strategies have been used for the Singing Plant.

Reactiveness	Multiple Layers	Non-linearity
There is a direct feedback loop between touching the plant and getting a sound response. This allows the participants to explore different ways of holding and touching.	The plant has multiple layers of accumulative weighting factors that adjust based on the interactions. With prolonged interactivity, the light in the room dims and a pinspot shines the light on the plant only.	To create a space for exploration beyond a simple binary *touch equals sound* reaction pattern, multiple non-linear algorithms have been created to detect things like activity and amount of touch over a prolonged time. Further, multiple sound filters with similar properties have been applied: chorus, echo, flanger, etc.

Expressive Complexity

The Singing Plant has been discussed as a way to exemplify different touch interfaces for social play and exploration (Hobye, 2014; Hobye et al., 2013), highlighting the novelty of adding an interactive light and soundscape to an organic object.

Annotations: *Strategies for Behavioral Complexity*

We suggest five annotated strategies for behavioral complexity as computational form. Through the examples presented in the portfolio, we identify a set of prevailing strands to enable other designers to have an informed discussion about the overall potential.

To honor the ideal of computational form as a generative knowledge contribution, we have included code patterns for each strategy. They are examples of behavioral complexity in practice. Most of them have been extracted from the examples in the portfolio. Here they have been stripped from larger dependencies. Instead, the common Arduino (see homepage of Arduino website: https://www.arduino.cc/) syntax concepts like digitalWrite and analogRead are used to exemplify input and output.

Create Reactiveness

The concept of expressive complexity is somewhat misleading when reflecting on the potential of expressions in interactive systems. The system does not only express, but also react to the surroundings. The expressions are a whole between the input, the outputs and the behavioral complexity of the system. Based on its internal logic, it constantly reacts to the inputs it gets from its surroundings. A reaction pattern can simply be summarized as seen in Source code 1.

The case is here to present a simple action-reaction scenario. The simplicity of this case is such that it can hardly be considered complex in its behavior. Reactiveness prevails throughout most of the following strategies and thus serves as a basis for behavioral complexity.

Figure 9 shows the essential computational form as the feedback loop between input and output with behavioral complexity as the mediator. Vallgårda (2014) express a similar term: computed causality, where the computer is used as the controlling property "to create the link between a cause-event and an effect-event" (p. 583). Through computational control, the causality "can be moderated, exaggerated, or entirely made up" (p. 583).

Playing with real-time reaction as an integrated part of the expression is a fundamental principle in most of the pieces in the portfolio. It is our observation through the experiments that

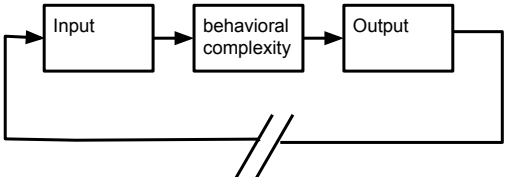


Figure 9. Boiled down to its essence, computational form within interaction design becomes a feedback loop between input and output (in the physical form) **with the behavioral complexity as the mediator.**

```
int buttonPin = 4;
int ledPin = 3;

void loop()
{

 // Turn on an LED if a button has been pressed
 if (digitalRead(buttonPin) == HIGH)
 {
  digitalWrite(ledPin, HIGH);
 }
 else
 {
  digitalWrite(ledPin, LOW);
 }

}
```

Source code 1. Pattern: *A simple reactive system.* In this case, an input (e.g., a button is pressed) results in some output (e.g., a light turns on). The reaction is instant and gives the impression of a clear connection between the interaction with the system and the reaction from the system.

real-time reaction holds an important dimension in understanding the expressions of the designed objects. Converting touch to sound in the Singing Plant created an artificial sense of aliveness. The slightest movement of the hand would change the pitch of the sound, thus giving the audience a sense of relating bodily to the plant. If the reactions to the input become too random or complex there will be a perceived loss of understanding of the relationship between the interaction, internal logic and the expressions of the system. For example, in the case of the Singing Plant, it became difficult for each individual participant to discern their own interaction when multiple people were touching it because the plant reacted to the accumulated amount of touch.

In scenarios that deviate from real-time feedback, it is at the cost of the possibility for the participant to interactively decode the expression. This is the case of the Mediated Pulse where the connection between the dancer's heartbeat and the pulsing heart is more conceptual. A participant holding the heart would not be able to discern the source of the pulse by interacting with the heart.

Create Multiple Modes

One recurring strategy for creating behavioral complexity is to have multiple modes of expression. Both Hobye (2014) and Larsen (2015) elaborate on this property with similar types of modes. Larsen describes three different modes of behavior: when something is sensed, idle state behavior when no interaction is present and wide sensing behavior when being aware of surroundings.

Typically, these modes have a binary threshold. Internal logic will decide which mode is the best fit for the current situation and act accordingly to the logic embedded in the mode itself. One such example was designed in a student project (see Figure 10) with the Animism Robot. The robot had an internal logic that would decide to be aggressive if something blocked its way a certain number of times. The internal mode would then shift from object avoidance to aggressive forward pushing, symbolizing an animal that had lost its patience.

Within computer science, a state machine is the simplest example of implementing a logical threshold for multiple modes. Each state has a set of code components that will be executed whenever the state is activated. In Source code 2 it is implemented with a switch statement.

Both the Animism Robot and N7331227 had multiple modes of behavior. N7331227 had idle mode when no presence was detected. Here it would look around to see if somebody were hiding in the corners of the room. In the following mode, it would keep an eye on participants while they moved through the space. In interactive mode, it would focus on a participant's face. There is no guarantee that two participants interacting similarly with the same system will receive the same expressions from the system because the internal mode may have shifted between the two interactions.

The level of behavioral complexity in this strategy becomes a matter of two things. Firstly, how complex is the individual complexity for each mode and secondly, how the change of mode is designed. For instance, one can have multiple simple modes with complex transition logic. Vice versa, one can have simple transitions between modes with a high level of behavioral complexity. In the second example, in the modes, it would be natural to use some of the other strategies presented.

Create Non-linearity

A noble aim within interaction design is to create some form of linear correlation between output and input. When you turn the light dimmer up, the light gets brighter and when you turn it the other way it dims. It makes sense in the sense of mimicking ways of navigating the natural world intuitively. However, as Vallgårda and Sokoler (2010) phrase it: "The computer's ability to compute based on an input and to make the result available through an output

Figure 10. A customized version of the Animism Robot with embedded Anthropomorphic behavior.

```
unsigned long lastActivity = 0;
int buttonPin = 2;
int mood = 0;

void loop()
{
 // Detect some activity
 if (digitalRead(buttonPin) == HIGH)
 {
  lastActivity = millis();
 }

 switch (mood) {
  case 0: // alive mood
   // Jump to idle mood when no activity is present
   if (millis() - lastActivity > 10000)
   {
    mood = 1;
   }
   break;
  case 1: // idle mood
   // Jump to a live mode when activity is present
   if (millis() - lastActivity < 10)
   {
    mood = 0;
   }
   break;
 }
}
```

Source code 2. Pattern: *A simple mode or mood changing system.* In this example two modes are present. One mode in which the interactive system is "active" and one mode in which the system is "idle". When nobody has pressed a button for 10 seconds then the system goes in idle mode. This can be used to create the expression that the system is being bored when not interacted with.

means that in principle it can establish any desired cause-and-effect. The computer can thereby be a powerful tool in playing with our experience of the laws of nature" (p. 8). Similarly, Reeves, Benford, O'Malley, and Fraser (2005) argue "[t]he use of non-linear mappings to partially obscure the relationship between manipulations and effects is common in artistic installations where it introduces a degree of ambiguity in an attempt to provoke curiosity" (p. 745).

With Electrolumen, great effort was taken to expand the potential interaction space. Instead of just considering a touch connection between two poles as a binary decision (connection or not connection), we created three types of non-linear touch interpretations (see Figure 11): 1. the amount of touch, 2. amount of change in the amount of touch and 3. calculation of activity over time, based on the amount of change over a longer period of time. The first is the actual input with the two others being mathematically derived from the first. Source code 3 is an example of what the code could look like for a system with multiple non-linear parameters.

```
float raw = 0;
float amountOfTouch = 0;
float amountOfTouchOld = 0;
float amountOfActivity = 0;
float amountOfChange = 0;

void loop()
{
 raw = analogRead(A0);
 amountOfTouch = amountOfTouch * 0.9 + raw * 0.1;
 amountOfChange = amountOfChange * 0.9 + abs(amountOfTouch -
  amountOfTouchOld) * 0.1;
 amountOfActivity = amountOfActivity * 0.99 + amountOfChange *
  0.01;
 amountOfTouchOld = amountOfTouch;
}
```

Source code 3. Pattern: *A non-linear system with multiple parameters.* Above, a non-linear system is presented. It takes an input (raw) as an analog variable, filters it of noise and stores it in the variable amountOfTouch. The variable is used to calculate multiple non-linear parameters. For example, the amount of change is derived.

Although the second and third value did not have a linear relationship to the input, they very much correlated to the input and thus still provided a basis for expressions that were reactive to the interactions of the system. Although all three varied in the directness of correlation to the interaction, all of them had some level of symbolic link to the interaction itself. For example, the non-linear strategy of change connected with the sense of tapping. In the case of the Electrolumen, the three values were primarily presented through sound, affecting elements like pitch, volume and modulation. This combination became a multi-layered approach to creating expression, which we explain in the following strategy.

Create Multiple Layers

Where a non-linear strategy focuses on possible ways of interpreting the input, this strategy focuses on ways in which the different non-linear elements can be combined into a multi-layered expression.

In the Multiple Modes strategy, switching between different modes was based on a binary threshold. This meant that it was not possible for the expression to be a part of two moods or modes at the same time. Either a design can be bored or happy. It cannot not be bored and happy at the same time. One way to bypass this binary logic is through accumulation (Hobye & Löwgren, 2011; Vallgårda, 2014). Vallgårda writes that by accumulating over time "one state of expression becomes gradually more explicit than the other state" (p. 583). Source code 4 shows a simple gradual change between two states.

Singing Plant used accumulation to make a transition between the two states: idle and active mode. This is similar to the multiple modes in the second strategy, but instead of a binary transition between the modes, the plant would gradually move between the two. If somebody came and interacted with the

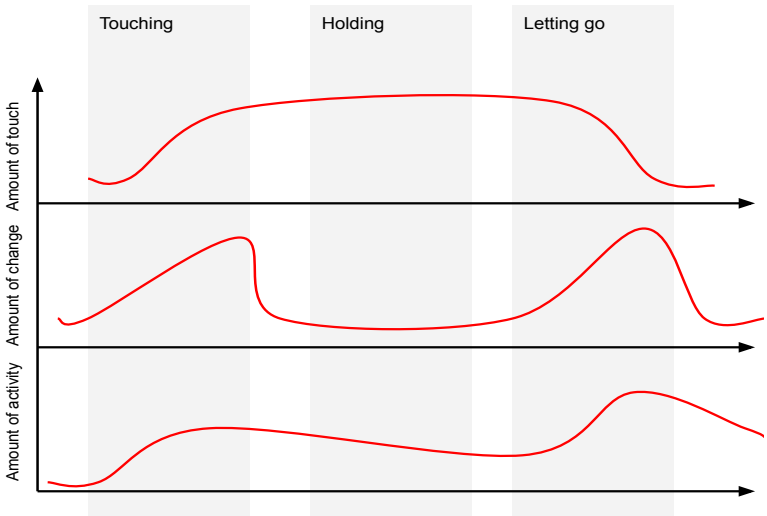


Figure 11. An illustrative example of the internal non-linear system of the Electrolumen (Figure from Hobye, 2014, p. 196).

```
int actitvityFader = 0;
int amountOfTouch = 0;
int redLedPin = 10;
int blueLedPin = 11;

void loop()
{
 amountOfTouch = analogRead(A0);
 if (amountOfTouch > 10) {
  actitvityFader = actitvityFader + 1;
 } else {
  actitvityFader = actitvityFader - 1;
 }
 actitvityFader = constrain(actitvityFader, 0, 100);

 analogWrite(redLedPin, map(100 - actitvityFader, 0, 100, 255, 0));
 analogWrite(blueLedPin, map(actitvityFader, 0, 100, 0, 255));
 delay(100);
}
```

Source code 4. Pattern: *A crossfader with multiple layers*. The pattern fades between two LEDs (red and blue) over time when a sensor has been touched. The red light will fade up when the blue light fades down and the other way around.

plant, the light in the room would slowly dim while the spotlight directly on the plant would brighten. If there were a pause in the activity, the light would naturally gravitate towards the idle mode of light in the room and there would be no light on the plant. This meant that the transition between the two modes was relative to the activity level and thus would shimmer back and forth as the amount of activity changed.

By contrast, accumulation becomes a gradual transition between two states, a multi-layered strategy that can be extended to create real-time space for exploration. By combining multiple parameters, it is possible to create behavioral complexity that gives a sense of multi-layered expressions. It does not really have specific states, but instead certain elements can come alive in different ways through the interaction. If enough layers are added, it becomes hard for the designer to be able to predict the different combinations (see Padfield & Andreasen, 2012).

Electrolumen used this extended strategy. It mixed multiple non-linear interpretations of touch (see Figure 11). By combining multiple non-linear interpretations of touch, a more variable soundscape was created for the participants to explore; tapping would modulate the soundscape in a different way than statically holding, etc. Combining Multiple Layers with Non-linearity properties, we argue for the potential of considering the different layers as *interweaved multidimensionality*, which unfolds with the interaction.

Create Alive Connotations

In many ways, behavioral complexity revolves around how to express liveness in non-living computational objects. Create Alive Connotations is when we play with the connotations of resembling a living thing (e.g., animal, human, plant, or organ) primarily through computational patterns, but as a strategy can play with both behavioral complexity and physical form for expressive complexity. In relation to behavioral complexity, the concept of animism (Larsen, 2015) comes closest to describing the potential of having behavioral complexity for expressive complexity. Animism is concerned with the potential of creating alive connotations in things that do not necessarily have human or animal form. The entanglement between behavioral complexity and expressive complexity calls for some reflection. In our initial distinction, we pointed out that other factors could contribute to the actual expression beyond mere code. Sometimes, the actual behavioral complexity is somewhat simple, but combined with physical properties it becomes a rather powerful expression.

Because of the Animism Robot's zoomorphic visual appearance, a minimal amount of code is needed for it to become *alive* in its expression. The infrared sensor resembles eyes and the configuration of the servos mounted on top of the robot platform gives association to a neck and a head. Therefore, adding code that tilts the head up/down and right/left is enough to give the impression of an emotional expression of the robot. A similar anthropomorphic property occurred in N7331227. What objectively speaking was a mechanical robot arm with a camera mounted on top became alive as if the arm itself was a body and the camera an eye. Even though basic movement of the robot arm would create alive connotations, a much more vivid expression was present when the robot arm used the camera to track participants in the space. It would create a real-time connection with the bodily movement of the audience. If they shifted to the left, the robot's head would follow suit and so forth. The robot's *awareness* of the participant's presence in the space gave a sense of it coming alive as if it had its own agency. The Animism Robot has also been used to illustrate this example. Programming the robot to move backwards if somebody were *too close* created the expression of wanting to maintain a safe distance towards other people in the space. Source code 5 shows the code for such example.

Turning touch into sound in the singing plant gave added connotations of aliveness. Where the plant itself was organic, a similar expression appeared with Mediated Pulse. The shaped form of a heart gave a sense of an organ-like expression, while the light pattern and the vibration gave it a sense of alive connotations. It was common for participants to react with sparkling eyes (Hobye & Löwgren, 2011) whenever they picked up the heart (see Figure 12).

Mediated Pulse is the least complex design in the portfolio from a behavioral complexity point of view. It vibrates and makes light animations based on the human pulse. However, it is relevant to include because the power of creating a *rhythm* (Vallgårda, 2014) in this case gave a sense of alive connotations even though the code was not complex. One such example is seen in Source code 6.

Both code examples in this strategy are surprisingly simple compared to the vivid expression they produced in combination with the physical form. They show that expressive complexity is a product of a whole and not just the behavioral complexity in the computational form.

```
int distance = 0;

Servo leftWheel;
Servo rightWheel;

void setup() {
 leftWheel.attach(9);  // attaches the servo on pin 9 to the servo object
 rightWheel.attach(9);  // attaches the servo on pin 9 to the servo object

}

void loop()
{
 distance = analogRead(A0);

 // do something when distance sensor read a value below 300
 if (distance < 300)
 {
  // Make the continuous servo motors move backwards
  leftWheel.write(70);
  rightWheel.write(110);
 }
 else
 {
  // Stop the continuous servo motors
  leftWheel.write(90);
  rightWheel.write(90);
 }
}
```

Source code 5. Pattern: *Creating alive connotations through distance reaction.* This pattern maintains a certain distance to its surroundings. If a person is too close the robot will back off until the distance criteria are met.

Figure 12. The ballet dancer senses her own heartbeat through the Mediated Pulse.

```
int ledPin  = 1;
unsigned long timer = 0;
boolean on = false;

void loop()
{
 if (millis() - timer > 2000) // do something every two seconds
 {
  timer = millis();
  on = !on;
  digitalWrite(ledPin, on);
 }
}
```

Source code 6. Pattern: *Create rhythm/pulse through timing.* By timing an interval this example can turn on and off, e.g., a LED, creating a pulse or rhythm that can give associations to a heartbeat or breathing.

Discussion: *Unpacking Implementation Strategies*

We have now presented five annotations to illustrate the concept of behavioral complexity as a computational design strategy to create expressive complexity. The five annotations set the stage for us to reflect on possible practical implementations. Although the strategies alone may elicit some level of participant exploration, how they are combined and how they play into the overall expression through the physical form is crucial for us to understand the potential of the overreaching design strategy. Therefore, in the following, we revisit our portfolio to discuss the nuances in the implementation of the strategies in practice. We look into the possibility of combining multiple strategies, strategies for preserving coupling and how the expressive complexity is a product of both the behavioral complexity and the physical form.

Combining Strategies

All of the designs in the portfolio make use of multiple behavioral complexity strategies. Table 6 maps out the different design examples in relation to the behavioral complexity strategies.

When mapping out the different expressions a few patterns start to occur. First and foremost, all of the design examples use 2-3 strategies indicating the need for at least two. It also seems that three is enough. Further, it can be seen that Reactiveness is a recurring strategy throughout the portfolio. This makes intuitive sense since it provides the participant with the possibility to iteratively explore different interactions to understand the possibility space. Mediated Pulse is the only one without Reactiveness. From the perspective of participant interaction, the behavioral complexity is a conceptual understanding of the connection to the performer's pulse. If the participant interacting with the object was also wearing a pulse sensor it may create a fundamentally different level of expressive complexity. With the version presented in the portfolio, the alive connotations

Table 6. The mapping between behavioral strategies and the design examples in the portfolio.

	Reactiveness	Multiple Modes	Non-linearity	Multiple Layers	Alive Connotations
Electrolumen	•		•	•	
Singing Plant	•		•	•	
N7331227	•	•			•
Animism Robot	•	•			•
Mediated Pulse			•		•

mostly lie in the physical form of resembling an organ and how the different animation patterns support this notion. The role of the Mediated Pulse therefore also shows a deviation of the core interest in the portfolio.

Two more patterns are immediately apparent. The last four projects in the portfolio can be grouped into two groups. Electrolumen and Singing plant share Non-linearity and Multiple Layers. N7331227 and Animism Robot both use Multiple Modes and Alive Connotations. N7331227 and Animism Robot both share the same interest in creating human-like traits. The multiple modes create the expression of an ability to change personality (e.g., from bored to happy) and the alive connotations creates a reaction pattern of them relating to the real world. With Electrolumen and Singing Plant their physical expression differs greatly. The plant is a natural organic living organism and Electrolumen is a rough industrial light pole. It is the only design in which the physical form does not play with the connotation of resembling a living thing. The reason for them to share the same two strategies is that they both explore the potential of creating analog reaction patterns of touch. The Non-linearity generates complex touch patterns for a multilayered expression.

Tieben et al. (2011) argue for the complexity of the system as one of multiple strategies to prolong the discovery of an installation. In the portfolio the general motivation behind combining behavioral complexity strategies is to prolong the time that it took for participants to decode the possible patterns in the system.

Preserving Coupling in Complexity

Designing with behavioral complexity can come at the cost of losing coupling for the participant interacting. For a design to be deemed interactive, it is necessary for the participant to have some level of understanding of how their interaction affects the system. This becomes a paradox. At some level one is interested in creating interesting and complex interactions, but on another level, interactions should not be so complex that the participant does not understand the coupling. Gaver et al. (2009), Hobye (2014) and Larsen (2015) all consider this paradox. Gaver et al. (2009) express how the lack of *sweet spot* between randomness and accuracy in a system can affect the interpretation: "The outputs were seen as wrong quite often, to the extent that at least some participants speculated that the sensors might simply be fakes" (p. 2215). Svanæs (2013) adds an embodied phenomenological point to coupling that "the action-reaction coupling should be one that is easily 'understood' by the body" (p. 26). Hence, "we should consider interaction techniques that allow for rapid coupling between user actions and system feedback" (p. 26). In our definition of behavioral complexity, we highlight this paradox by both requiring an action/reaction relationship of the environment and by pointing towards the design of non-linear and non-deterministic properties.

The need for preserving coupling may be one reason why none of the design examples deploys more than three types of strategies at the same time. Further, the risk of the participant losing coupling is more present in some strategies than others. Reactiveness and Alive Connotations do not inherently come with the cost of loss of coupling because both seek to create vivid real-time interaction with the participants. Whether the strategy of creating Multiple Modes affects coupling greatly depends on the different kinds of modes deployed and the logic behind the choice of mode. If the modes are connected meaningfully to the interaction, the participant will not lose the sense of what is going on. Conversely, if the robot changes the mood in an unpredictable way, the participant will lose their own coupling to the interaction.

The strategies Multiple Layers and Non-Linearity both deliberately push the boundaries of coupling. They seek to open the interaction space to complex interaction patterns that need exploration and allow higher levels of mastery by the participant. In the design examples from the portfolio, a strategy of dividing different non-linear layers between different mediums has been used. With the Singing Plant, the lights gave an overall sense of the accumulation of energy, while the sound output was more directed to touch interactions. Electrolumen used light for direct and clear feedback of touch and a complex soundscape in which multiple parameters affected the sound output (see Figure 13). By dividing the different parameters into different physical expressions, it is possible to give a sense of behavioral complexity without compromising a sense of direct coupling to the interaction itself.

Preserving coupling in complexity can be seen as a matter of catering for both masters and novices at the same time. Clearly coupled feedback, for example, in the form of light, allows the novice to grasp the basic interaction. When the initial coupling is mastered, the fine nuances embedded in the behavioral complexity allow for new interactions. By separating coupling and complexity into two different mediums, both can exist at the same time. Alternatively, one could use an accumulation strategy to dynamically adjust the amount of behavioral complexity based on an assessment of the participant's skill level.

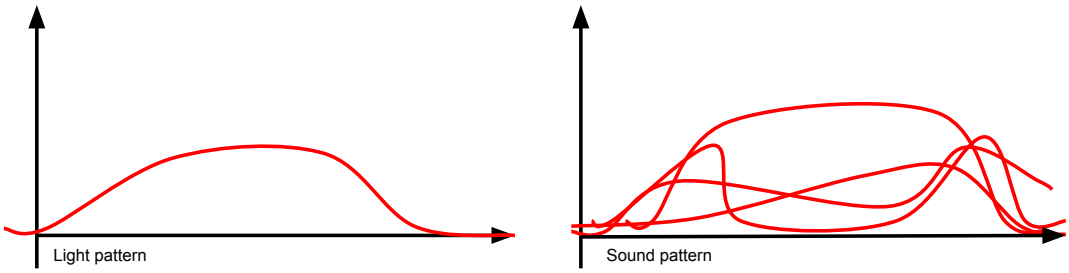


Figure 13. Illustration of using the different non-linear patterns as an expression on different mediums. The light has a direct coupling to touch and the sound have a more complex mix between multiple parameters (Figure from Hobye, 2014, p. 101).

Conclusion

Multiple academic voices have similar interests in discussing behavioral complexity, although at first glance they may seem to have varied agendas when it comes to the experiential qualities they intend to elicit. In the greater picture, concepts like curiosity (Tieben et al., 2011), play (Gaver, 2009), novelty (Gaver et al., 2003; Hobye, 2014), extended material qualities (Vallgårda, 2014), ambiguity of information (Gaver et al., 2003) and animism (Larsen, 2015) are close cousins when it comes to behavioral complexity to create alive and adaptive expressions.

Our knowledge contribution follows our threefold intention with the paper. Firstly, we have argued for a shared agenda within interaction design for a further exploration of computational complexity within computational material as a resource in design. We have illustrated this through a model that introduces the concept of behavioral complexity as a computational design strategy to create expressive complexity in order to propose that computational complexity is a central part of a form giving practice within interaction design.

Secondly, we have exemplified the relationship between behavioral complexity and expressive complexity through five design examples in an annotated portfolio where we suggest five strategies of behavioral complexity exemplified with programming patterns to serve as inspirational building blocks for designers/developers: create Reactiveness, create Multiple Modes, create Non-linearity, create Multiple Layers and create Alive Connotations.

Thirdly, we have initiated a discussion of the pros and cons of combining the strategies and how the mapping of different strategies in combination affects expressive complexity. We conclude that there is a need for balancing the sweet spot and preserving coupling in complexity.

We do not consider our design strategies to be an all-encompassing taxonomy. Instead, we see the properties and strategies as a practice to be further evolved. For example, with the adaptation of technologies like artificial intelligence and machine learning, one can expect the system to behave in more complex ways than we can yet imagine.

Acknowledgements

The Singing Plant

Mads Hobye, Nicolas Padfield, Schack Lindemann, Thomas Jørgensen, Thor Lentz, and Åsmund Boye Kverneland.

Mediated Pulse

Mads Hobye, Maja Fagerberg Ranten, and Nina Gram. Done in collaboration with the Royal Danish Theatre. Glass form development as a part of Dynamic Transparencies with Henrik Svarrer Larsen, Peter Kuchinke and Mads Hobye. Blown by Bjørn Friborg.

Animism Robot

Mads Hobye, Nicolas Padfield, and Nikolaj Møbius. Done as a part of Fablab RUC.

N7331227

Brian Josefsen, Eva Kanstrup, Jonas Jongejan, Mads Hobye, Nicolas Padfield, Nikolaj Møbius, Schack Lindemann, Thomas Fabian Eder, and Thomas Scherrer Tangen. Done as a part of illutron.

Electrolumen

Done as a part of a large-scale installation by illutron with: Bent Haugland, Brian Josefsen, Christian Liljedahl, Emma Cecilia Ajanki, Halfdan Jensen, Jacob Viuff, Jiazi Liu, Johan Bichel Lindegaard, Jonas Jongejan, Lasse Skov, Lin Routhe Jørgensen, Lizette Bryrup, Mads Hobye, Marie Viuff, Mathias Vejerslev, Mona Jensen, Nicolas Padfield, Nikolaj Møbius, Philip Jun Kamata, Sally Jensen Ingvorsen, Schack Lindemann, Simo Ekholm, Sofie Kai Nielsen, Sofie Walbom Kring, Sofus Walbom Kring, Sonny Windstrup, Tobias Bjerregaard, Tobias Jørgensen, Troels Christoffersen, and Vanessa Carpenter.

References

1. Buxton, W. (2007). *Sketching user experiences: Getting the design right and the right design.* Burlington, MA: Morgan Kaufmann.

2. Bødker, S. (2006). When second wave HCI meets third wave challenges. In *Proceedings of the 4th Nordic Conference on Human-Computer Interaction* (pp. 1-8). New York, NY: ACM.
3. Fallman, D. (2008). The interaction design research triangle of design practice, design studies, and design exploration. *Design Issues, 24*(3), 4-18.
4. Gaver, B., & Bowers, J. (2012). *Annotated portfolios. Interactions, 19*(4), 40-49.
5. Gaver, W. W., Beaver, J., & Benford, S. (2003). Ambiguity as a resource for design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 233-240). New York, NY: ACM.
6. Gaver, W., Bowers, J., Kerridge, T., Boucher, A., & Jarvis, N. (2009). Anatomy of a failure: How we knew when our design went wrong, and what we learned from it. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2213-2222). New York, NY: ACM.
7. Gaver, W. (2009). Designing for homo ludens, still. In T. Binder, J. Löwgren, & L. Malmborg (Eds.), *(Re)searching the digital Bauhaus* (pp. 163-178). London, UK: Springer.
8. Gaver, W. (2012). What should we expect from research through design? In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 937-946). New York, NY: ACM.
9. Hallnäs, L., & Redström, J. (2002). From use to presence: On the expressions and aesthetics of everyday computational things. *Interactions, 9*(4), 11-12.
10. Hallnäs, L. (2011). On the foundations of interaction design aesthetics: Revisiting the notions of form and expression. *International Journal of Design, 5*(1), 73-84.
11. Hobye, M., & Löwgren, J. (2011). Touching a stranger: Designing for engaging experience in embodied interaction. *International Journal of Design, 5*(3), 31-48.
12. Hobye, M., Padfield, N., & Löwgren, J. (2013). Designing social play through interpersonal touch: An annotated portfolio. In *Proceedings of the Conference on Nordic Design Research* (pp. 366-369). Copenhagen, Denmark: KADK, School of Design.
13. Hobye, M. (2014). *Designing for homo explorens: Open social play in performative frames* (Doctoral dissertation). Malmo University, Malmo, Sweden.
14. Larsen, H. S. (2015). *Tangible participation–Engaging designs and design engagements in pedagogical praxes* (Doctoral dissertation). Lund University, Lund, Sweden.
15. Levillain, F., & Zibetti, E. (2017). Behavioral objects: The rise of the evocative machines. *Journal of Human-Robot Interaction, 6*(1), 4-24.
16. Löwgren, J. (2002). *The use qualities of digital designs.* Retrieved March 20, 2018, from https://pdfs.semanticscholar.org/260e/8360b33b8ac003a5e244a13396471cd9a47a.pdf
17. Löwgren, J. (2007). Forskning om digitala material [Interaction design, research practices and design research on the digital materials]. In S. Ilstedt Hjelm (Ed.), *Om design forskning* (pp. 150-163). Stockholm, Sweden: Raster Förlag. Retrieved from http://jonas.lowgren.info/Material/idResearchEssay.pdf
18. Padfield, N., & Andreasen, T. (2012). Framework for modelling multiple input complex aggregations for interactive installations. In *Proceedings of the 2nd International Conference on Ambient Computing, Applications, Services and Technologies* (pp. 79-85). Roskilde, Danmark: Roskilde university. Retrieved from https://rucforsk.ruc.dk/ws/portalfiles/portal/38396286
19. Padfield, N., Haldrup, M., & Hobye, M. (2014). *Empowering academia through modern fabrication practices.* Paper presented at Fablearn Europe, Aarhus, Denmark. Retrieved from https://rucforsk.ruc.dk/ws/portalfiles/portal/49670
20. Redström, J. (2017). *Making design theory.* Cambridge, MA: MIT Press.
21. Reeves, S., Benford, S., O'Malley, C., & Fraser, M. (2005). Designing the spectator experience. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 741-750). New York, NY: ACM.
22. Svanæs, D. (2013). Interaction design for and with the lived body: Some implications of Merleau-Ponty's phenomenology. *ACM Transactions on Computer-Human Interaction, 20*(1), Article 8.
23. Tieben, R., Bekker, T., & Schouten, B. (2011). Curiosity and interaction: Making people curious through interactive systems. In *Proceedings of the 25th BCS Conference on Human-Computer Interaction* (pp. 361-370). Swinton, UK: British Computer Society.
24. Vallgårda, A. (2014). Giving form to computational things: Developing a practice of interaction design. *Personal and Ubiquitous Computing, 18*(3), 577-592.
25. Vallgårda, A., & Sokoler, T. (2010). A material strategy: Exploring the material properties of computers. *International Journal of Design, 4*(3), 1-14.
26. Vallgårda, A., Winther, M., Mørch, N., & Vizer, E. E. (2015). Temporal form in interaction design. *International Journal of Design, 9*(3), 1-15.

Paper 3| Ranten, M. F., Hobye, M. & Gram, N., 2020, *The Implications of Using Interactive Artifacts to Bridge the Divide Between Audience and Stage in a Conventional Hall Setting.* PARtake: The Journal of Performance as Research. 3, 1

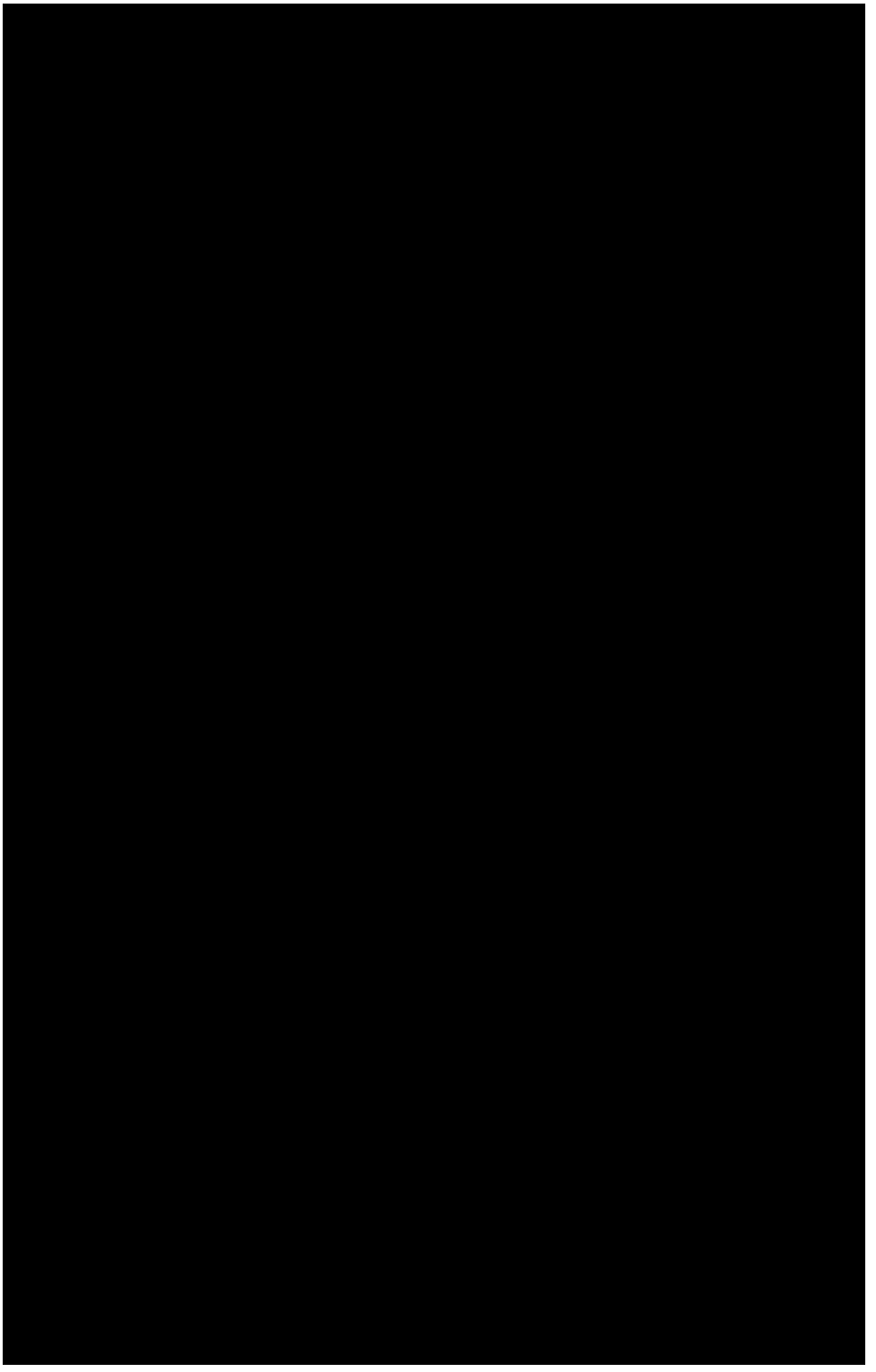
Originally published in: PARtake: The Journal of Performance as Research. Special Issue on Knowledge Formation. https://doi.org/10.33011/partake.v3i1.465

Joint work with: Mads Hobye and Nina Gram

PARtake: The Journal of Performance as Research
Volume 3, Issue 1 – Spring 2020
ISSN: 2472-0860

The Implications of Using Interactive Artifacts to Bridge the Divide Between Audience and Stage in a Conventional Hall Setting

Maja Fagerberg Ranten—Roskilde University
Mads Hobye, PhD—Roskilde University
Nina Gram, PhD—Royal Danish Theatre



[redacted]

[redacted]

[redacted]

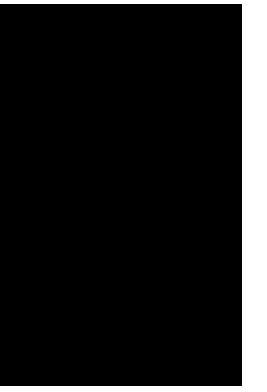
[redacted]

[redacted]

[redacted]

[redacted]

[redacted]



[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Paper 4| Hines, M., Kadish, D. & Ranten, M. F., May 2020, Sound as Material for Eco-technogenesis. *Proceedings of RE:SOUND 2019*. British Computer Society, s. 195-201 (Electronic Workshops in Computing).

Originally published in: Proceedings of RE:SOUND 2019 - 8th International Conference on Media Art, Science, and Technology; August 2019.
https://doi.org/10.14236/ewic/RESOUND19.30

Joint work with: Megan Hines and David Kadish

http://dx.doi.org/10.14236/ewic/RESOUND19.30

Sound as Material for Eco-technogenesis

Megan Hines
Department of Art
Stony Brook University
2224 Staller Center for the Arts
Stony Brook, NY 11794
United States
megan.hines@stonybrook.edu

David Kadish
Robotics, Evolution, and Art Lab
IT University of Copenhagen
Rued Langgaards Vej 7
DK-2300 Copenhagen S
Denmark
davk@itu.dk

Maja Fagerberg Ranten
Department of People and Technology
Roskilde University
Universitetsvej 1, 10.2,
DK-4000 Roskilde
Denmark
mranten@ruc.dk

This paper delineates the conceptual outcomes from a two-week intensive cross-disciplinary conversation between an art historian, an interaction designer, and an artist/engineer. With the aim of applying the concept of technogenesis to an exploration of sound as material for art and design, we consider sound as a material force within an ecosystem. Through this lens, sound produced by either life- or technological-forms allows us to consider the ecological impact and potential meanings of generated sound. Drawing on biosemiotics, we propose that the co-evolution of sound, technology, and environments, what we call eco-technogenesis, demands relational, and thus ethical, thinking. The rowdy krause, an autonomous sonic agent, designed by Kadish to identify and inhabit an acoustic niche within an ecosystem, serves as a case study for thinking through eco-technogenesis.

Biosemiotics. Ethics. Soundscape ecology. Sound objects. Technogenesis.

1. INTRODUCTION

This article is the conceptual outcome of a two-week intensive research- and practice-based collaboration between Megan Hines, an art historian, Maja Fagerberg Ranten, an interaction designer, and David Kadish, an artist/engineer. Drawing on conversations that took place at Catch: Center for Art, Design, and Technology, Helsingør, and the RE:SOUND Conference, Aalborg, we discuss sound as a material and the ecological impact and potential meanings of generated sound. Approaching our topic from a cross-disciplinary lens, we posit that the increasing presence of generated sound within ecosystems demands expanding technogenesis to the non-human realm. We propose bio- and eco-technogenesis as tools to consider the relationality of generated sound.

Technogenesis, as developed by Bernard Stiegler (1998) and expanded on by Katherine Hayles (2012) describes human evolution as occurring as a result of interactions with the environment and the available tools or technologies within that environment. Technogenesis is a co-constituted process of becoming, an intertwining of the past, present, and future trajectories of the techno-human ensemble. In this framework, technologies drive shifts in human genetic, epigenetic, and developmental traits. Though the process is non-teleological, the entities as they currently exist could not have existed independently and are rendered meaningless without one another. Stiegler (1998) traces a line from the emergence of bipedal mobility and the freeing of the hands to the beginnings of tool use and the development of a co-constitutive relationship between technics and human genetic and epigenetic changes. He argues,

> "the prosthesis is not a mere extension of the human body; it is the constitution of this body *qua* 'human'" (1998, p. 152).

Hayles (2012) focuses on contemporary technogenesis, aiming to describe the unprecedented change and amplified feedback loops that digital technologies have activated in our environment and ourselves.

We argue here that this process of technological becoming can and should be applied to other biological forms as well as to ecosystems. The inherently relational quality of sound provides an excellent medium through which to introduce ecological thinking to the concept of technogenesis. Soundscape ecology, sometimes called ecoacoustics or soundscape studies, is the study of sounds in an ecosystem. Its history predates its naming. For example, ornithologists took advantage

of sound recording technologies as soon as it was plausible to bring them into the field in the late nineteenth century. These studies concentrated on single bird songs in order to preserve and analyse them. Soundscape ecology incorporates individual sounds into a whole soundscape, a term coined by Canadian composer R. Murray Schaffer (1969). Schaffer's concept of a soundscape was groundbreaking for including sounds made by humans, nature, and machinery, whether electric or mechanical (Ibid., 5-6). The soundscape was a landmark contribution to soundscape ecology because it moved the study of sonic relations beyond the confines of music. Furthermore, the soundscape pushed the study of sound into a wider realm that included non-human and non-organic listeners and creators. To accept that sound acts as an ecological force implies that its effects go beyond human aesthetics and touch on material relations within an environment.

1.1 Cross-disciplinary Backdrop

The topics of technogenesis and soundscape ecology are necessarily cross-disciplinary, spanning fields as wide as sound studies, ecology, evolutionary biology, anthropology, and media studies. As representatives from three different fields of study, we spent two weeks together in Denmark in August 2019: the first week as participants at the workshop Artistic and Curatorial Practices in the Age of Technogenesis at Catch in Helsingør; and the second week at the 2019 Media Art Histories conference in Aalborg titled RE:SOUND Sound, Media and Art - Theories, Histories, Practices.

Throughout the two weeks, we discussed what is at play when we consider sound as material within an ecological soundscape. How do we define and perceive sound? How do nonhumans perceive sound? Moreover, what happens when one perceives sound that is computationally generated? By acknowledging that sound acts as an ecological force, we discuss the effects of sound beyond human aesthetics within an ecosystem.

The work-in-progress explored at the pre-conference workshop, Kadish's the *rowdy krause*, serves as a subject for our conversation. We begin our discussions through the presentation of three conversation themes, followed by a conversation between us based on our respective practices. We posit that viewing technogenesis from a cross-disciplinary lens can broaden the perspective on sound as material within ecological soundscapes. The two conversation themes are sound as computational material and eco-technogenesis.

1.2 The Rowdy Krause

The rowdy krause is an autonomous sonic agent that is designed to inhabit an ecosystem and find an acoustic niche for itself within that ecosystem's soundscape. The work is currently in progress (see Figure 1), but the rowdy krause is already able to perform its search for a niche using a recorded soundscape, while future iterations will perform this in real-time, embedded in an ecosystem.

The rowdy krause begins its search for a niche by listening to the soundscape in which it is placed. It makes note of the different sounds that it hears and analyses their spectra so that it can start to determine which frequencies are least used. It continues listening and revising its understanding of what already exists in the soundscape throughout the process of evolving its own voice.

To make sound, the rowdy krause makes use of a computational model of a mammalian vocal tract so that the sounds that it produces have something in common with sounds that one might hear from a biological creature. The simulator was developed by Neil Thapen and is called Pink Trombone.[1] The rowdy krause controls the simulator using an evolutionary neural network that uses a process called the neuroevolution of augmenting topologies (NEAT), meaning that the structure and weighting of the neural network both undergo evolution (Stanley, 2002).

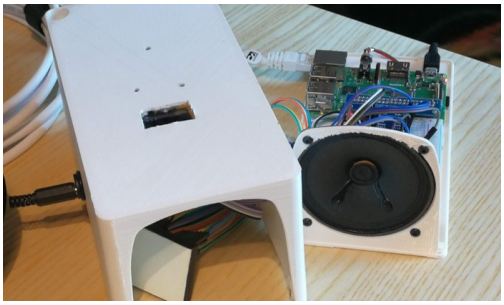


***Figure 1**: The rowdy krause's physical instantiation in progress. The rowdy krause's computation occurs on a Raspberry Pi single board computer, and it senses its surroundings using a microphone, temperature and humidity sensor, and light detector, while engaging with the world through an amplified speaker.*

Every time the neural network produces a vocalization by controlling the vocal tract, the vocalization is compared to all of the sounds that the rowdy krause has already heard in the ecosystem's soundscape. The neural network is assigned a fitness based on how different the sound it produces is from the existing soundscape and the networks with the best fitness are more likely to pass on traits to the next generation of neural networks in the evolutionary process. Over time, the rowdy krause tends toward finding a voice that occupies a unique niche within its soundscape.

While the parameters for the rowdy krause's voice are selected by Kadish, the actual voice arises from the particular composition of the ecosystem that it inhabits. At the same time, the projection of the evolving vocalizations into the ecosystem adds to the soundscape and affects other ecosystem inhabitants. Their responses and the new voice are part of the ecosystem's continual evolution, and also drive the evolution of the rowdy krause's vocalization, an example of eco-technogenesis in action.

2. SOUND AS COMPUTATIONAL MATERIAL

Sound made by humans and machinery ranges from recordings, digitized sounds and algorithmically-generated sounds. Typically, humans author content; the composer, artist, designer, or developer uses sound as material in their technologically-aided practice. The idea of sound as immaterial or ephemeral has changed as the technological possibilities for the recording and manipulation and sound increased. Composer Pierre Schaeffer was the first to refer to an "object sonore" or sound object (Schaeffer, 1966). As audio technologies progressed, recorded sound objects no longer referred to a sound source, but existed as objects in their own right (Chattopadhyay, 2017).

Joseph Klett has extended the materiality of sound to the sonic object setting, the place of interaction between material sounds and their interpreters (Klett, 2014). Besides labelling sound as social as it occurs among bodies, Labelle (2006) addresses sound as spatial. Sound is always more than one place and performs with and through space. Sound is a relational phenomenon: from immaterial to material, from inside one's thoughts to others', and through space (Labelle, 2016, p. xi).

Søndergaard (2019) describes sound as the perfect material for experimental practices because of its "difficulty" as time-based, immaterial and fugitive. He adds that sound is nothing without being experienced. He describes sound as an artist's material and the first media art practice:

> "...and because of the invention of technologies that make it possible to liberate sound from its source, sound even became the first technologically emerging artistic material; as such, sound art could be seen as the first media art practice, historically." (Søndergaard, 2019, p. 96).

Cox (2013) elaborates on sound having a sonic ontology. He states that whereas the ontology of "matter" privileges sight and touch, the invisible, intangible and ephemeral objects of smell, taste and hearing exist in the shadows compared to solid materials. He concludes that sound has a different ontology and materialism:

> "...a conception of being and matter that can account for objecthood better than an ontology of objects can account for sounds." (Cox, 2013).

According to Cox (2009), sound instead affirms an ontology of flux, where objects are replaced by events; a sonic philosophy of sound as flux, event and effect.

The same can be stated about computational material. It too can be described as an intangible matter and as an ontology of flux. We are bodily affected through, with, and by computational material, and no longer differentiate between the subjective inside and technology from the outside. Rather than dividing the human-technology relation into a matter of a foreground and a background we can unpack Hayles' (2012) claim that digital media and the actions of computers are embodied, that technical objects have agency or the potentiality of computational material as autonomous.

When Hayles expanded the concept of technogenesis, the idea that humans and technics coevolve, the focus was on contemporary digital technologies. She relates technical beings versus embodied living beings and focused on the interfaces between programmable machines and humans:

> "...the actions of computers are also embodied, although in a very different manner than with humans. The more one works with digital technologies, the more one comes to appreciate the capacity of networked and programmable machines to carry out sophisticated cognitive tasks, and the more the keyboard comes to seem an extension of one's thoughts rather than an external device on which one types." (Hayles, 2012, p. 3).

Thus, embodiment takes the form of an extended cognition where larger networks beyond the desktop computer are entangled with human agency and thought. Hayles clearly described technical objects as having agency. In the sense that technical objects are agents of complex temporalities, in evolutionary terms, they are repositories of change. (Hayles, 2012, p. 85)

Carvalhais (2010) addresses the autonomous quality of programmable media beyond their creators and users:

> "A system's autonomy can be regarded not only as an amount of control that is conferred to or appropriated by it but also as a transfer of some amount of agency to the system." (Carvalhais 2010, p. 421).

He compares procedural systems to biological systems and claims that computational material too can be complex. With reference to Herbert A. Simon he describes an inner and outer environment of a system as the substance and organization of the

artefact and the operating surroundings (Carvalhais, 2010, p. 634). Manovich (2001) makes a related distinction between the cultural layer and the computational layer as the distinction between the interface and what the computer reads.

Computational material is potentially autonomous. Computational media and sound are not just mediators, but also programmable, and thus potentially autonomous beyond their makers and users/listeners. The notion of sound as material and computational material is interesting in relation to the rowdy krause. Is the rowdy krause autonomous, and who is the author of the voice of the new species? What is the role of the computational material in relation to the rowdy krause? In what follows, we situate potentially autonomous technological forms as material forces within ecosystems and ask how an example such as the rowdy krause impacts and is impacted by the relationality of sound within its environment.

3. ECO-TECHNOGENESIS

Eco-technogenesis describes the co-becoming of ecosystems and technologies. Hayles asserts,

> "technical objects embody complex temporalities enfolding past into present, present into future" (2012, p 86).

While Hayles applies this idea to human development, here we apply it to an understanding of the past and future development of ecosystems. The contemporary farm is a good working example of eco-technogenesis (Mazoyer, 2006). The typical large wheat monoculture found in mid-western North America, for example, did not arise overnight, but is the result of tens of thousands of years of co-evolutionary development involving technical ensembles, human societies, and ecosystems. When the first hunter-gatherers scattered seeds from their food in a known location or the first metalworkers forged a plow, their goal was not to produce unbroken hectares of wheat monoculture. And yet, that ecosystem is only possible because of the advent of seed harvesting and metal plows, the selection and evolution of new crops and countless other technological and biological changes.

Examples of the co-evolution of humans, technology, and ecosystems abound, but what about non-human eco-technogenesis? This is a more difficult proposition to consider, given the difficulty of observing the slow changes continually modified by feedback loops between animals and environments occurring on evolutionary and geological timescales. Scholars have pointed to habitat-modifying species like the beaver as an example. Beavers are best known for cutting trees to dam rivers, creating larger pools of water within a river ecosystem. The technical object of the dam is, on its own, a significant factor in the formation of these dammed river ecosystems. It has an impact on the plant and animal communities in the ecosystem (Rybczynski, 2007), reshaping the network of interactions and relationships in the landscape. Dams become an essential component of the development of the ecosystem. Considering the evolutionary history of beavers provides evidence that this behaviour evolved through technological and evolutionary reinforcement. Natalia Rybczynski argues the building of dams evolved from simpler behaviours like cutting and feeding on smaller vegetation (Ibid., 2007). It implies a long, slow, multigenerational process in which dams began as smaller debris and eventually took the form of larger constructions, thereby reconstituting the ecosystem and reinforcing the behaviour. Beavers' activities are implicated in the evolution of fish and amphibians in dammed rivers as well as the defences of nearby tree species (Ibid., 2007). Beaver dams can be considered a canonical example of eco-technogenesis.

3.1 Sound and eco-technogenesis

Returning to soundscape ecology, we argue sound provides a domain in which to think through the possibility of eco-technogenesis. In fact, this idea is not entirely new. The intermeshing of sound, technology, and ecology exploded into public consciousness in 1962 with the publication of Carson's landmark book *Silent Spring*, in which she revealed the devastating effects of industrial chemicals on bird populations by pointing to gaps in the sound spectrum as bird species went extinct. Carson's method of measuring ecological health using sound predated yet paved the way for the acoustic niche hypothesis (ANH) (Krause, 1987) and the acoustic adaptation hypothesis (AAH) (Morton, 1975). The ANH is based on empirical observations that suggest sounds produced by species vocalizing within an ecosystem tend not to interfere with one another, creating a partitioning of the acoustic range (Sueur and Farina, 2015, 495). Relatedly, the AAH argues animal-generated sounds have adapted to their particular habitat, taking into account the properties of the landscape and plant life to maximize sound dispersal (Sueur and Farina, 2015, 495). The ANH and AAH provide the basis for thinking in terms of the co-constitution of sound and landscape. Based on Carson's and Krause's work, an ecosystem's soundscape became an indicator of its diversity and health. Loss of diversity across the acoustical space indicated an imbalance and an infiltration of human activity in the ecosystem. For example, Krause observed that smaller parks in the American Northwest established by lumber companies and characterized by a monoculture of young pines displayed a shocking lack of biodiversity evidenced by large gaps in the acoustical space (Krause, 1993).

Soundscape ecology allowed for thinking of the intermeshing of sound, technology, and ecology and the technogenesis of soundscapes, while preserving the nature/culture divide. Having defined eco-technogenesis, we now focus on the possibility of technogenesis across human, non-human, and non-organic or technological systems. Throughout the course at Catch, we considered autonomous agents capable of creative sound generation through case studies and in practice. Our aim here is to situate generative sound practices within local ecologies. Kadish's rowdy krause, developed over the course of his doctoral studies and presented for the first time at Catch, provides a case study. Given that we have accepted sound as a material force in an ecosystem, we conclude by speculating on the ethics of an eco-technogenesis that includes non-organic sound generation.

There are a number of automated or robotic sound-generating systems that are designed specifically to engage with ecosystems in a dynamic and generative manner. David Dunn's *Sonic Mirror* (1986) is an early example of this type of work. Dunn's *Sonic Mirror*, which he considers a sound performance, arose from an interest in rules and systems for processing and reproducing soundscapes (Dunn, 2013). *Sonic Mirror* involves the recording of sound in an ecosystem by an autonomous computer system, the processing and modulation of that recording, and the subsequent reprojection of the sound into the ecosystem. Dunn, who was trained as a composer, observed that the ecosystem inhabitants began to engage with the recording and playback system, and noted the ecosystemic nature of sound:

> "The song of a bird is not just grist for compositional manipulation; it is a code of signification not only between members of that particular species, but also for the extended fabric of mind that forms the biohabitat within which that species resides" (Dunn, 2013, p. 100).

Dunn's statement parallels our own argument, that eco-technogenesis demands that non-organic self-organizing systems be considered as relational elements within an ecosystem.

In 2001, biologist Claus Emmeche specualted, "Does a robot have an *Umwelt*?" (Emmeche, 2001). The biologist Jakob von Uexküll's concept of *Umwelt* is defined as an organism's perceptual world (1909, 1992). From the concept of *Umwelt*, it follows that an organism acting within a perceptual environment relies on signs to interpret the material world and is a communicative being, even if one does not accept this as proof of high-level reasoning. Emmeche speculated autonomy and self-organization would be necessary qualities for occupying an *Umwelt*, and that robots could therefore have an *Umwelt*. In response, biologist Winfried Nöth offered the example of a robot successfully moving around its environment and argued even if it did have an experience of *Umwelt*, it would be impossible for humans to know anything about that experience (Nöth, 2001). In 2012, Hayles referring to Uexküll's famous example of a tick (Uexküll, 1992) agreed, arguing if an animal as simple as a tick could have an *Umwelt*, surely a spatially-aware robot could. (Hayles, 2012, p. 249n4). Each of these examples stresses vision and proprioception as markers of semiosis. We argue here just as a robot moving around its environment has an *Umwelt*, an artificial intelligence system occupying an acoustical niche has an *Umwelt*.

The rowdy krause meets this threshold by listening to its environment, identifying the least utilized portions of the audio spectrum, and evolving a voice to fill those frequencies. It performs the acoustic niche hypothesis as an autonomous technological species, its *Umwelt* framed by its primary sensory organ: its microphone. As its vocalizations evolve to fill previously empty portions of the soundscape, how do existing inhabitants of the ecosystem perceive its calls? Its interference in their own communication is minimal by design, but the rowdy krause's calls are nevertheless part of the acoustic environment.

3.2 Biosemiotics as a basis for an ethics of generated sound in eco-technogenesis

Technogenesis belies the idea of infiltration and instead presents the problem of intermeshing and relationality. Relationality forces the question of ethics, a code that governs behaviour within a social setting. Hoffmeyer, Kull, Tønnensen, Beever, and Hendlin have all approached ethics from the perspective of biosemiotics, the production and interpretation of signs in the living world beyond human language. (Hoffmeyer, 1993; Kull, 2001; Tønnensen, Beever and Hendlin, 2015). We argue here that the creative use of sound requires an exploration of the ethics of sound generation within an ecosystem, an occurrence that only promises to increase as techniques for sonic manipulation continue to develop. By thinking through eco-technogenesis, sounds regardless of origin contribute for better or worse to a biosemiotic ecosystem, an environment within which the generation and interpretation of sounds as signs evolve in co-constitution with one another regardless of origin, whether biological, natural, or technological. Given this description, preserving the nature/culture divide proves likely to be a fruitless enterprise in the face of ongoing technological development. As sound-generating autonomous agents increasingly become part of the soundscape, it is crucial we consider how to design responsible inhabitants. This idea follows Cox's argument that sound art provides an opportunity to explore the ontogeny of sound (Cox, 2009). But whereas in Cox's argument, sound art points to a realm of

sound outside human sensory experience, in our estimation, sound not only points to a realm of sensory experience outside the human, it acts as a source of potential various meanings to an ecosystem's inhabitants. Even if these sounds are generated by non-living self-organizing systems, their potential to occupy an *Umwelt* makes them "morally considerable" (Beever and Tønnessen, 2015, p. 45).

Part of the appeal but also the challenge of biosemiotic ethics is its insistence on the existence of systems of meaning that reside outside of human experience (Hoffmeyer, 1993; Kull, 2001; Tønnensen, Beever and Hendlin, 2015). Traditionally, however, conservationist rhetoric has relied on anthropocentric notions of beauty to drive home the necessity of caring for ecosystems (Harries-Jones, 2008). Like beautiful works of art in a museum, it was reasoned, landscapes should be preserved for future generations to enjoy. Even Carson relied on this line of thinking by lamenting the loss of bird songs for human ears (Carson, 1962). Recently, it has become apparent that these human-centred values are not only questionable in their efficacy, but also potentially harmful to the ecosystems they try to protect (Harries-Jones, 2008). In emphasising stasis over dynamics, the idea of beauty as applied to ecosystems betrays their essence. Peter Harries-Jones argued Bateson's idea of an ecological aesthetics, which leaves behind human-centred ideas of beauty, has finally started to gain traction, if without full appreciation for its biosemiotic implications (Ibid.). Bateson's concept of ecological aesthetics, in which systems interact through feedback, provides a foundation for thinking of ecosystems as composed of layers that add up to something greater than themselves (1972). In other words, ecological aesthetics is a type of holistic thinking that resists reductionism.

4. CONCLUSION

Throughout this article, we considered sound generated by an autonomous agent as contributing to the co-constituted becoming of ecosystems and technologies. Based on our collaborative work and discussions, we offer insights into sound as computational material, eco-technogenesis, and the possibility for an ethics of sound generation based on biosemiotics in this new ecological paradigm.

We do not present an exhaustive account of the subjects but invite other scholars and practitioners to continue the conversation and further explore the subject of technogenesis in relation to sound and ecosystems. Finally, the thorny questions of ethical approaches to eco-technogenesis will continue to present themselves in the future, especially as the possibilities for technological sound generation increase. Here we offer a starting point for considering ethical relationality from the perspective of biosemiotics.

Acknowledgments

Artistic and Curatorial Practices in the Age of Technogenesis was a joint project between Catch, the IT-University of Copenhagen and Aalborg University. Thank you to the academic supervisors Morten Søndergaard Laura Beloff and Catch supervisor Majken Overgaard. Megan Hines would like to thank the Stony Brook University Graduate Student Organization for their financial support.

5. REFERENCES

Bateson, G. (1972) *Steps to an Ecology of Mind*. Ballantine, New York.

Beever, J. and Tønnessen, M. (2015) 'Justifying Moral Standing by Biosemiotic Particularism', *Zeitschrift für Semiotik* 37 (3-4), pp. 31-53.

Carson, R. (1962) *Silent Spring*. Houghton Mifflin, Boston.

Carvalhais, M. (2010). "Towards a Model for Artificial Aesthetics. Contributions to the Study of Creative Practices in Procedural and Computational Systems." Doctoral thesis. Universidade do Porto.

Chattopadhyay, B. (2017). 'Beyond Matter: Object-disoriented Sound Art', *Seismograph*. <https://seismograf.org/fokus/sound-art-matters/beyond-matter-object-disoriented-sound-art> (retrieved 09 November 2019).

Cox, C. (2009) 'Sound Art and the Sonic Unconscious', *Organised Sound* 14 (1), pp. 19—26.

Cox, C. (2013). 'Sonic Philosophy', *ARTPULSE Magazine*. <http://artpulsemagazine.com/sonic-philosophy> (retrieved 09 November 2019).

Dunn, D. (2013) 'Nature, Sound Art, and the Sacred', in David Rothenberg (ed.), *The Book of Music and Nature: An Anthology of Sounds, Words, Thoughts*. Wesleyan University Press, Wesleyan.

Emmeche, C. (2001) 'Does a robot have an *Umwelt*?', *Semiotica* 134 (1/4), pp. 653—693.

Harries-Jones, P. (2008) 'Gregory Bateson's 'Uncovery' of Ecological Aesthetics', in Hoffmeyer, J. (ed.), *A Legacy for Living Systems: Gregory Bateson as Precursor to Biosemiotics*. Springer, Dordrecht.

Hayles, N. K. (2012) *How We Think: Digital Media and Contemporary Technogenesis*. University of Chicago Press, Chicago.

Hoffmeyer, J. (1993) 'Biosemiotics and ethics.' in Witoszek, N. and Gulbrandsen, E. (eds.), *Culture and E nvironment: I nterdisciplinary A pproaches*. Centre for Development and the Environment, Oslo.

Klett, J. (2014) 'Sound on Sound: Situating Interaction in Sonic Object Settings', *Sociological Theory* 32 (2), pp. 147--161.

Krause, B. L. (1987) 'Bioacoustics, Habitat Ambience in Ecological Balance', *Whole E arth Review* 57, pp. 14–18.

Krause, B. L. (1993) 'The Niche Hypothesis: A hidden symphony of animal sounds, the origins of musical expression and the health of habitats,' *The Explorers Journal*, (Winter), pp. 156-160.

Kull, K. (2001) 'Biosemiotics and the problem of intrinsic value of nature', *Sign S ystems S tudies* 29, 1: pp. 353–365.

Labelle, B. (2006). *Background Noise: Perspectives on Sound Art*. Continuum, London.

Manovich, L. (2001) *The Language of New Media*. MIT Press, London.

Margulis, L. (1970) *Origin of eukaryotic cells; evidence and research implications for a theory of the or igin an d ev olution of microbial, p lant, and animal c ells on t he P recambrian ea rth*. New Haven: Yale University Press.

Mazoyer, M., & Roudart, L. (2006). *A H istory o f World Agriculture: From the Neolithic Age to the Current Crisis*. Earthscan, London.

Morton, E. S. (1975) 'Ecological Sources of Selection on Avian Sounds', *The American Naturalist*, 109(965), pp. 17–34.

Nöth, W. (2001) 'Semiosis and the *Umwelt* of a robot', *Semiotica* 134 (1/4), pp. 695—699.

Rybczynski, N. (2007) 'Castorid Phylogenetics: Implications for the Evolution of Swimming and Tree-Exploitation in Beavers', *Journal of Mammalian Evolution* 14(1), pp. 1–35.

Schaeffer, P. (1966) *Traité des objets musicaux*. Éditions du Seuil, Paris.

Schaffer, R. M. (1969) *The New Soundscape*. Berandol Music Limited, Ontario.

Søndergaard, M. (2019) 'Exscribing the Archive: Curating the Unheard (in Scandinavia)'. in Weibel, P. (ed.) *Sound A rt*. MIT Press, Cambridge.

Stanley, K. O. and Miikkulainen, R. (2002) 'Evolving Neural Networks through Augmenting Topologies', *Evolutionary Computation*, 10(2), pp. 99–127.

Stiegler, B. (1998). *Technics a nd Time 1*. Stanford University Press, Stanford.

Sueur, J. and Farina, A. (2015) 'Ecoacoustics: the Ecological Investigation and Interpretation of Environmental Sound', *Biosemiotics* 8, pp. 493--502.

Tønnessen, M., Beever, J. and Hendlin, Y. (2015) "Introducing Biosemiotic Ethics', *Zeitschrift f ür Semiotik* 37 (3-4), pp. 3-12.

Uexküll, J. (1909) *Umwelt und Innenwelt der Tiere*. Julius Springer, Berlin.

Uexküll, J. (1992). 'A Stroll Through the Worlds of Animal and Men' in Uexküll, T. (ed.) *Semiotica* 89 (4), pp. 273—391.

[1] Thapen, N. https://dood.al/pinktrombone/ (retrieved 09 November 2019).

This dissertation is about Bodily Interaction Design and how designers can work with particular attention to a phenomenological perspective in the design development process. It is aimed at designers working in the fields of interaction design, human-computer-interaction (HCI), and interactive art.

The work is conducted as programmatic research based on practical work with interactive installations that elicit embodied behavior from a first-person experience of attention to embodiment in the design development process. The research program is informed by Merleau-Ponty's phenomenology, and by materialism. The overall goal is to raise awareness of the fact that the body is an active part of the design process and to present a broader outline of work around the conceptions of bodies within research through design, and to position the bodily view in a material interaction design context.

The dissertation explores and present knowledge contributions about designing bodily interactions from three angles: firstly, Bo-dily Interaction Design, a bodily perspective informed by a phen-omenological perspective; secondly, phenomenological research through design, a suggested methodology for designers to work within the body perspective; and thirdly, the materiality of bodily interaction design, an unfolding of the materials of the metho-dology.

Finally, this work suggests dividing performing phenomenological research through design into three parts – before, during, and after. The three parts further act as a placeholder for the contributions presented throughout the dissertation as inspira-tions for designers to think through and with the program of Bodily Interaction Design.

ISBN 978-87-91362-13-2