Haptic Media Scenes

Elisabeth Nesheim

Thesis for the degree of Philosophiae Doctor (PhD)
University of Bergen, Norway
2020

UNIVERSITY OF BERGEN

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at the University of Bergen

Date of defense: 28.08.2020

Year: 2020
Title: Haptic Media Scenes

Name: Elisabeth Nesheim
Print: Skipnes Kommunikasjon / University of Bergen

SCIENTIFIC ENVIRONMENT

This dissertation is the result of research conducted at the University of Bergen (UIB), Humanities Faculty, Department of Linguistic, Literary, and Aesthetic Studies between August 2012 and March 2020, as part of a PhD research fellowship in Digital Culture.

The funded doctoral program is two-fold, where 75% of the contract is assigned individual research to develop the doctoral thesis. Teaching and program specific research activities constitute 25% of the fellowship. Courses taught include DIKULT103, 104, 208, 250, and 302, in the areas of digital art, electronic literature, media aesthetics, philosophy, and digital humanities. My main supervisor is Scott Rettberg, professor of Digital Culture at UIB, and my co-supervisor is Jill Walker Rettberg, professor of Digital Culture at UIB.

I have been part of two research groups throughout the fellowship: the Digital Culture Research group and the Bergen Electronic Literature research group (BEL), and been partaking in workshops, conferences, and exhibitions organized within the program. In addition, important meetings and conversations have taken place at conferences, workshops, and festivals, such as Transmediale, Piksel, Ars Electronica, Medialab Prado, the TBLR PhD seminar, and the E&T Education and Technology summer school.

ACKNOWLEDGMENTS

Writing a doctoral thesis is an extensive process, with many twists and turns. A lot of people have influenced my direction and drive, and some mentions are in order.

First and foremost, I want to extend my deepest gratitude towards Scott Rettberg, supervisor extraordinaire, for encouraging me to take a PhD in the first place. For your generosity, including me in your scientific network, introducing me to relevant artists and scholars, as a peer. For your patience, insights, and your feedback. Thank you.

To Jill Walker Rettberg, for your sharp and precise mind, strong ethics, and caring nature. For seeing me as more than a PhD candidate with a research topic, as a person, and a mother. You are an inspiration.

To Daniel Apollon, for our many talks and broadening my perspective, introducing relevant and important topics, themes and problems, many which have found their way into the thesis. For promoting the notion of the scientific author, as a person on top of her theoretical findings and discussions.

I am ever grateful to Gisle Frøysland who has been formative in my thinking about technology and art. Your insights from the FLOSS-movement and artistic practice are ever relevant and working with Piksel opened the door to the rich and vibrant European media art world. On this note, I also want to extend a thanks to Marco Donnarumma for challenging my concept of interactivity and interface, for teaching me Xth sense, and introducing me to biomusical art.

I am indebted to the numerous talks on the topic of haptics, embodiment, interactivity, interface, extension, augmentations, and art, with Michelle Teran, Johnny Holmvåg, Rolf Guescini, Per Martinsen, Luciana Gattass, Nick Montfort, Servando Barreiro, Judd Morrisey, Espen Gangvik, Talan Memmott, Anne Sofia Karhio, Laetitia Le Chatton, Sylvia Duerr, Øli Parker, Bruno Fractale, Danja Vasiliev, Taras Mashtalir, Álvaro Seiça, Patricia Tomaszek, Kathi Inman Behrens, and Daniela Arriado. And my colleagues and peers at the University of Bergen, Daniel Jung, Henning Skarbø, and Anders Gullestad. A particular thanks to Rob Wittig, for our

talks (and walks) throughout the development and writing of the master thesis, and eventually during the formulation of the PhD project, which have had a great impact on my thinking, particularly the notion of play and interface.

To Elisabeth Døskeland, for allowing me to heal, and get back on track. To Claire, my French guide, for your structured and practical mind helping me take the last important steps towards the end. You have been invaluable.

I also need to send a heartwarming thanks to all my friends, who have been involved in this process from beginning to the end. To Kristine for love and USB. To Thomas for your energy and concern, my big brother from another mother. To Paola and Silje for our shared talks and cheering me on. To Michael Zepf for science fiction insights and letting me be a ninja. To Margrethe Norheim for your generosity, your love and support.

Last, but not least, my family. To my awesome mother, Annlaug Nesheim, for your continuous faith and constant encouragement coupled with strict advice. For understanding the nature of writing and the academic realm. For your heart, soul and mind. I love you. To Anders, dearest brother, for sharing the curious mind, the interest of science and technology, for challenging my thinking bringing in the mindset and practice of the electronic engineer. For ModoSol and technical play. You are forever in my heart. To my love, Stig, for letting me be me, for your support and encouragement, giving me room and time for writing and playing, for generously adding to my pool of knowledge. Now a new chapter begins! And finally, to my two loving daughters, Anna & Sunniva, born during this period of research, for shining bright, offering inspiration and easy access to the realm of love, laughter, and exploration, as a healthy break from abstract thinking. Intelligenz Bureau.

ABSTRACT

The aim of this thesis is to apply new media phenomenological and enactive embodied cognition approaches to explain the role of haptic sensitivity and communication in personal computer environments for productivity. Prior theory has given little attention to the role of haptic senses in influencing cognitive processes, and do not frame the richness of haptic communication in interaction design—as haptic interactivity in HCI has historically tended to be designed and analyzed from a perspective on communication as transmissions, sending and receiving haptic signals. The haptic sense may not only mediate contact confirmation and affirmation, but also rich semiotic and affective messages—yet this is a strong contrast between this inherent ability of haptic perception, and current day support for such haptic communication interfaces.

I therefore ask: How do the haptic senses (touch and proprioception) impact our cognitive faculty when mediated through digital and sensor technologies? How may these insights be employed in interface design to facilitate rich haptic communication?

To answer these questions, I use theoretical close readings that embrace two research fields, new media phenomenology and enactive embodied cognition. The theoretical discussion is supported by neuroscientific evidence, and tested empirically through case studies centered on digital art.

I use these insights to develop the concept of the haptic figura, an analytical tool to frame the communicative qualities of haptic media. The concept gauges rich machine- mediated haptic interactivity and communication in systems with a material solution supporting active haptic perception, and the mediation of semiotic and affective messages that are understood and felt. As such the concept may function as a design tool for developers, but also for media critics evaluating haptic media. The tool is used to frame a discussion on opportunities and shortcomings of haptic interfaces for productivity, differentiating between media systems for the hand and the full body.

ABSTRACT

The significance of this investigation is demonstrating that haptic communication is an underutilized element in personal computer environments for productivity and providing an analytical framework for a more nuanced understanding of haptic communication as enabling the mediation of a range of semiotic and affective messages, beyond notification and confirmation interactivity.

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Touch is not optional for human development. […] From consumer choice to sexual intercourse, from tool use to chronic pain to the process of healing, the genes, cells, and neural circuits involved in the sense of touch have been crucial to creating our unique human experience.

David J. Linden in *Touch* (2016)

INTRODUCTION

The haptic sense, linking sensations of touch, posture, and position, is vast and complex, distributed over our bodies, and extended outwards through movement. It is an inherent component in human experience and consciousness and frames our embodiment. Still, mediation of social communication and productivity primarily uses screens and smooth surfaces lacking texture or tactile cues, and so the visual sense guides and frames our means for navigating information, producing knowledge, managing relationships, and more. Experience is inherently multisensory, our senses do not operate separately or independently of each other, but rather simultaneously. And while our haptic apparatus plays a significant role in human perception, it is currently underemployed in our everyday interaction with computers.

I am investigating how haptic communication and interfaces beyond touch screen surfaces can be integrated into our personal computer environment, setups which today are primarily engaging us via screens, leaving other modalities in the background. This is problematic not only because it neglects the rich multisensory quality of human experience, but also because it affects our sense of embodiment and as a result our cognitive functions. This coincides with the fact that more and more of our daily activities are mediated through the screen. And while haptic interfaces are becoming more sophisticated (i.e. detailed input/feedback devices), we still lack both a precise understanding of how haptic technologies address material, semiotic and affective dimension of communication, and descriptions of how haptic gestures and control can fluently enter current personal computer environments aimed for productivity.

The title *Haptic Media Scenes* aims to frame the specificity of the haptic interface and growing and dynamic field of research on haptic communication. It also points to the unique role of haptic media in engaging performing bodies, mediating tactile and proprioceptive sensations, as well as meaning and affect, as active explorations of space. This is reflected in the use of the case study as a research strategy, analyzing works of digital art exploring haptic experience and sensitivity.

Topic and background

The visual iconography of the graphical user interface (GUI) introduced in the late '70s for desktops, and later laptops, was designed to ease the interaction between human and machine. This interface has framed personal computing environments for decades. Nonetheless, it situated the interactor[1] in a keyboard-mouse-screen hardware setup while leaving much of the body's appreciation for tactile and proprioceptive input unaddressed. Mobile touch screen devices attempt to counter this shortcoming, but as the same icon-based GUI has transcended into the mobile domain of applications, and the hardware interface is a smooth touch screen surface—these devices are still constricting the user from the rich perceptive environment of haptic information.

Many of these shortcomings may be accommodated by engaging our inherent tactile and proprioceptive understanding and appreciation of shape, texture, and locative space and motion in directing goals and solving tasks, and commonplace haptic technologies do exist, embedded in our various touch screen devices. However, these devices' primary interfaces are smooth, non-tactile surfaces. By letting you tap, swipe, trace and pinch, they support single and multi-touch gestural input. But as the surfaces lack sufficient tactile markers, the user must additionally use the sense of sight to navigate. The haptic output repertoire is limited to rather static vibration feedback, mostly used for simple notifications and confirmation, leaving very much to be desired. All in all, we see that visual language dominates the capture and reading of information in such interfaces, whereas haptic interactivity is primarily utilized to navigate and input information, leaving out the richness inherent in haptic communication.

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[1] The term interactor was introduced by Nick Montfort in *Twisty Little Passages: An Approach to Interactive Fiction* (2003), to describe the role of the reader in interactive fiction, as an active contributor to the literary experience. In this dissertation I will use the term interactor more broadly to situate the active participation and contribution in interactive experiences in general.

The extent of active haptic exploration is framed by our embodiment, the ability of our body to engage in sensorimotor couplings with the world. The moment of touch is more than a physical encounter between two bodies, it is also a moment loaded with meaning and emotion. In encounters with media machines, communication is dependent on more than a rich material support for haptic input and haptic feedback, the system also needs to acknowledge the rich semiotic and affective content inherent in haptic interactivity. With digital technologies and availability of sensor technology, hardware and software solutions for active haptic perception for input and feedback is increasingly supported. What is lacking is a shared understanding of what rich haptic communication entails.

Research on haptic interaction is dispersed over several research fields, ranging from human-computer interaction (HCI) and neuroscience, to theoretical treatments in philosophy, sociology, and psychology, and finally in artistic experimentation and reflection. HCI research has emphasized the transmissive qualities of haptic interaction, the mechanical and digital rendering of haptic signals, and has focused less on haptic communication as a nuanced message-carrying activity, involving aspects of affect and semiotics. On the other hand, theoretical reflections often present insufficient insight into the practical aspects of designing a well-functioning haptic device. There are also few descriptions that set the limits and potential for the haptic interfaces, or the extent of haptic communication as a means to address tasks and actions for productivity in multimodal/cross-modal interfaces.

The extent and role of haptic sensitivity in mediating experience is underappreciated in human-computer interaction, and the field is in need of a concept framing haptic communication as well founded materially, and supporting semiotic and affective messages. Haptic interfaces also come with certain limitations and possibilities that need to be framed accordingly.

To successfully understand the potential role of haptic communication in interfaces, we need to source insights across disciplines. This thesis therefore draws upon theoretical insights from new media phenomenology and the enactive-extended embodied cognition framework[2] which argues the active role of the body in shaping cognitive processes. The theory is supported by neuroscientific evidence and reflected in a critical analysis of a series of multimodal interactive artworks.

Outcome and research questions

This thesis study aims to source a cross disciplinary field of research on haptic interactivity, in order to frame rich machine mediated haptic communication, and present potential and limitations in haptic interfaces for productivity. Specifically, I aim to establish a connection between embodied reach and distribution of cognition as theorized in the extended and enactive embodied cognition framework, enactivism and extended functionalism, and the specific role of the haptic perception in cognition.

I address the ability of the haptic sense to mediate not only contact confirmation and affirmation, but also rich semiotic and affective messages—demonstrating the contrast between the inherent ability of haptic perception, and current day support in haptic systems. I use these insights to develop a concept and analytical tool that gauges the richness of haptic communication as a means to help researchers and developers. I will use this tool to frame a discussion on opportunities and shortcomings of haptic interfaces for productivity. By productivity I mean day-to-day tasks and actions we perform, at work and at home, to design and create, produce knowledge, handle information, manage our productions and relationships, which are currently maintained by desktops, laptops, and mobile devices.

Finally, I aim to promote works of digital art as valuable research objects for interrogating haptic sensitivity and mediation. The research and discussion in this thesis are driven by two questions:

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[2] There are several positions in the embodied cognition thesis, rooted in the extent of an agent's embodiment and cognitive reach. The strongest view is proposed by Andy Clark and David Chalmers in the extended mind thesis and enactivism proposed by Shaun Gallagher and Francisco J. Varela. Both positions argue that an agent's cognitive processes are extended and enacted into the environment, beyond the brain and body proper. See chapter 3 for a richer discussion of these positions.

Research question 1: How do the haptic senses (touch and proprioception) impact our cognitive faculty when mediated through digital and sensor technologies?

I will use theories of new media phenomenology to argue that digital and sensor technologies present novel opportunities for extending sense of agency across modalities and space, by means of body schema revisions. I will use theories presented within enactivism and extended functionalism to argue that cognition is not a purely mental activity, but an embodied process, that may be distributed. The first research question is explored and answered in chapter 1, 2 and 3.

Research question 2: How may these insights be employed in interface design to facilitate rich haptic communication?

I will argue that haptic communication needs to be framed in accordance with the material solution of the system and its ability to support haptic perception, as well as delivering semiotic and affective messages. Haptic interfaces will, additionally, need to be scrutinized for the tasks and actions they accommodate to function as useful personal computing environments for productivity. The second research question is answered in chapter 4 and 5.

Theoretical framework and research terminology

The theoretical close reading embraces two research fields, new media phenomenology and enactive embodied cognition, supported by neuroscientific evidence, and tested empirically through case studies centered on digital art.
The phenomenological framework, presented by Merleau-Ponty and actualized for digital media by Mark B.N Hansen, explores and underlines the significance of the body in the study of consciousness, the objects of direct experience, and the structure of experience. The body is a medium of experience, not a material object, which sets the extent of our embodiment.[3] Phenomenology argues the inherently

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[3] Embodiment may be used to discuss all aspects of a phenomenon or thing, the quality of an idea as in "charity is the embodiment of compassion." If not stated otherwise, I will use the term embodiment in the phenomenological sense, to denote the bodily mediation of experience as informed by sensorimotor activity.

active quality of subconscious or even preconscious perception in guiding actions and directing goals, and the permeating role of tactile and proprioceptive sensations in perception. For this reason, phenomenology is no longer a purely theoretical exercise to understand the relationship between bodily experience and the formation of consciousness:
it also becomes key in helping us understand the potential of haptic technologies. Contemporary consumer technologies utilize gesture and touch technologies—haptics are becoming more mainstream. For this reason, phenomenology has something to offer practitioners and theorists of human-computer interaction of today. Equally, the enactive embodied cognition thesis as presented by Shaun Gallagher holds that physical characteristics of the body, techniques and tool-use are shaping cognitive processes, which are significantly influenced in the encounter with digital and sensor technologies.

The theoretical close reading is tested empirically through the use of case study research chapter by chapter. A significant number of the cases are sourced from the art world. Works of digital and electronic art are specifically apt in demonstrating new or innovative uses of haptics and cross-modal interactivity. Artworks are also unique sources for problematizing aspects of human nature and goals of technological innovation less biased by economic forces and policy, and as such a very suitable research object for digital culture.

Adapting insights from so many different research fields begs for a literature review explaining the core terminology I will be using throughout the dissertation, particularly the notions of touch, haptic and haptics. The additional treatment of relevant research terminology relating to ocularcentrism, body schemata, embodied cognition, and theory of interaction and interface will be framed individually in chapters 1-5.

Main findings

In this thesis I demonstrate that screens, while great surfaces for organizing thought and visualizing complexity, are poorer mediators of presence. The mediation of presence depends on the support of rich haptic, not only tactile, perception, beyond visual representation. I build upon the claim that our action potential is set by the body schema, plastic motor control programs that frame bodily reach, and which are influenced by habit, techniques, tools, and technologies (Gallagher 2001,149; Carman 1999, 219), to show that extending haptic perception allows for new sensorimotor couplings, and extends our action potential and allows us new experiences of consciousness.

A key contribution of this thesis is the concept of haptic figura, which I introduce as an analytical tool to frame the communicative qualities of haptic media. Specifically, the concept gauges rich machine mediated haptic interactivity and communication in systems with a material solution supporting active haptic perception, and the mediation of semiotic and affective messages.

I show that there are specific limitations and opportunities inherent in haptic media interfaces with regards to productivity, both in stand-alone systems or integrated in audiovisual mixed reality systems. Certain haptic tasks, pertaining to physical thinking processes, spatial creativity, and gestural control, are best supported by hand interfaces, while experiences of presence in virtual and augmented reality systems benefit from full-body interfaces.

Thesis chapter overview

Haptic Media Scenes consists of five chapters, each centered around a key concept relevant to the discussion on haptic interactivity and communication, which is framed in theory and empirically analyzed in case studies. The conclusion in each chapter sets the premises for the following chapter, but the chapters may also be read individually.

Chapter 1 discusses the concept of ocularcentrism by means of the pervasive screen interface and aims to show how different vision technologies impact the sense of embodiment and mediation of presence.

Chapter 2 introduces the concept of body schemata as theorized in phenomenology. Body schemata are motor-control programs that govern our potential for action, the bodily space. The schemata are not fixed but shaped through processes of confirmation and revision. Tactile and proprioceptive sensations are central to body schema revisions, as a frame for haptic agency and repertoire represented in all sensorimotor coupling with environments. The extent of our embodiment is set by the sense of ownership and agency of actions, and is as such framed by tools, techniques, and technology.

Chapter 3 investigates the concept of embodiment and cognition as extendible, theorized in the embodied cognition framework, and exemplified through cases of technological extension of touch and proprioceptive senses. Embodied cognition argues that there is a deep connection between embodiment and cognition, proposing that not only are a significant amount of cognitive processes inherently embodied, we also use our bodies to strengthen processes of learning and remembering. Our embodiment may be extended beyond the skin border, through the use of tools or via technology as cross-modal mediations, virtual reality or telepresence experiences, and cognitive processes are exteriorized beyond the body with cognitive technologies. However, the limit of embodiment and cognitive distribution is not set. To frame machine mediated haptic communication we still need to set a preliminary border. And in accordance with enact embodied cognition, this border is set at the reach of sense of ownership and agency.

Chapter 4 introduces the concept of haptic figura to frame machine mediated haptic communication. The haptic figura is proposed as an analytical tool for investigating material, semiotic and affective qualities of haptic communication. Haptic materiality is dictating the degree of authenticity of haptic interactions, both in terms of reproducing or mirroring sensory experience and affording rich active haptic perception. The material solution supports the successful transmission of haptic signals, as signs and messages, and potentially, affective content. Haptic semiotics is analyzing the tactile-gestural communication, where the semiotic solution enforces the requirements for moving beyond informational exchange, to a domain of meaning generation and interpretation of haptic messages.

Chapter 5 extends the notion of haptic interactivity and communication to frame haptic interfaces for productivity, the ability to perform desired tasks and actions. The chapter presents relevant design strategies and metaphors and identifies elements of user interactivity suitable for interfaces affording rich haptic communication and productivity. These findings are discussed in three distinct interactive scenarios, the Hand, the Body, and The Sign, each headlining specific opportunities and limitations of different haptic interfaces.

LITERATURE REVIEW

Haptics in Interactive Scenarios

The term *haptic* has been used fairly differently in various research fields over time, and still to this date there is no consistent definition of the term. For this reason, I will offer the reader a short introduction to the concept and its usage before proposing an understanding suitable for the discussion ahead. I will distinguish between haptic (a term both used to denote the sense of touch, and as well as the somesthetic senses), haptic perception (active use of the haptic senses), and haptics—that is, technologies directed at the haptic senses.

Haptic sensitivity: from touch to haptic perception

The history and research on the sense of touch, in philosophy and medical science, from antiquity to the present, is extensive and well deserving of its own treatment,[4] and beyond the scope of the short introduction provided in this literature review. Touch, from being analyzed strictly as a skin sense which responds to external stimuli, has also been an object of philosophical contemplation and reasoning, proposed as the primary source for human experience. Its unique position is understandable. Touch is the only sense that is not centered in one specific location or organ in the body. It is everywhere—close to ubiquitous to our bodies.

Most phenomenological studies of the structure of human experience include an account of bodily, sensory perception, and several scholars have provided us with

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[4] For a longer treatment of the history of touch, I recommend David Parisi's dissertation *Touch Machines: An archeology of haptic interfacing* (2008). Parisi's book *Archeology of Touch: Interfacing with Haptics from Electricity to Computing* (2018) provides a comprehensive treatment of the history of touch and touch technology. Here, Parisi follows research on the haptic apparatus in medical sciences in the 18th, 19th and 20th century, and points to the quantification of the haptic sense seen in the development of haptic technologies (haptics). Equally, he gives the reader an insight into the understanding of haptic and haptics in visual art and media aesthetic research conducted in the last 30 years.

insightful analyzes of the sense of touch. In 1954 Hans Jonas formulated a phenomenology of the senses, arguing for the unique role of touch as a rooting mechanism confirming reality. When we touch, sensing and the sensed coincide, and any illusion is dispelled. As such, sight alone is an insufficient sense conduit to form a meaningful understanding of the world. No matter how extensive the reasoning qualities of our intellect, we need to include touch sense data to fully grasp reality. Jonas concludes that "[t]ouch is the truest test of reality: It can dispel every suspicion of illusion by grasping the doubtful object and trying its reality in terms of the resistance it offers to my efforts to displace it" (Jonas 1954, 516). With the introduction of virtual objects with artificially rendered textures, the claim of touch separating reality from illusion needs to be refined and nuanced. Still, the overall treatment of touch in philosophical settings points to the significance and importance of the sense and offers valid arguments for including tactile sense data in interactive scenarios. But to form a more accurate language of touch interactions, we need to include other areas of study on the sense of touch, such as the work done in the fields of psychophysiology and human-computer interaction.

From touch to haptic

The word haptic first appeared in Max Dessoir's extensive paper "Ȗber den Hautsinn" published in 1892, to suggest a field of medical research on the sense of touch.[5] As pointed out by Titchnerer in his review of the paper the following year, "Dr. Dessoir proposes the word Haptics to cover all cutaneous sensibility with the exception of temperature-sensation." (1893, 76). At this point important pioneering experiments on skin sensitivity had already been conducted by anatomist Ernst Heinrich Weber identifying the two-point threshold on human skin, which is the threshold for discriminating between two individual points of touch, and for the first time establishing a map of the skin (Weber 1851). From Weber's early experimental designs, research on the touch sense in the field of physiology and psychology was

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[5] In the same work Dessoir introduced and coined the term psychophysiology pointing to the interdisciplinary field of physiology and psychology in understanding the human sense of touch.

enriched by several scientists towards the beginning of the 20th century: Max von Frey, continuing Weber's work developed an instrument for identifying pressure points on the skin, as well as policing strict guidelines for experimental methodology (Grunwald & John, 20-21), experimental psychologist Révész offered the initial contribution connecting the haptic sense and blindness (1938), psychologist Katz argued for and proposed a methodology for psycho-physiological research directed at the haptic sense (1925, 1989), Skramlik's comprehensive monograph *The Psychophysiology of the Senses of Touch* provided a detailed overview and presentation almost all haptic and tactile perception studies done to date (1937). Together, these researchers provided us with the foundation for psychophysiological research on the haptic sense.

Haptic vision and visual art

Beyond its introduction in medical sciences in the late 19th century, Austrian art historian Alois Riegl has been attributed the first scholarly introduction of the term haptic. In his foundational work *Late Roman Art Industry* (1901;1985), Riegl introduces the notion of *tactile vision* by distinguishing between tactile and optical modes of representation. The year after, in the article "Late Roman or Oriental" (1902, 1988), Riegl exchanges the term tactile with haptic. The conventional reading of Riegl suggests that he considered all haptic experiences essentially visual. In this view, visual experiences trigger the haptic sense, and the role of the haptic sense is to assist and confirm visual perception. However, as David Parisi pinpoints in reading Riegl's take on sculpture, Riegl in that work explicitly describes the sense of touch as a "pre-dominant" source of perception (2008, 72), which suggests that Riegl does see the haptic sense operating independently of visual cues. This is in contrast, Parisi argues, to the way Riegl's work positions the connection between haptic and vision and how it is referenced and used in visual art, where many art critics and researchers either view the haptic sense as a function of the visual sense, or that the haptic sense, uncritically, is positioned as a remedy to an ocularcentric design regime.

Somesthetic senses: touch, proprioception and haptic sensing

The terminology on touch has become increasingly nuanced in the last 50 years, especially with the expansion of the fields of neuroscience, experimental psychology and psychophysiology. An umbrella term for touch perception in the broadest sense is somesthesis, which includes the skin sense as well as the sense of position and movement of our limbs, often referred to as proprioception.[6] In addition the term haptic is used to define a particular aspect of somesthetic sensing, namely active touch (Robles-De-La-Torre 2006, 27). In 1999, Craig and Rollmann provided a review on somesthesis, which they categorized as the sense of touch, haptic and kinesthesia (sense of movement), sense of temperature, and the sense of pain. In the review they differentiate between the active and passive touch,[7] where haptic is defined as active exploration using the touch sense (314-315), primarily with the use of the hand. Although mentioning the position sense (proprioception) in the introduction, the word never re-appears in the text, and the term proprioception only shows up in references.

A decade later, a second review of studies of the somesthetic senses is given by Hollins (2010). The somesthetic sense now consists of the sense of touch, sense of temperature and sense of pain. Here the touch sense is defined by the following parameters: tactile acuity (originally mapped by the two-point threshold experiment developed by Weber), vibrotraction (dynamic stimulation governed by intensity and pitch), texture perception (feel of surface), perception of location and movement (localization of skin stimulus), affective touch, and tactile attention (inhibition of return, attentional blink). The mention of the term proprioception is missing altogether, except in references. The terms *haptics* is briefly addressed in the introduction as the “study of active exploration (especially) by the hand” (244), referring to the research of Jones & Lederman on sensorimotor perception, again separating passive tactile sensing from active, which is considered haptic (2006). In

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[6] Some researchers differentiate between the sense of limb position as proprioception from the sense of limb movement as kinesthesia. In the following I will use proprioception to account for both sensations.

[7] The distinction between active and passive touch was noted already by Ernst Heinrich Weber (1851).

a neurophysiological review on haptic sensing by Henriques and Soechting haptic sensing is defined as “the extraction of information about an object's properties such as its size, shape, and texture by means of exploratory manual movements” (2005, 3036). What these reviews show us is that in the fields of experimental psychology and physiology the term haptic sense or haptic perception is specifically used to denote active exploration using the sense of touch. Haptic sensing involves more than purely tactile sensations, but also sensations relating to position and movement, namely proprioception.

Linking touch and proprioception

The review above suggests an intimate bond between touch and proprioception that deserves a closer look. Mark Paterson, based on the research of Cole (1995) and Oakley et al (2000), proposes that the haptic is “relating to the sense of touch in all its forms” and lists proprioception and tactile forms of perception among these. Proprioception includes vestibular, kinesthetic, and cutaneous sensations, while the tactile is “pertaining to the cutaneous sense, and more specifically the sensation of pressure (from mechanoreceptors) rather than temperature (thermoreceptors) or pain (nociceptors)” (Paterson 2007, ix). In line with Paterson, Brian Massumi suggests haptic to cover more than the sense of touch. He offers a more nuanced understanding of haptic, which he sees as an interaction between three different sensory states:

> [P]roprioception, defined as the sensibility proper to the muscles and ligaments as opposed to tactile sensibility (which is “exteroceptive”) and visceral sensibility (which is “interoceptive”). Tactility is the sensibility of the skin as surface of contact between the perceiving subject and the perceived object. Proprioception folds tactility into the body, enveloping the skin’s contact with the external world in a dimension of medium depth: between epidermis and viscera.” (Massumi 2002, 58)

Proprioception becomes a significant contributor to the touch sense as it extends the touch dimension from the skin surface outwards into the world and inwards throughout the body. Paterson and Massumi's proposals stand up to experimental scrutiny as well. In a setup led by cognitive scientist Frederique de Vignemont, test subjects were given proprioceptive stimulus (by vibrating the biceps or triceps muscles) on the right upper arm while touching the right index finger on the left one. Depending on whether the biceps or triceps muscles were stimulated the subjects reported that their index finger felt as though it either was elongated or shrunk. The vibration of muscles produced the proprioceptive illusion which resulted in a distorted tactile interpretation of size, suggesting that "tactile perception of an external stimulus is mediated by the proprioceptive representation of the body part that is touched" (Vignemont et al. 2005, 1286). This effect was not equally prominent when the triceps muscles were vibrated, producing the proprioceptive illusion of shrinking the fingers, suggesting we are bound by some body representations or schemata in the direction of growth.

In other words, we have empirical evidence that the sense of touch is highly integrated with the proprioceptive sense, especially regarding the sense of size. But this is far from the only reason why the significant interconnection between touch and proprioception should be acknowledged.

The haptic sense in human-computer interaction

In the fields of computer science and human-computer interaction the haptic sense is often defined by how we can interact with it technologically, in the analysis of design parameters for interacting with and manipulating people and objects. As such the haptic sense is understood in terms of its ability to recognize variances in pressure, stiffness, position, resolution and force magnitude (Tan et al. 1994). This is a rather mechanical approach, which will fail to identify the subtler aspects of human multisensory experience. A less singular and strict definition is offered by researcher and computer scientist Karon Maclean, who uses the term haptic to denote the touch sense, more specifically the ability to recognize texture, temperature, pressure, and pain as well as the ability to interact with the touch sense (2008, 149). Maclean's approach also takes interactive elements of touch sensing into account, but without specifically addressing the role of proprioception. This lack is remedied in a more recent review of tactile and haptic sensing by robotics researchers Silvera-Tawil, Rye and Velonaki, who summarize the complexity quite well:

> The somatosensory system comprises two different subsystems: cutaneous and kinaesthetic [62], [63]. The cutaneous subsystem involves physical contact with the outer surface of the body and generates sensory inputs through receptors embedded in the skin. The kinaesthetic subsystem receives sensory inputs from receptors in muscles, tendons and joints, and provides information about the position and movement of the body and limbs. Typically, the term "tactile" is used to describe conditions affected by the cutaneous subsystem alone, while the term "haptic" is used to describe inputs that combine both the cutaneous and kinaesthetic subsystems. (Silvera-Tawil et al. 2015, 231-232)

In discussing the role of haptic sensitivity in interactive scenarios, I find it suitable and in accordance with this research review to discuss tactile sensations as specifically relating to the skin, and proprioceptive sensing as relating to the sensations of position, posture and limb movement. I will use haptic sensitivity (the ability of the haptic sense to read perceptive cues and signals) to denote the combined tactile and proprioceptive sensing, and the term haptic perception to denote the active exploration of environments and manipulation of objects, using the haptic senses. In Chapter 4, I will offer the reader a more detailed overview of possible parameters for interacting with the haptic sense, suggesting the concept of the haptic figura to understand the material, semiotic and affective qualities of interacting with the haptic sense.

From haptic to haptics: understanding haptic media

We also need to distinguish between haptic and haptics. Whereas haptic refers to the actual sense, haptics stands for the wide range of technologies that are directed towards the haptic senses—input and feedback mechanisms alike—and that are more often labelled as haptic technologies and haptic interfaces. In terms discussing technologies that aim to generate artificial touch and proprioceptive sensations a valuable distinction can be made between noninvasive haptic technologies, invasive haptic stimulation (stimulating the brain or nervous system), and robot haptics where robots are provided with an artificial touch sense, generated by force and tactile sensors (Culbertson et al 2018). In this dissertation, I will primarily be concerned with noninvasive haptic technologies, although valuable insights into haptic interaction are found in research on robot haptics, particularly work on machine recognition of social and affective touch sensations.

The history of haptics may be traced from the early tactile interaction with electricity in the 18th and 19th century, via the development of applications for teleoperations during WW2 as proposed by David Parisi (2008), however, such a treatment is beyond the scope of this review. For the purpose of our discussion, a more recent and suitable origin may be proposed in the development of haptic displays (that utilize force feedback mechanisms), pioneered by Margaret Minsky in her work on texture simulations (Minsky et al. 1990) and continued in Brook's work on haptic displays for scientific visualizations in project GROPE (Brooks et al. 1990). The jump from scientific explorations on haptic technologies to a commercially available haptic interface came with the arrival of Phantom, the first desktop haptic display[8] developed by Sensable Technologies (now Geomagic) in 1996 (Massie & Salisbury 1994; Geomagic 2017). And during the last decade consumers have been presented with trackpads and tactile displays that respond to a wide range of haptic input and gestures, as well as offering a limited haptic feedback repertoire (mainly

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[8] This first and later haptic technologies that offered tactile and proprioceptive feedback over larger surfaces has been labelled displays, which may be confusing as display is primarily associated with visual screen media.

force vibrations). From the mid-90s and increasingly in the 00s, a range of international conferences and workshops have been organized on the topic of haptics, such as IEEE World Haptics, Eurohaptics, and the HAID workshop running from 2006-2013. In recent years the conferences have included contributions from a larger cross-disciplinary field, such as new media art and design, however the majority of contributions are grounded in the fields of neuroscience, psychophysiology, robotics, mechanics, and engineering, as well as computer science (i.e. Eurohaptics[9], World Haptics[10], and Smart Haptics[11]).

While tactile displays and touch screens dominate the market of consumer haptics, both hardware and software solutions have improved significantly in recent years, specifically in the fields of haptic feedback. Haptic glove systems, gestural controllers, and the implementation of haptics in virtual and augmented reality applications, are areas of research that deserve particular attention. In chapter 5, three interactive scenarios, presented under the headings the Hand, the Body, and the Sign, discuss potential and limitations of these new directions in haptics.

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[9] http://eurohaptics2020.org/

[10] http://www.worldhaptics2019.org/

[11] https://www.smart-haptics.com/

1 SCREEN MIRAGE

Oculus Prime and the Haptic Turn

In our everyday life we interact with objects and people using the full extent of our sensory apparatus. All of the senses participate in gathering information that forms the content of our experience. That does not mean that all senses play an equal role, or that the roles stay fixed from experience to experience. Whereas the sense of hearing is not critical in the act of consuming food, it is significant in enjoying a radio show. Many of the devices we engage with are designed to cater to a particular sense. Screens are one such device perfectly designed to entice our visual sense—and they surround us.

I am caught in a daily screen migration routine. Each morning the mobile phone provides me with the status of my network communication: I skim incoming emails and sort them by urgency, before I take a quick scan through my social media news feed. Later, I move to a tablet or laptop for news and general productivity. In between places and sections of the day I revisit the mobile phone, before retreating to a larger screen in the evening for TV-entertainment, gaming, or a wall-projected movie experience. These are my personal screens: close to my body, in my home and workplace, but they are hardly the only screens I engage with throughout a day.

Screens have become the prominent media for information gathering and task handling, not only in our personal life and work situation, but increasingly in every aspect of our daily public lives. Flickering advertisement screens in malls and travel centers, ATMs, screens on vending and ticket machines, and searchable information screens, are but a few of the screen media surfaces I encounter in a day. Screens almost seem to be following us throughout the day. Close up and from a distance, at different ratios, and increasingly ubiquitous, masquerading as mirrors and windows, doors of perception. It seems we have moved on to the next general-purpose artifact, each of which has a dominating feature in human history: from the Stick, to the

Wheel, to the Screen. How have screens come to be the prominent media artifact they are today and what does this entail for us?

Current personal computing interface setups today—either the GUI/WIMP of laptop/desktops or the touch screen of mobile devices as a navigational surface—prioritize the sense of sight, and are as such ocularcentric. Due to the primary position of the screen, these hardware interfaces downplay the role of other bodily senses as preceptors of information. The screen, as currently utilized, promotes certain experiences while demoting others. Still, experiments in the art world demonstrate proprioceptive and haptic qualities of screen media, and the introduction of haptic input and feedback systems shows the broader potential of the screen medium in engaging our somesthetic senses more directly. To answer the question above, I will investigate how screen media affect the sense of embodiment, by analyzing their ocularcentric and haptic properties. More specifically, I will situate the screen in current personal computer interfaces by discussing visuality in connection to screen properties, both material and representational.

This chapter is divided into four main parts: Oculus Prime, the Multiple Screen, Screen Mirage, and the Haptic Turn. Part I presents ocularcentrism as a paradigm for thinking and machine design, as well as discussing possible effects of this paradigm. Part II offers insight into the diversity of screen media, both materially and as representational surfaces. Part III uncovers the lure of the ocularcentric screens; what makes these screens so attractive and yet limiting? Part IV discusses haptic qualities of screen media presenting digital artworks that utilize screens to reveal novel bodily experiences.

1.1 Oculus Prime

Vision technologies, ranging from screens to advances in machine vision, are dominating consumer technology for communication and productivity. Current interfaces of personal computing are highly ocularcentric in nature, meaning that the sense of sight is predominant in how we process content and options of functionality, although our hands are significant assistants in manipulating and navigating within the interface. Beyond the technological limitations at the time of the standardization and commercialization of the PC in the early '80s, or the earlier formalization of first order cybernetics thinking in the mid-’40s, I argue, we can track the origin of this interface design (hardware setup and interface metaphors alike) in a Cartesian tradition of cognition, where sight is considered the main conduit for abstract reasoning and reflection.

Ocularcentrism means the privileging of vision over other senses, and accounts for the prominent role of sight and visual perception and its connection to reason in Western philosophy. Ocularcentrism holds the premise that the sense of sight is primary and the most essential sense for conveying information. Ocularcentrism is already present in Platonic texts, such as in the cave allegory—where enlightenment comes from escaping the shadows by following the light. The sense of sight is connected to reason, enlightenment and thought. Still today, thinking processes leading to realizations and knowledge are gained through *insights*, *enlightenment*, by *seeing* something clear, *focusing*, etc. In 1644 Descartes’ influential work *Principia philosophiae* (Principles of Philosophy) was published, a text which proposes the complete split between mind and body, summarized as *Cogito Ergo Sum* (“I think, therefore I am”), arguing for the disembodiment of thought and reason. This tradition of cognitive thinking, often referred to as Cartesianism, can be seen as an extension of early ocularcentrism, which has had an enormous impact on Western thinking and art, as well as technological development.

Origin of ocularcentrism: distance and surface as an instrument for thought

We may ask ourselves if ocularcentrism is inherent in human culture. We certainly know that it occurred prior to the mind-body dualism proposed by Descartes. It is one thing to distinguish human senses, identifying individual qualities, but another to prioritize one sense at the cost of others. To understand how the sense of sight has attained such a privileged position I first turn to philosopher Hans Jonas. In 1954 he published the study “Nobility of Sight.” Here he outlined a phenomenology in which he analyzes the distinctive qualities and limitations of the various senses individually. For the discussion ahead, it is his insight on the sense of sight which is particularly useful.

Three characteristics make up his definition of the visual sense. Firstly, sight is *simultaneous* as visual sensations from various sources are paired the moment we open our eyes. Likewise, the stream of juxtaposed visual sensations is presented continuously. This is not the case, Jonas argues, with the auditory sense. We hear one thing, then the next in succession, and we have great difficulty in separating different spatial sources of sound. The touch sense, on the other hand, manages to synthesize touch sensations from various sources, but the sensations are still successive.

Secondly, sight *neutralizes cause-effect* relationships because we can choose what, when and if, we want to look at something, and is as such the least realistic of the senses. For this reason, it is a selective sense, and Jonas argues that "from this distinction [between the object in itself and how it affects me] arises the whole idea of theoria and theoretical truth." (Jonas 1954, 515)

A third characteristic, and perhaps most pressing for this discussion, is his claim that sight operates with *distance*. Sight is probably the one sense that doesn't benefit from increasing proximity with the object, as our eyes will struggle to put the object in focus. Sight, as such, is a sense for reflection, a device for theoretical exploration set apart from (or above) the immediacies of the physical world. Jonas gives us an inkling of how sight has been promoted since the renaissance and catered in the development of vision machines. It is the sense of reasoning, of information processing, detached from material and the immediate.

The notion of distance and detachment is also reiterated in the work of historian and philosopher Walter Ong. In his treatment of the transition from spoken word to written text in *Orality and Literacy: The Technologizing of the Word* (1982), Ong notes how we are situated differently to the sense of sight than to auditory sense:

> Sight isolates, sound incorporates. Whereas sight situates the observer outside what he views, at a distance, sound pours into the hearer. Vision dissects, as Merleau-Ponty has observed (1961). Vision comes to a human being from one direction at a time: to look at a room or a landscape, I must

> move my eyes around from one part to another. When I hear, however, I gather sound simultaneously from every direction at once: I am at the center of my auditory world, which envelops me, establishing me at a kind of core of sensation and existence. (42)

Ong continues to explain how these qualities of sight become particularly articulated in the process of writing, because "[w]riting separates the knower from the known and thus sets up conditions for 'objectivity', in the sense of personal disengagement or distancing." (45) So, not only does it seem to be an inherent quality of the visual sense to promote abstraction and objectivity due to the distance it places between subject and object, me and the world. There is also reason to suggest that the distance is exaggerated with writing, as the visuality of writing on a flat surface leads to a distance between reader and text (viewer and screen), a place of separation and analysis, whereas speech (sound) harmonizes and integrates.[12]

The idea that the visual first became distanced from the body senses when we began using flat surfaces to show images and text is supported in the work of Barbara Tversky. She discusses how different visualization strategies have been implemented throughout time to collectively present and structure thought, starting with a group of hominids living 750,000 years ago. In contrast to speech and gestures which only exist in situ, visual representation on two-dimensional surfaces offers novel opportunities for organizing though. As she states:

> [P]aper, silk, parchment, wood, stone, or screen, are more permanent; they can be inspected and reinspected. Because they persist, they can be subjected to myriad perceptual processes: Compare, contrast, assess similarity, distance, direction, shape, and size, reverse figure and ground, rotate, group and regroup; that is, they can be mentally assessed and rearranged in multiple ways that contribute to understanding, inference, and insight. (2010, 500)

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[12] It is worth noting that while Jonas and Ong seem to agree on sight being a distancing sense, they are occupied with different aspects of sound. Jonas discusses how sound may never be a distancing sense as we cannot turn it off—we hear continuously as vibrations hit our ears, one after the other in sequence. Ong, on the other hand, is preoccupied with the omnidirectional quality and, consequently, harmonizing effect of hearing. We hear from all directions at the same time, as opposed to vision, which is framed by the direction of our gaze.

It is not only because these articulations could be stored in a record that the method of visual representation rose to such a specific position, it has also to do with the spatial qualities of visualizations, Tversky argues:

> [T]hey allow human agility in visual-spatial processing and inference to be applied to visual-spatial information and to metaphorically spatially abstract information. In contrast to purely symbolic words, visual communications can convey some content and structure directly. They do this in part by using elements, marks on a page, virtual or actual, and spatial relations, proximity and place on a page, to convey literal and metaphoric elements and relations. (502)

This suggests that not only is sight a distancing sense that stimulates objective reasoning, this ability of abstraction also seems to be accentuated in processes of visualization. Already present as a strategy in early hominin culture for organizing life and sharing plans, these processes show how inherent the foregrounding of visual representation is in structuring thought. It definitely suggests that ocularcentrism has old roots, and also gives us a first idea why screen media has become so powerful and ubiquitous. However, beyond visualization as a method for thinking, moving into the middle of the 20th century, an additional layer was added to the ocularcentric lens, namely that of thought and information as disembodied entities.

Cybernetics and visual perception

While ocularcentrism is well-rooted in society, it is in the early concept and design of media devices and computers in the ‘40s informed by cybernetics that its influence becomes obvious. Cybernetics, which connects the idea of the feedback loop with the concept of information flow, was first formulated during the Macy conferences running from 1943-1954. Here prominent and influential scholars across disciplines discussed and presented papers on the nature of systems and communication between systems formulating a new paradigm for understanding interactions between man and machine. In *How We Became Posthuman* N. Katherine Hayles identifies how key contributions from selected scholars built the first cybernetic lens, giving rise to an intellectual paradigm that views man and machine as information processing entities (1999).[13] From Claude Shannon (1953) came a theory of information which advanced a view of information as non-material patterns without meaning, Warren McCulloch and Wlater Pitts provided a concept of neurons as networked system for information processing (1943), and John Von Neumann's theory of cellular automata (Von Neumann and Burks 1966), as well as his architecture of the digital computer, became a proof of concept. The man with the vision largely responsible for assembling the lens was Norman Wiener. During the first and the consecutive conferences, a corpus of a first order cybernetics perspective was formed, where systems were conceived as informationally closed (no information would enter the system from the outside) and homeostatic (self-sustaining and able to self-regulate through feedback loops). In extension, all mechanical, electrical, and even biological systems were viewed through this cybernetic lens. The machine as well as the human brain were considered closed systems that regulate themselves via feedback loops. The system could be observed from the environment outside, but the environment did not influence the system.

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[13] In her book, Hayles identifies three waves of the cybernetic movement leading up to the late 90s and the date of the publication. The first cybernetic wave, retrospectively labelled 1. order cybernetics, ran from 1945-1960. Here the main focus was on the concept of *homeostasis* viewing man and machines as informationally closed, self-regulating systems. In the 60s the concept of *reflexivity* was introduced in cybernetic thinking through the contributions of von Foerster (observing systems), Maturana and Varela (autopoiesis), as well as Luhmann (system theory), and redefined cybernetics. Reflexivity as a concept introduced a second-order of cybernetics. It proposed that the environment, thought of as the observer of the system, affects the system, and is in turn a system that can be observed. Autopoietic theory proposed that events outside a system were able to trigger events within, but system and environment were nonetheless separated by boundaries through which no information could pass through. System can self-organize, but it cannot experience anything outside the system, only its systemic organization. Information and meaning is reconnected, but only within the system, as reflexive loops. The idea of reflexivity was not particularly welcomed by the science of physics community as it severely threatened the notion of objectivity in the system to be observed. In the 1980s a third wave of cybernetics came about centered around the concept of *emergence* and *virtuality*. From viewing self-organization of systems as production of internal organization, self-organization was seen as emergence. Hayles extends the history of the cybernetic movement with her contribution in the reference book *Critical Terms for Media Studies* (Hayles 2010). She proposes a fourth wave of cybernetics that began in the 2000s emphasizing the notion of *mixed reality* - the merging of virtual and real environments. Finally, she suggests a third wave of cybernetics is coming about focusing on the construction of the observer in social and linguistic environments, powered by the onset of networked technologies and mixed reality environments.

This perspective was embraced by engineers and system theorists alike and supplanted itself in machine design and early artificial intelligence theory.

Hayles identifies the theoretical mechanism that allowed us to arrive at the concept of bodiless information as the *platonic form* (1999, 12). The platonic form consists of two moves. First, the platonic backhand, where one reduces the complexity and messiness of the world to simplified, abstract forms. The second move, the platonic forehand, which is also the more problematic move, arises when we then theorize that the simplified abstraction is the original form of reality from which complexity forms. As such, materiality is a question of instantiation. This mechanism promoted thinking of both machines and humans as closed information systems/processors, where the body functions as a mere sensory organ providing the brain with data for internal processing and concluding: Descartes' split set in practice.

Media theorist Mark B.N. Hansen follows the impact of first order cybernetics and discusses how the ocularcentric premise in system design notably manifests itself in the conceptualization of and experimentation with early virtual reality technologies (the head-mounted displays, in particular). He tracks how psychologist J.J. Gibson's work on visual perception and the concept of affordances and perceptual invariants (Gibson 1950, 1977), is presented as an argument that (virtual) reality can be presented via the visual sense alone, and argues that there exists a "deep connection between linking the privileged role of vision with the desire to explain 'reality' in terms of information (or, more precisely, informational exchange between system and environment). In both cases, what is left out is the grounding role played by the body and by experiential modalities—tactility, proprioception, internal kinesthesia—proper to it" (Hansen 2006, 118). The onset of personal computers in the '80s equally foregrounded visual presentation and iconography as the main mediators of information, via the WIMP/GUI setup.[14] Even today, sensory data acquired by, and feedback given from, touch and proprioceptive senses are not

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[14] In human computer interaction design, WIMP refers to user interfaces which utilizes Windows, Icons, Menus, and Pointers. WIMP is a type of GUI, a Graphical User Interface, and the WIMP/GUI setup became the predominant user interface for personal computers.

particularly developed for personal computer environments, even though we see a rise in ambient and wearable technologies that monitor selected body features. We do tap, swipe and pinch to navigate our devices, and health apps and similar monitoring devices are equipped with bio sensors that measure our steps, pulse, temperature, moisture levels and movement patterns. But much of our active interaction with computers is offered at the mercy of the screen, even more so with touch-sensitive screens, where content and functionality, the representational and the navigational layer, is presented via the one and the same surface.

The ocularcentric regime extends itself into the very production of images we access through our screens. Maybe we don't expect these representations to be reworked or adjusted in any way. Yet much of their construction is digital. The framing, the capturing, the presentation, the distribution and embedding of the image is happening outside the realm of the human observer. Through 3D imaging techniques, simulation programs, virtual reality environments, face recognition and tracking-mapping technology we are presented with visual landscapes beyond our inherent perceptive range. In short, not only are screen technologies the main interface for social, entertainment and data handling purposes, vision itself is on the verge of becoming machinic, automated,[15] or even algorithmic in that we use digital technologies to see and to explore the world.

The machine eye

Galileo Galilei pointed his telescope at the sky and identified the Jovian Moons, and the rugged surfaces of our own natural satellite. The mechanical extension of sight gave Galileo access to new worlds. Four centuries later using NASA's interactive real-time technology *Eyes on the Solar System,* we can follow the spacecraft *Juno* as it orbits Jupiter with the option to filter the image feed to include readings of the magnetic field, aurorae, and the radiation belt of the gas giant (Greicius 2015). All

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[15] In *New Philosophy for New Media*, Mark B.N. Hansen distinguishes between *machinic* (borrowed from Deleuze) and *automated vision* (borrowed from Virilio), where machinic vision points to cases where digital technology extends human vision beyond "the organic-physiological constraints of human embodiment" and an automation of vision refers to the replacement of human vision by scientific and military instruments, as well as other visual prostheses (Hansen 2004, 99).

this is presently available to you via a screen connected to the internet. Likewise, with the development of electron microscope technology we can see cells and even atoms. The development of vision technologies to extend our sense of sight by giving us access to remote objects and translating data into our visual range, has not only increased our scientific understanding, it has boosted human experience. However, given the highly multisensory quality of our perception, we need to acknowledge the impact of technologies set to promote and extend specific senses, while disregarding others.

Second sight

With a starting point in phenomenology, philosopher Don Ihde describes our experience as consisting of *whole-body perception*, that our "experience of some object that is seen is simultaneously and constantly also an experience that is structured by all the senses" (Ihde 2002, 38). Yet, he argues, in science practices machine-mediated visualization strategies are so embedded, that our whole-body perception becomes unbalanced. This shift to technological visualism in science, with its origin in the renaissance and the development of perspective painting, is traced back to the late 15th century to the works of Leonardo Da Vinci and Galileo Galilei, and the shift is twofold. Vision becomes the prime sense in science, and at the same time a specific type of vision is favored. Idhe states: "the shift to vision is an enhancement of the visual over and above and often to the detriment of either full perceptual or nonvisual perceptions" (41). This development is continued today, where whole fields of science require the aid of a "second sight" which extends and enhances analog vision, i.e to make visible distant or small objects, or technically translate non-perceivable data into our visual range. However, this embedding of visualization is extending beyond science practice into our everyday life, through our interaction with the computational devices we carry with us.

Automated vision

Computer vision[16] is becoming a commonplace expression, signifying algorithms tailored to let the computer capture and interpret the physical world. We teach the machine how to see and read natural phenomena and human features, modify the content before it is (re)presented to us. The machine is now involved in the production and dissemination of algorithmic images from the widespread use of filters in selfies, to becoming the all-seeing eye recognizing facial features, postures and movements in databases and streams. We are offered an edited version of reality on screen, and this has an impact.

Hansen, paraphrasing French media critic Paul Virilio, states that the body is not natural, rather it is "an index of the impact of technological change: the body *as it coevolves with technology*, and specifically, *as it undergoes self-modification through its encounter with automated vision*" (2004, 102). Here, Hansen points to the specific role of vision and the impact it has on the body perception proper, as it is modified by current vision technologies. Something has changed since the shift to technological visualism in the 15th century as identified by Ihde. Hansen continues: "In contrast to earlier technology like the telescope and the microscope (not to mention cinema itself), which function by *extending* [my emphasis] the physical capacities of the body, contemporary vision machines bypass our physiology (and its constitutive limits) entirely." The danger, he continues, is loss of significance: "what we face in today's vision-machines is the threat of *total* irrelevance: because our bodies cannot keep pace with the speed of (technical) vision, we literally cannot see what the machine can see, and we thus risk being left out of the perceptual loop altogether." (103) Beyond form-factor and interface constraints in vision technologies, we are becoming increasingly unaware of the automated and algorithmic editing of content presented to our personal screens. With the

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[16] Computer vision and machine vision are often used interchangeably. While machine vision denotes the general use of machines to extend vision, ranging from the analog to the digital, computer vision is specifically tied to the computer, and the option of programmability involved in capture and interpretation of image and video.

development of algorithms such as deep video analysis[17] and camouflage technology[18] the camera feed on your screen might be severely edited and present a significantly altered or filtered representation of an event. We are training machines to see for us, identify and track objects, and in return we are given a summary via our screens. They offer us the hidden and imperceptible translated into a visual image. Through our engagement with vision technologies we seem to carry out a balancing act between extending the range of perception versus replacing human vision altogether. By developing vision machines that cater to the eyes alone, neglecting or even overriding non-visual sensory input, we might lose the ability to see and grasp what is presented to us.

Screen essentialism

Many of us find it difficult to imagine a computer without a screen. Or more specifically—to imagine how to interact with a computer without a screen. As we move from laptops with keyboards to tablets and mobile touch screens, screens are becoming the primary interface for engaging with a computer.

In 2004 computer scientist and code poet Nick Montfort gave a talk at the MLA convention where he introduced the term screen essentialism to describe the position of new media critics to understand computers as essentially screen-based (Montfort 2004). Through his extensive practice and production of code artworks and programs, Montfort states that although screens now have become fixed in productive and creative computing environments, computers have, historically, been conceived without a screen. By addressing several artworks and programs created and running on screen-less computers, Montfort invited his audience to reconsider what a computer is and can be in terms of materiality, and more specifically, in terms of the creative production of electronic literature. Associate professor of

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[17] Deep video analysis, e.g. *Deep Fake,* are machine learning tools for inserting visual elements and mapping them onto existing video footage. Deep Fake, in particular, allows you to replace a face of someone with another in a video.

[18] There are several projects devoted to the development of camouflage technology. The camouflage research group at MIT focuses on how to hide 3D objects that can adopt the appearance of various backgrounds presented via photographs and camera feeds. http://camouflage.csail.mit.edu/

English at the University of South Carolina Upstate, George Williams, extends Montfort's point arguing that screen essentialism is not only a historical perspective, it is very much present today and defines how interfaces are designed and conceived and used. He elaborates:

> Montfort points out that screen essentialism obscures the diversity of computing interfaces that have existed prior to the appearance of the modern electronic screen; in particular, as he describes, early computing programs relied on paper interfaces. Montfort's point is historical, but screen essentialism also obscures the diversity of contemporary interfaces used by people with disabilities and, increasingly, by all people. (Williams, 2012)

Screens are without doubt the dominant feature of personal computing environments today, whether it is a laptop, a phone or a watch. It is becoming essential to the point we have difficulties contemplating engaging with a machine without it. I argue that the core of this essentialism is rooted in early ocularcentrism and strengthened within the paradigm of first order cybernetic thinking. However, not all screens are ocularcentric and many engage our multisensory perception. In order to navigate between all these different screens, we need to get closer to the material and, in extension, representative qualities of the screen.

1.2 The Multiple Screen

Screens have over time come to signify a range of qualities and objects and are not that easy to define. A quick dive into popular encyclopedias and dictionaries[19] reveals a range of definitions in which the screen is equated with processes of concealment, selection and filtering, as well as being designated an object of separation, a selector or a surface. In his ongoing research to compile a history of the screen platform, media archeologist Erkki Huhtamo scrutinizes the screen media within its historical context and current cultural use (2004). Specifically, he

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[19] Oxford Dictionary, Collins English Dictionary, Random House Kernerman Webster's College Dictionary, Merriam Webster Dictionary. The American Heritage® Dictionary of the English Language.

distinguishes public screen practices from private ones and seeks to pinpoint how the materiality and cultural context of different screen media technology has cultivated distinctive practices. By following the migration of the meaning of the word *screen*, first appearing in dictionaries in the 14-16th centuries, to denote wall dividers, translucent hand-held picture-frames (folding screens), and fire shields—objects pertaining to the domestic and private world—Huhtamo notes that in the 1810 Oxford English dictionary, screens are defined as the projection surfaces used in the public mechanic magic lantern show *Phantasmagoria* (40). From this first divide, Huhtamo starts drawing a historical line between screens used within the privacy of the home and publicly accessible screens. In addition to tracing screen practice within the private and public sphere, he notes that screen practice within the home is not always personal, but often shared (as with the introduction of television). Equally, many public screens are used by only one person at the time, e.g. public peep show installations.

As this short introduction aims to demonstrate, screens are so many different things, and location, situation, as well as cultural and historical setting all influence their significance and purpose. If we are to navigate screen media and move on to identify specific ocularcentric qualities of such media, we need a guiding principle. I propose we start by distinguishing between screen materiality (the media platform) and the representation (screen metaphors) of the screen. These two approaches are discussed below in the Material Screen and Screen Metaphor sections, respectively.

The Material Screen

The material composition of the screen is informed by many factors. A taxonomy of screen platforms could be developed by differentiating various simple projection systems from computers whose surfaces operate as projectors, viewfinders for cameras, or interface and interaction surfaces—all of them screens as such in themselves. Another approach is analyzing screens in terms of the spaces they occupy, and discriminate private screens (desktop/laptop or phone screens) from ones that are more public in nature (information, advertising or propaganda screens). Some screens are aimed at interior spaces such as galleries and cinema environments, others are featured in exterior/urban spaces (public interactive installations, telepresence or projection mapping events). However, an important distinction, and the one I will advocate, is set between the hardware and software system in itself, the screen material, and the content it presents, mediates, and most certainly shapes. This distinction is pursued by several media theorists. Media critic and researcher Ian Bogost argues that an investigation of various screen types and their specific properties needs to be part of any screen media analysis, in particular, the screen technology itself needs to be considered separately from its applications and the computer that runs it. In a 2012 mailing list discussion on screens hosted and facilitated by the -empyre- community,[20] Bogost states that:

> We need to attend both to the screen-as-concept and the specific screens that actually exist in the material world, and the complex relations of influence among them" as "the tendency to take the screen for the entire apparatus is a convenient metonymy, a nice shorthand in conversation, but it shouldn't (any longer) be a sufficient method to talk about the specifics of different technologies of representation. (2012a)

Together with Montfort, Bogost has initiated the book series Platform Studies[21] "to invite focused analyzes of specific platforms (computer platforms, in our case), and the relationship between the unique, and often very weird specifics of those platforms, and their influence on creativity and culture"(2012b). One of books in the series, dedicated to the Atari video computer system (Montfort and Bogost 2009), explores how the material properties of the phosphor screen, and limitations in computer processing power, presented constraints that radically informed the

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[20] -empyre is a global network of curators, theorists, scholars and artists engaging in monthly discussions on topics related to the field of media art and digital culture. The discussions are facilitated by selected hosts and commenced in a mailing list format. http://empyre.library.cornell.edu/

[21] Platform studies is a MIT Press book series which seeks to investigate the specifics of various hardware and software systems, and creative works produced with them. http://platformstudies.com/

games made for the system. The ghost of McLuhan (1964) appears, reminding us of the formative qualities of the medium.

Perception of material

The perception of media content definitely depends on the screen material. While projection systems dominate in the presentation of content in larger show settings such as cinema, art exhibitions, and festivals, the most common screen platforms today are flat panel displays utilizing LCD, plasma or LED technologies for representing pixels. These computer screens project light toward the eye, in the additive RGB color format, matching trichromatic color vision held by humans, and most primates (Rowe 2002). Screen development in this area is primarily focusing on increased pixel resolution, frame size and thinness, as well as bendability of the screen surface.[22]

This material design makes up the majority of screens used in personal computing today, from desktops and laptops, to tablets and phones. And despite variation in size, all of these screens are intended to present content similarly. Diverse screen material can present similar content, but the perceptive qualities will differ. And while we may have temporarily agreed upon the material setup for widespread screen use, there is value in examining alternatives that seek to challenge or at least extend this norm. The effect of screen material on media content has been theorized broadly, but there is also significant value in analyzing artistic demonstrations of screen media. When not restricted by demands for commercial application the significance of screen material can be investigated more freely. This can be seen in several of the works of artist duo Kimchi and Chips (Son and Woods n.d.), who challenge the notion of screen surface and components, making design decisions that radically inform the perception of content.

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[22] But also an increasing support for haptic input and feedback.

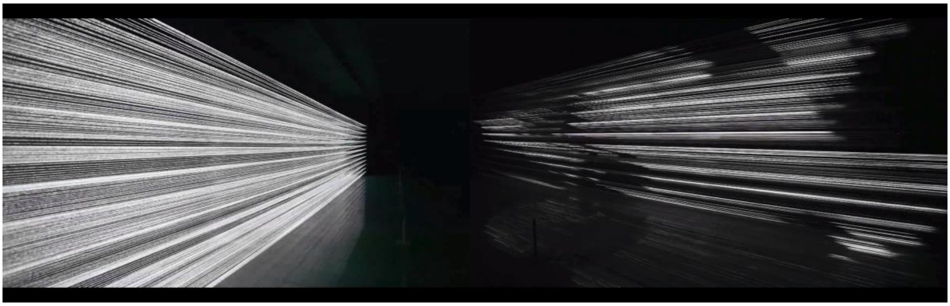

Figure 1 and 2. Screenshot from video documenting *483 Lines* (2014) by Kimchi and Chips. Courtesy of artists.

The artwork *483 Lines* (2014) is an analog projection system, where 483 nylon strings make up a media surface for projection. The number 483 corresponds to the visible scan lines—the number of lines of light—that constitute the image of a television screen utilizing the analog NTSC (National Television System Committee) standard. In *483 Lines,* Kimchi and Chips widen the analog video picture to 16 meters and simultaneously fold the image vertically to fit the gallery space. A video projection is fine tuned to map each of these lines, producing a layered image consisting 483 lines of video that can be viewed individually or in totality. Folded and layered imagery makes the video feed difficult to read as full format linear narrative. On the other end, it proposes that screen content can be presented spatially in novel ways, opening the doors for perceiving and experiencing visual content.

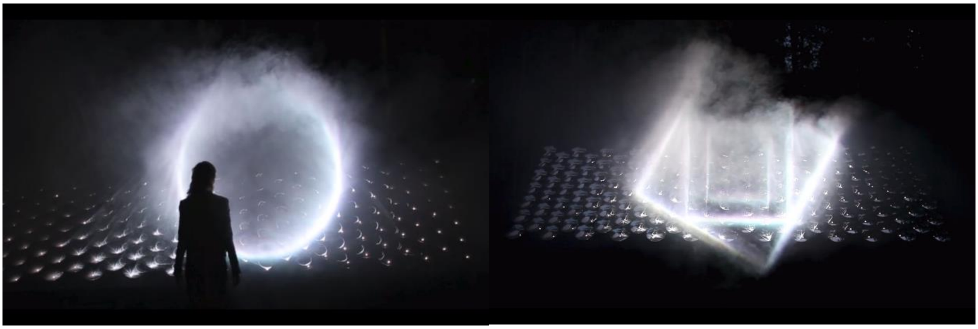

Figure 3 and 4. Screenshot from video documentation of *Light Barrier* (2014) by Kimchi and Chips. Courtesy of artists.

In *Light Barrier* (2014) the notion of screen material is taken further. Light is carefully directed towards a matrix of convex mirrors. Combined with water steam, the installation offers dreamlike manifestations. The screen appears a mirage or an ever-evolving phantom image. Again, the artists challenge what visual representations on a surface may be.

Kimchi and Chips' works show that the material foundations constituting screens are manifold, and certainly allow for a range of multisensory experiences. Strings and steam are but two alternative hardware solutions for disseminating content, and while admitting both these setups cater to specific media messages, as well as offering limited usability in terms of productivity—they do remind us of the diversity of screen material and its varied impact. Not only is the media content informed by the platform, it also directs how we interact with and use the platform. These and similar works demonstrate how projection systems present us with the opportunity to shape our own screen frame. But in personal computing environments, and even in show arenas and exhibition spaces utilizing screen projection, we somehow keep on returning to the flat rectangular shape. Why is this the case?

The natural field of view and the rectangle

The question of how screen proximity and screen sizes affect the sense of embodiment is a complex one, however there seems to be a relationship between common screen sizes and our natural field of view. Given the various screen formats we engage with on a daily basis, what happens when the aspect ratio of the screen extends the field of view? The natural field of view (f.o.v) of humans[23] when eyes are stationary, extends about 190° horizontally (up to 290° when allowed to wander) and 135° vertically (Howard and Rogers 1995, 32). Our binocular field makes up 114° horizontally. This is our general visual aspect ratio. I note that the traditional TV and video formats, as well as the traditional viewfinder and image format of traditional still cameras, approximate the aspect ratio of our unaided f.o.v., matching visual perception without having to move our heads and body. The width of computer screens has increased in the last decades, partly to accommodate program menus, but also, I imagine, to better present visual narratives in films and games. This is akin to cinematic canvas, which most often are horizontal widescreens. The widescreen format will encourage head movements to a larger degree. While more specialized screen formats exist for use in museum settings and galleries, screens intended for the personal computer environments are given a more general shape due to the variety of functionality they are to present to the individual user. Presently, such screens will arrive in 4-5 main sizes with similar aspect ratio—mobile, tablet, laptop, desktop monitor and TVs, all pertaining to a 16:9 16:10 ratio, many allowing for both vertical and horizontal rotation. These are our everyday screens, close to becoming ubiquitous to us. And again, the artists are there, to remind us of our everyday engagement.

In the work *Popular Screen Sizes (60", 55", 46", 40", 32", 27", 24", 21", 19", 17", 15", 13", 11", 9.7", 7", 4", 3.5")* artist Rafaël Rozendaal presents the interactor with a set of mirror surfaces representing the most common media surfaces we engage with on a daily basis. All of the surfaces are rectangular, and the choice to present the various screen sizes as mirrors with reflective surfaces is an intriguing one. Not only does it become striking how prevalent the rectangle is, the mirrors mimicking screens

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[23] Perhaps *unaided field of view* is a more precise description as so much of our experienced view of the world is an enhanced, extended, skewed representation offered by technology (the extension of the human field of view through spectacles, telescopes, and microscopes and camera software applications).

become closed-loop surfaces that merely reflect our world back to us, in various frames, but always at the same scale.

Figure 5 and 6. Rafaël Rozendaal's installation *Popular Screen Sizes (60", 55", 46", 40", 32", 27", 24", 21", 19", 17", 15", 13", 11", 9.7", 7", 4", 3.5")* (2011). Photos courtesy of Nordin Gallery.

The work suggests what kind of media content the different sizes affords. Simultaneously, it reflects and frames fragments of the gallery backdrop and turns the mirrors into a set of live images, defined by the interactor's position and movement. As such, the artist explores the screen as a shape that actively participates in our perception, to the extent that we lose awareness of it. By presenting these shapes as a collective in a gallery setting, we are invited to recognize their place in our everyday lives. The geometrical shape of the screen has followed us for centuries and is becoming ever more present. How often do we not imagine our productions and present the results of them in the same rectangular surfaces that we first began to explore them through? There seems to be a framing of ideas, and a fitting of the ideas within the frame. PowerPoint presentations are an obvious example, however I imagine that the rectangular conditioning is deeper than that, considering book formats, landscape paintings, and (papyrus) scrolls, perhaps traceable all the way back to the first hominis letting the natural field of view set the frames of the visualization.

Media critic Lev Manovich considers a screen any "flat, rectangular surface positioned at some distance from the eyes—[where] the user experiences the illusion of navigating through virtual spaces, of being physically present somewhere else” (Manovich 2001, 99). This not only includes the multitude of computer displays and TVs in contemporary culture, but any framed surface that invites the spectator elsewhere or beyond the physical structure, material or space of the surface. And thus, every painting or drawing becomes a potential screen. Perhaps even theatrical stages, amfi or street theater stages may be considered screens in this context? As presented, the screen is any frame that encloses and separates the real from the virtual. Manovich offers his own hierarchical, top-down taxonomy of screens, based on how the framed surface presents visual information and negotiates between “two absolutely different spaces that somehow coexist.” The most general screen is the *classical screen;* static and fixed in our normal space and acting as a window into an equally fixed representative space where the difference is perceivable in terms of scale, color palette, or abstraction. He includes painting and still photography, as well as static computer displays in this category. A subtype of the classical screen is the *dynamic screen*. This screen type has, in addition to the aforementioned qualities, the ability to display different visual information over time, albeit sequentially, and encompasses the single channel view beginning with cinema and the later TV screens. With computers and VR systems, new opportunities have arisen in screen mediation, content can be presented in real-time and in multi-channel views (the windowed computer screen or the many TV channels that one can swap between in one viewing), disrupting the sequential, single view of events that have occurred in the past. These new screens constitute a third type of screen, after the classical and dynamic screen, labelled *the screen of real time*. The subtype of real time screens are interactive screens, where the users may influence the image sequence displayed. Manovich uses radar as an example, but I imagine all use and display of mapping and tracking technologies would apply when displayed.

Our fixation with rectangles in screen media systems is not new. As Manovich correctly points out this form can be traced to early camera projects systems. Even though history has provided us with exceptions, i.e. the round televisions sets of the early ‘50s or current takes on creating curved TV sets (which still must be considered rectangular), screens and the default layout of projected images have been and are predominantly rectangular in shape. Manovich's hierarchy gives us insight into the historical development of screens, however, he does not clearly separate between imaging technologies, various display media and the suggested screen types in his outline. Manovich's emphasis on the screen's function of framing a virtual space against a physical space, appears rather *either-or,* and discourages the classification of augmented reality screen applications where the layering of the virtual on top of the physical/actual in one screen representation. Secondly, Manovich's insistence on screen as a rectangular, flat surface is problematic. This classification works rather well for paintings and cinema, but with the plethora of interactive computer screens and VR-experiences, the definition makes less sense. In fact, the introduction of virtual reality technologies forces Manovich to conclude that the screen has disappeared because, he claims, it overlaps our field of view (101). Using the terminology of immediacy and hypermediacy introduced by Bolter and Grusin (2000, 20-52), this it would mean that only hypermediate media, media where the interface or point of reference is visible to the user, are screen media. Immediate media are something else, which aim to hide the medium from its interactors altogether. Still, Manovich acknowledges a connection between screens and VR. He analyzes the relationship between subject and screen media—ranging from the camera obscura, cinema to the computer screen, and suggests that the subject is somewhat captured by the screen's representational space, fixing our gaze, immobilizing our bodies. Virtual reality technologies, he states, "continues the screen's tradition of viewer immobility by fastening the body to a machine, while at the same time it creates an unprecedented new condition, requiring the viewer to move" (Manovich 2001, 111). Even if the screen has disappeared it still captivates us. This connection between increasing and overlapping field-of-view and bodily immobility is acknowledged by several theorists.

Media archaeologist Huhtamo notes a parallel between an interactor's body when engaging with peep devices[24] and virtual reality technologies (specifically VR-

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[24] Peep devices are optical display machines designed as boxes with view holes for individual viewing. Including peep shows in which the boxes contained images, or motion picture devices such as the Kinetoscope (Bellis 2019) and Mutoscope (Robinson 1996, 56), or even early stereoscopic photography

solutions involving head-mounted-displays). Other than asking if both media technologies are allowing the viewer to "escape from the body's physical confines by fleeting to some immaterial mode existence" (18), he does not dig deeper into this correlation. It appears, though, that screens that encircle the eyes generally seem to divorce the interactor from the body, as the body isn't addressed or specifically targeted in these primarily visual narratives. This might suggest that these vision technologies more easily promote disembodiment.

Both Manovich and Huhtamo suggest that VR technologies which enclose the eyes disrupt the interactor's sense of embodiment. While Manovich suggests there is a conflict between the screen's ability to immobilize the interactor and virtual reality narrative's incentive to make the interactor move,[25] Huhtamo advances the idea that such technologies offer out-of-body experiences. I will argue that both suggestions are legitimate, and that the notion of disembodiment is connected to the interactor's ability to orient their bodies within the screen space. Something happens when we lose contact with the screen frame, as screens extend beyond our field-of-view or enclose them. In the following, we will discuss the former premise, while the latter will be the topic of discussion in the third section: Screen Mirage.

The expanding field of view

The classical cinematic experience is traditionally understood as big canvas movie projections intended for large, seated audiences. The big screen is meant to engulf you, engage your imagination and invite you into its narrative. Still, it is mainly a story for your eyes and in extension your mind. You are to remain seated, enthralled, while your mind wanders. Only slight head movements are needed to see the whole screen. While cinema is essentially a non-interactive, broadcasting media, techniques from virtual reality technologies, such as stereoscopic imaging,[26] are

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presented within installations supporting several individual viewing stations such as the Kaiserpanorama (Luhmann, n.d.)

[25] By presenting a three-dimensional space which affords exploration through movement, few VR systems offer much more than tracking of the head as a means to navigate the virtual space.

[26] Stereoscopic imaging was introduced for home cinema setups in 3D TVs, but never gained popularity. Its failure was not only due to the expensive equipment needed to display 3D content. It also demanded an extreme finetuning, in positioning of equipment and furniture, to optimize the viewing environment for the

presently being introduced into the cinematic setup to extend the notion of reality and or presence. Further attempts to challenge the one-sidedness and immobility of cinema is explored within the field of expanded cinema which accounts for a range of formats and techniques arriving from film and performance and virtual interactivity. As Tate defines it, expanded cinema denotes “film, video, multi-media performance or an immersive environment that pushes the boundaries of cinema and rejects the traditional one-way relationship between the audience and the screen” (Tate 2018). The notion of interactivity is key, we are to engage with the narrative and place in which it is set. However, to allow the immobilized body to be re-engaged, and addressed, the expanded cinematic experience must go beyond the act of extending the field of vision. Interactivity should entail bodily movement.

Beyond the field of view

How far and how wide can the screen be before its character changes radically? There is a significant difference between the handheld smartphone, the TV-screen enjoyed from the distance of a sofa, the cinematic experience of the movies, and giant installations that extend our line of sight. What happens when the screen exists beyond the natural embodied field of view?

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stereoscopic effect, and finally, there was very little content made for this setup. Every person watching needed individual glasses calibrated to the screen and had to sit still during the session. And finally, very little content was ever made to support this setup.

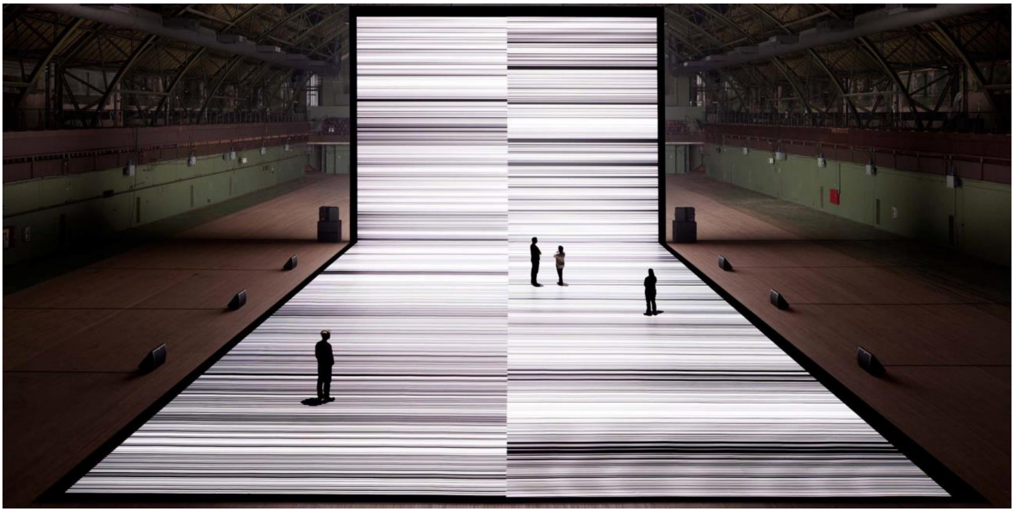

Figure 7. Documentation footage of *test pattern (enhanced version)* (2011) by Ryoji Ikeda. Courtesy of the artist.

New media artist Ryoji Ikeda's installations are often large-scale projections, extending the field of view showing repetitive, minimalistic and mathematical scenarios, in which each visual movement is mapped to a sound. A person will need to physically turn her head and move around to see the entire work. In his renowned screen works *test pattern* (2011) and *data.tron* (2009-10), both part of his larger Datamatics project, the artist aims to texturize and materialize data, through image and sound, make it perceivable. The interactors walk on and are surrounded by a large screen. The very high frame rate in which the images and sounds are presented proves a test for the human perceptive response system, inviting you to make use of touch and motor senses in processing the incoming data. It is no longer an option only to let the eyes wander or let the head move to grasp the totality of the screen. Simple head movements and eye orientation are not sufficient to capture everything, and as a result these installations both allow and force the whole body to orient itself in relation to the experience. In contrast to virtual reality experiences presented via head-mounted displays, these works offer the interactor a chance to move beyond visual experience, as other bodily senses need to be engaged to fully grasp the totality of the work. Perhaps they even help the interactor recognize how their bodies play a role in terms of perceiving and organizing experience.

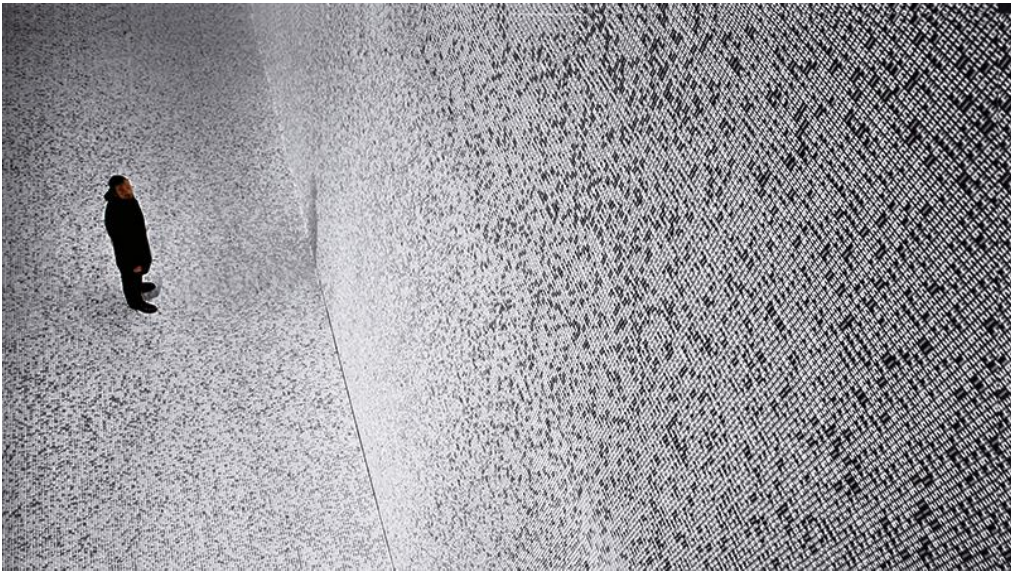

Figure 8. Documentation footage of *Data.tron* (2009-10) by Ryoji Ikeda. Courtesy of the artist.

Both earlier and more recent versions of CAVEs (Cave Automatic Virtual Environments) offer similar bodily sensations. In these interactive environments interactors are surrounded by screens in which the projections match their movements and postures. Navigation of the space may occur via handheld controllers and/or gesture-recognition software, in addition to movement, and the visual projection is viewed through stereoscopic goggles. In contrast to strict virtual reality environments where the three-dimensional environment is mediated solely via a head-mounted display, CAVE goggles augment the screen environment by adding a virtual layer. This allows the interactor to see herself, her body as part of the environment. But much like virtual reality systems, beyond bodily orientation, the physical movement encouraged as a means to navigate the virtual narrative is limited and restricted by the physical space. My claim is that the size of the screen in relation to a human body forces this reorientation, rather than the novelty of the experience. We need to move, re-position ourselves, actively explore the whole surface to grasp the totality of the screen environment and the content it mediates, and we see and feel ourselves as part of it—every time we engage with it.

Sum of the parts

To guide our understanding of the screen as a medium, we have made several important distinctions. First and foremost, we discriminate between the platform (the screen material) and the content it mediates and shapes. Secondly, the screen is separated from any framed surface, with its ability to present dynamic content. This means that the media platform itself is not bound to fixed images or messages, but the content of varied design.[27] As such, the screen is not limited to digital or electrical technologies, as mechanical projection systems like shadow theatre setups or the zoopraxiscope just as readily can present mixed moving images. The media archaeological approach provides us with a history of the screen, at the same time, recalling McLuhan, we need to keep in mind that each screen platform comes with its own possibilities and constraints, which frame the content. The material aspects of a screen (size, shape, fidelity, resolution etc.) impact users' experiences. Projecting a cartoon or news program on a building affords a very different experience than seeing the same content on a small mobile device. Likewise, the time and place location of the screen and the time at which the content is shown, are important, and changing these will favor different experiences. Just think of the presentation of censored or taboo content on public screens, in contrast to viewing the same content in the privacy of one's home. In terms of screen shapes there is a long-lasting preference for the rectangle, which can be traced back to earlier types of written records and presentation formats. Perhaps this preference is linked with our natural field of view, as a border for visual representation we can produce using our hands. The size of the screen is directly linked with our embodiment. When we engage with screens that go beyond the field of view something happens to our bodies, as our eyes are no longer able to contain the experience on their own. Virtual reality technologies based on head-mounted displays encircle our field of view, yet they promote disembodied experiences as the body is not given the proper option to

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[27] As mentioned above, Lev Manovich describes paintings as a type of classical screen. Likewise, screens may refer to room separators and decorative panels, as well as light-proof drop-down curtains; all devices that protect you from or set you apart from something. Still, all of these devices are incapable of presenting dynamic content and fall beyond the scope of this discussion.

navigate in the same perceptive space as the visual sense. We need to move and reposition ourselves to grasp the totality. This process of reorientation is, as later chapters will show, of great importance. It is not only the material qualities of the screen that has made it so successful. It also has a high representative value, as a gateway metaphor that may be communicated, which adds to the versatility of this medium.

Screen Metaphors

The representative qualities of the screen are vast and the metaphors for describing the qualities of the screen are equally diverse: A *frame* for separating something from everything. A *surface* for emphasis and highlight. A (truthful) *mirror* or reflection of self. A *mirage* deceiving us from what is really there. A *selector* which includes and excludes. A *channel* for communication. A *tunnel* connecting places. A *wormhole* connecting times. Screens afford so many functions, options and roles, and we need to take this into account when analyzing any particular screen media. If we are considering screens as on-demand devices or multifunctional surfaces, we can easily imagine screens doubling as windows, a surface at the same time transparent, opaque and data saturated. To understand how and when such screens are to be used, they need to communicate their representative values.

Windows, Frames, Virtual, and Screen

Media theorist and historian Anne Friedberg has produced an extensive analysis of screen media. Her account opens with the narrative of Alberti's window to describe the onset of Renaissance perspective paintings and arrives at a discussion of screenless images. In *The Virtual Window: From Alberti to Microsoft* she offers a comprehensive account of the historical and architectural development of the window (as a frame, mirror and metaphor), its many virtual surrogates, and the development of multi-windowed screen media. In addition, each media format or period is connected to a thinker offering a philosophical perspective or lens alongside the historical account of screen media periods. The first lens is offered by

Descartes and his use of *window* as a descriptor of the eye. The second lens is reserved for Heidegger's notion of the *frame* as a metaphor for "representational thought" (2006, 95), where he puts no emphasis on the screen apparatus itself, but rather on the thoughts and experiences it frames. Bergson's definition of the *virtual* to distinguish between the possible and the actual constitutes the third lens. As Friedman elaborates, for Bergson "the term 'virtual' serves as a descriptor not only for the immateriality of memory but for the image that is mediated by 'medium' (his word)" (142), suggesting that Bergson considers the virtual to embrace both our mental imagery as well as actual images produced by screen media. Friedberg invites us to revisit earlier definitions of the virtual and challenges the notion that virtuality is merely the representation offered by a screen medium. Rather, she claims, it is "an immaterial proxy for the material," a register of representations, both mimicry and simulacra (8). The fourth and final lens is provided by Paul Virilio's understanding of the screen's ability to "dissolve material space" (184), so that actual space is perceptually altered through screen media. How the GUI desktop metaphor represents office elements within a screen, or surface projections extending physical borders, are rather straightforward examples of such a dissolvement. But for Virilio, this development indicates that screen square is increasingly replacing the real horizon of our perception.

In conclusion, the four lenses offer perspectives on the screen as an eye, as a container for representational thoughts, as a doorway to a virtual space of reproductions and hyperreality, and finally, as an immaterial space. Beyond offering these four lenses, Friedberg suggests that while we are still bound within the frame with all its qualities, potential and deceptions, the catering for the visual sense is now becoming multiple—we engage with multi-windowed frames within the screen, or multi-screens within our production milieu. Friedberg asks: "Is there a new logic to vision as our windows, frames, screens are ever more fractured and virtually multiplied?" (242), but she does not offer a clear answer to what such a logic entails. Rather, she introduces her analysis within the conclusion: "The limits and multiplicities of our frames of vision determine the boundaries and multiplicity of our world" (7), which almost seems to suggest that any vision-based technology also sets the boundaries for our experience. If so, it begs us to carefully consider the screen media interfaces we are designing and engaging with, in terms of providing fruitful and encompassing frames for our life experience. At the same time, Friedberg's conclusion appears ocularcentric, arguing the pole position of vision and vision-frames (screens, displays, monitors, surface projections etc.) in mediating our reality. While screens certainly do mediate experiences, there are several limitations in this mediation, as we shall see below.

The mirror and the mirage

Screens are never just one thing, which makes it both tempting and useful to explain them in terms of metaphors. Multipurpose screens or on-demand screens often require metaphorical interpretation to allow the interactor to identify its use in any given situation. While metaphors are useful as guides, a metaphorical presentation of the screen may also collude its material impact. The most common metaphors utilized in presenting screens for productive personal computing environments production are typically centered around the frame as a selector of content and task, the window as an access point to particular places and people, and a doorway to virtuality—presenting the opportunities of the digital. On this note, some screens take up the qualities of the mirage, being illusory in terms of promising access to more than more than they might be able to mediate. And while screen metaphors in general are thoroughly explored in the new media art field, there is one set of works specifically concerned with the screen as a mirror. These works warrant particular attention as they force us to revisit our relationship with the screen as more than a relationship between the eye and the surface. The last sections of this chapter are dedicated to these two directions: The screen as mirage and mirror.

1.3 Screen Mirage: Promise and Pitfalls

Screens are gateway devices connecting times, places and spaces. The extent to which the body is addressed or engaged in the interaction with the screen is what sets the ocularcentric frame. While many screens solely cater the eye, other screens involve several senses. In the following section I will address screen setups selected for their ocularcentric qualities and discuss their attraction and shortcomings. What is the mirage—the promise and potential pitfalls of these screen media—that warrants special attention? I suggest that there is substantial evidence that most screen media are limited in what they can mediate of human experience and presence.

I bring forth my smartphone and with close-to-automated gestures I stroke the screen surface and gain access to functionality within. The seductiveness is obvious: These devices are small, fitting the hand perfectly, and supermobile. They are enticing by virtue of functioning as a doorway to a plethora of experiences that are both productive, communicative, and entertaining, and even more—it is a personal wearable and an extension of self, holding memories and access points. However, access to these worlds and opportunities are funneled via a tiny screen which doubles as your input controller. This tiny gateway to all, which is so engulfing that we see people immersed in these devices whenever there seems to be a spare moment, also relies heavily on one sense. As material clicking noises previously associated with keyboard tapping are disappearing with touch interfaces, the sensorium is further constricted.

A feast for the eyes

This singular fixation on the eyes in mediating experiences is a recurring theme in the design of vision technologies. And as we discussed above, this premise is specifically pursued in virtual reality technologies in which screens encloses the eyes, shutting the body proper out.

Where the 1st generation of VR developed in the ‘80s and ‘90s, had the tendency of trapping its users in the “barfogenic zone”,[28] new VR hardware might have lessened the gap between real and virtual visual perception, but not closed it altogether. This perceptual gap coined the “uncanny valley” by robotics professor Masahiro Mori, was first used to describe the discomfort and uneasiness humans feel

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[28] Coined by Thomas Piantanida in 1993, then head scientist at SRI International Virtual Perception Program, to describe the nauseating feeling most people experienced when using head mounted displays.

by perceiving robots that look almost, but not fully human (Mori 2012). We feel this discomfort because we empathize with the robots, and the more realistic they appear the more disturbing the (diminishing) gap is felt. Mori thus proposes a relationship between likeness and affinity. Professor Paul Dizio, psychologist at Brandeis University, reapplies the notion of the uncanny valley to describe recent VR technology development stating that "the more physically realistic the rendering becomes, the more icky the perception becomes" (Barras 2014). One may wonder if the feeling of uncanniness is an important one, as it makes us able to realize that we are indeed presented with an interface, a screen, albeit persuasive, and not a direct connection to what is shown. There exists a notion that the failure of the virtual reality technology of the '90s was due to low-resolution imagery, high latency, insufficient view field and pixel depth, and that if these things were to be mended, virtual reality environments would not only be fully *immersive*, you would be *present*. The argument was restated by Facebook CEO Mark Zuckerberg after acquiring VR hardware Oculus Rift earlier in 2014: "This is really a new communication platform. By feeling truly present, you can share unbounded spaces and experiences with the people in your life" (Zuckerberg 2014). The promise of VR is still captivating our hearts and minds, we want these experiences and transfer our present state from *here* to a virtual or telepresent *there*. What is not so certain is that virtual reality technologies as they are proposed presently can ever fulfill this promise.

The trust in the eyes as the sole provider of presence and conceiver of reality is repeated in the promise of eye tracking technology. In 2012 I visited the Ars Electronica Center and Future Lab, an impressive building in Linz, Austria, housing (among other things) an artistic research center and an exhibition space in the style of a science museum with interactive installations suitable for audiences of all ages and abilities. I did, however, notice that there was a striking emphasis on eyes; on interfaces where eye rotation was tracked, and the movement path and pauses acted as selectors and triggers for control of a software presented via screen. Eye tracking in itself is a widely adopted technology with several applications both in psychology and medical research, as well as the advertising industry, providing data on how a subject reads or scans a given environment. Eye tracking interfaces, on the other hand, where the user actively operates an interface with her eyes to navigate its environment, are something else. There are noteworthy candidates, among them *Eyewriter*.[29] This tracking project was initially developed for graffiti artist *Tempt* who, severely affected by ALS, has been paralyzed neck down and unable to perform his art unaided. The Eyewriter interface provided him and others in similar situations a possibility to operate a simple graphics program with eye movements alone.

These are specific uses, but to what extent is eye-tracking useful for operating interfaces for able-bodied persons? Obviously, the passive reading of human eye movements means we will have records of the line of sight and focal points at any given time. Not only is this data useful for usability studies trying to identify how and what we track in our environment. In various VR-applications (either artworks, games or advertising) it would also allow us to orient visual content towards the binocular vision of the interactors at all times. Still, if the same technology is becoming an interface for active interaction, where specific eyes gesture becomes input signals, this is ocularcentrism taken to its extreme. Not only do you have to process available information via the sense of sight, the same organ is also the interaction controller, leaving the interactor caught in a visual feedback loop.

Screen miniaturization and body proximity

Just as we discussed how larger screen surfaces force the interactor to move to grasp the totality of the experiences, the perceptive experience will equally be influenced as screens become smaller and is set closer to the body. Current head-mounted displays for virtual reality are still rather cumbersome and restrict movements as the interactor is engulfed by the virtual, cutting of the physical environment. Some promise on that end is seen in smart glass devices capable of augmented reality

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[29] www.eyewriter.org

experiences, such as Magic Leap,[30] Hololens,[31] or Google Glass,[32] screen bifocals meant to be worn close to the eyes as goggles. Here tiny cameras track and map the surroundings and human features, and relevant digital data is superimposed onto the field of view of the user. Current augmented reality goggles are too expensive, bulky, and visually restrictive to function well as day-to-day wearables. However, their promise intrigues developers and technology enthusiasts alike, and a great deal of effort is currently involved in ongoing development of smart glasses and contact lenses. The promise of smart glasses and screen proximity is taken to the extreme in an episode of the science fiction series *Black Mirror* called the "The Entire History of Self" (Welsh 2011).

Figure 9. Screenshot from the Black Mirror season 1 series episode "The Entire History of Self."

In this near-future world all humans are equipped with screen contact lenses powered by a tiny memory implant. As a result, the eyes function as cameras that

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[30] https://www.magicleap.com/

[31] https://www.microsoft.com/en-us/hololens

[32] https://www.google.com/glass/start/

record everything, as well as displays for playback. In this world, nothing is private or hidden, and consequently never forgotten. Recorded footage can be cast to any display for public viewing or played back in before one's own retina. But as a result, people strive to be intimate and do not trust their bodily perception. They live in closed-off personalized worlds, detaching themselves from experiences, as they rely solely on the ability of the lens to capture reality, and play them back. The Black Mirror scenario is taking the concept of the eye screen to the extreme. Yet, these devices downplay the role of the body, by rewarding the eye with the key role as a mediator of life experiences. Visual input and stimuli are given a much higher weight in funneling life experience to the brain. This funneling is occurring not only sometimes, but *all the time* the device is active. And as the screen moves closer to the body, the ability to turn it off or even remove it becomes increasingly difficult. In the Black Mirror episode, the main character goes to extreme lengths to get rid of the device and ends up performing ad-hoc surgery on himself to remove the implant.

Screens affect our sense of embodiment, and just as large screens force us to use our bodies to orient ourselves, screens that engulfs the eyes are prone to give us out-of-body experiences, as they restrict us from navigating physical space. Considering the ongoing miniaturization and increased body proximity of screen media, it seems relevant to ask if we need media distance to be able to reflect on the medium itself? What happens there is no mediation of an artifact, e.g. in cases where the projected image is presented in your mind only? In these cases, your brain becomes the display. Your previously private inner images are now populated by externally immigrating images. The material object has disappeared and can no longer remind you of the reality of the mediation. If the object of mediation is disappearing, we will need a public discourse to regain a grasp or rather, gain a prehension (pre-apprehension) of our own perception of experienced reality.

What is certain is that the bodily distance of the screen media as well as its size affect how we may relate to it. Sight, as we discussed previously, benefits from distance. It is when we capture the object in its totality with our eyes, that we separate from it. Large-scale screens will force us to utilize the full body apparatus to grasp the object. On the other end, we find small screens that function as an eye layer. We will never be able to take a step back to distance and separate ourselves from these screens, should they come too close.

Screen mediation and presence

Screens by themselves are insufficient media for mediating presence, the feeling of being here, and yet they are often presented as if they do, especially in virtual reality and telepresence scenarios. The advertised promise of video conferencing to mediate real presence, as the system connects physical spaces via screens, is but one example of the rooted belief in the ability of the visual sense to convey complete perceptive experiences. While the mind seems to have an adequate capability to fill the missing holes of sensory input, by allowing unimodal visual representation to present reality to us, we are at risk of promoting sensory blindness. The inadequacies of two-dimensional screen displays in mediating presence on its own, delivering experiences that are incomplete, disembodied and selective, can be countered with the support of haptics as later chapter discussions will show. Still, there is a persistence and seductiveness of the screen media as the go-to interface which begs for insight into what screens may reveal and what they may camouflage.

Many artists have explored the limits of screen mediation. In *Screens - Viewing Media Installation Art* Kate Mondloch investigates how viewers experience screen-based media, especially in gallery and museum settings (2010). Mondloch offers insight into the limits of screen mediation in her discussion of screen-based media art installations. One of her key examples is Ken Goldberg's well-known work *Telegarden*[33] as this artwork shows the difficulties in mediating presence in a twofold way. Whether the audience is accessing the work off-site via the Internet or on-site next to the garden—they are never allowed to directly engage with the garden. Mondloch concludes that "these artworks show that mere connectivity may not be enough to turn telepresence into presence." (91) Instead, they often end up

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[33] Ken Goldberg's installation *Telegarden* features a small garden with selected plants, which is tended and nurtured by a robotic arm. The arm is controlled via a web-based interface allowing spectators, within the physical space of the garden or elsewhere in front of a screen, to water the garden and plant seeds. http://www.ieor.berkeley.edu/~goldberg/garden/Ars/

revealing interactive restrictions to the interactor, that which cannot, or is not mediated—namely complete embodied presence. The limits of screen mediation are connected to the ability to mediate perception directly. Philosopher Hubert Dreyfus points to the difficulties in assessing evidence without direct multisensory access to objects of perception. In his discussion of telepresence technologies where presence is mediated through displays he notes that "as more and more of our perception becomes indirect, read off various sorts of distance sensors and then presented by means of various sorts of displays, we are coming to realize how much of our knowledge is based on inferences that go beyond the evidence displayed on our screens" (2000, 53). He identifies two paths that telepresence experiences might take. Either they will offer 100% sensory involvement with the mediated space/place, and as such invoke the epistemological doubt first presented by Descartes, and in extension a reactualization of mind-body dualism. What is real, what can be trusted? Mediated presence with no perceivable glitches (no lag, full resolution, repleteness, and with risk) presents us with experiences which we cannot verify, nor disqualify. Otherwise, they will offer those sensory glitches that make us able to distinguish the reality of *here*, versus the mediation of *there*. In fact, this is perhaps the unintended mode of most telepresence.

Media artist and engineer Myron Krueger argued for the potential of immersion and telepresence using interactive three-dimensional environments as his prime medium for exploration, as opposed to strict 2D mediation. His proposal for such a space was VIDEOPLACE, a responsive environment developed in the mid-1970s with an extensive catalogue of applications, ranging from single-player games to multi-user telepresence programs. The environment demanded no goggles or gloves for exploration, as cameras tracked the position and posture of the interactor in real-time. The silhouette of the interactor was projected on screen as she engaged with virtual entities or other participants.

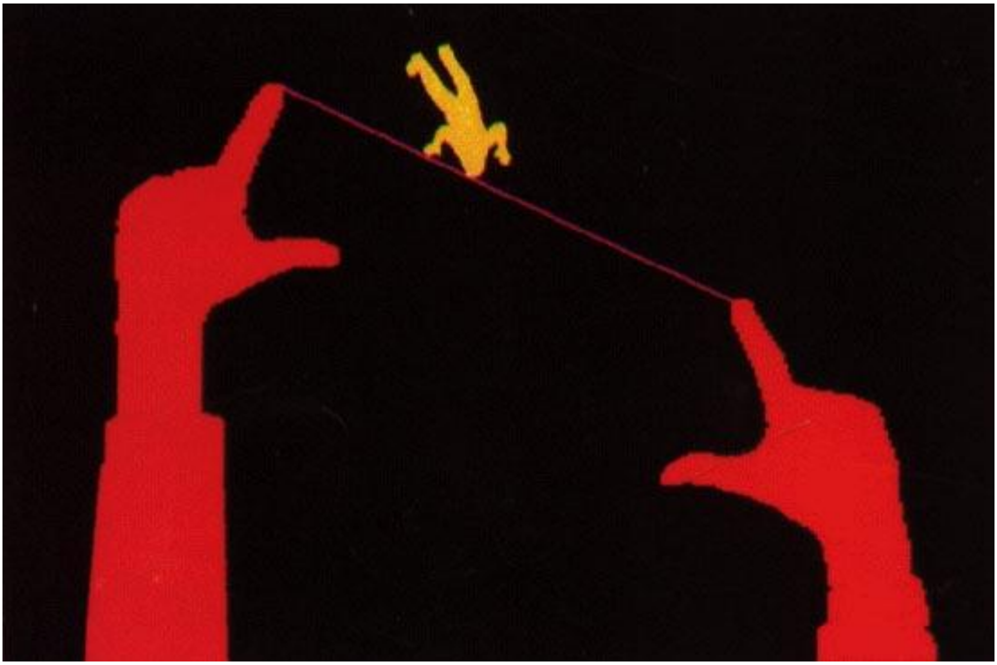

Figure 10. Screenshot from the Artwheels Interaction, one of the many interactive player games developed for the VIDEOPLACE Environment, presented at the Golden Nica Prix Ars Electronica 1990. Here a VIDEOPLACE interactor is being rolled down a string held by a VIDEODESK participant. Source image from Ars Electronica Archive.

Krueger has shown skepticism towards 2D-displays as systems for mediating presence as they primarily cater to our conceptual selves. However, he claims that 3D responsive environments are capable of such transfer—provided they offer real-time interaction and the bodies of the human participants are active while engaging with the environment. In a 2002 interview with CTheory's Jeremy Turner, Krueger makes his argument clear: "The degree of physical involvement [is] the measure of immersion" (2002). And immersion is a measure of the extent to which an interactor perceives herself as physically present in a non-physical world. Virtual environments and interfaces must therefore build on our real-world experiences to bridge our conceptual and physical world. The human body is the ideal interface, around which we should form our technologies. And while current VR-technologies aren't up to the task of mediating full-range sensory experiences, at least not just yet, Krueger reminds us of the centrality of the body as a motor in future screen applications.

1.4 The Haptic Turn

Throughout this chapter we have discussed how the material solution and metaphorical representation of the screen affects our sense of embodiment.
The material solution dictates the experiences supported by the screen, and the representative value shapes the role given the screen. We have discussed how screen size and the distance of the screen media from the body affect our ability to scrutinize it. And finally, we have noted there exists a foregrounding of vision in screen media, a belief that real life experience can be fully mediated via vision technologies alone. That said, not all screen experiences are ocularcentric. Haptic qualities are introduced into our everyday computing environment with the introduction of portable smart devices equipped with touch screens. The everyday consumer is presented with the option to navigate screen surfaces with their hands and be rewarded with selected haptic feedback. And while this is one step away from ocularcentric screen media, the coupling of navigation and presentation on the same surface locks the user in a visual feedback loop.

Many scholars and developers argue, with good reason, for a move towards a more body-centered model of perception. Media theorist Hansen, among others, finds a solution within the arts, new media art in particular. He proposes that, with its exploration of and experimentation with sensor, communication, and haptic technologies, "new media art configures the body as a haptic shield …. [and] transforms this haptic prosthetic function into the basis for a supplementary sensorimotor connection with the digital" (2004, 121-122). As later chapters will show, haptic technologies offer a significant promise in mediating a richer and more nuanced experience of the digital, than screen-only interfaces. But even screens may be utilized to actively trigger haptic sensations.

The Body in the Screen

There are screen experiences that promote contact with haptic senses that are otherwise ignored or underutilized in our everyday engagement with screen technology. We have already discussed how large screen projections force interactors to move their bodies to grasp the screen experience. But there are also other strategies for involving our haptic senses in screen media. VIDEOPLACE aside, the new media art scene of the late '60 and early '70s gave rise to several artworks that interrogated the screen as media for body awareness. These works scrutinize the relationship between the screen display and the body of the viewer, through different setups that experiment with the concept of mirror and the separation of video cameras and display monitors.

Figure 11. Screenshot from Bruce Nauman's *Live-Taped Video Corridor* (1970). Courtesy of the artist.

One well-known example is Bruce Nauman's *Live-Taped Video Corridor* (1970), an installation consisting of two monitors at the end of a narrow corridor, each monitor displaying a video feed. The upper video feed captures the interactor from behind as she walks down the corridor towards the monitors, presenting an ever-diminishing image, while the bottom monitor shows pre-taped footage of the same corridor, empty of people. The installation is eerie in several ways. In the attempt to catch an image of herself on the top monitor, the interactor only ever sees herself from behind, walking away from the camera eye. Movement becomes oppositional, as walking towards the screen is shown as walking away. Attempting to get a clearer view of oneself in the video image by approaching the screen, will lead to the opposite. As you approach the screen, the image zooms out. The bottom monitor which appears as a live feed of the same scene, has edited the interactor out altogether. The combined screen setup completely contradicts the expected visual signals we usually get about the body's position when approaching a mirror image, forcing us to re-direct our attention towards our body, its posture and position.

Figure 12. Screenshot from Peter Campus' *Three Transitions* (1973). Courtesy of the artist.

Another important work is Peter Campus' influential video artwork *Three transitions* (1973). In a 10-minute video the artist investigates the notion of self and body image in three different segments. In the first of the three, we see the artist standing in front of a paper canvas. He turns towards the canvas and starts to slowly cut a hole in the canvas. What we realize, as the first cut is made and a sharp object is protruding from the artists back, is that we are looking at a projection of a video feed of the artist from the flipside of the canvas. The scene gives the impression of the impossible case of a person folding into and out of himself. The viewing sensation is visceral, as I try to place myself and my body in this scenario. These works and others similar to it investigate real-time video recordings and feeds that are either presented asynchronously in time or asymmetrically in space, constantly challenging the interactor's expectations of body image and body position, giving rise to new bodily awareness. Something happens when the visual image no longer matches the actions of the body. Asynchronous and asymmetrical mediations of body images trigger haptic sensations, as we are physically reminded of our own position and movement in space. Screen experiences centered around the mirror image affect the sense of embodiment, and as we shall see below, digital technologies, as opposed to analog and electrical, allow for a whole new set of mirror images to be explored and experienced.

Reflection and identification in the mirror

The mirror image is a recurring theme in many works of digital art. These works investigate notions of self-perception, mirror reflections and identity. It might seem convenient and easy to label the physical glass mirror and the reflection it produces as real and oppose them to artworks investigating the mirror image utilizing digital and sensor technology, cameras and network communication. However, such a distinction is hardly sufficient or even beneficial. Any mirror image, whether analog or digital, reflects a body image open to interpretation by the spectator. We always have a bias when looking at ourselves, informed by tradition, society and history.

The analog mirror image is essentially inverted (flipped back to front) and offers a very particular reflection. Moreover, the physical mirror media itself is always informed by its makers. Attributes such as size, curve and frame of the mirror, as well as the quality of the mirror indicating its ability to reflect the physical characteristics of light, are all parameters that come into play in the design. However, there are some key features locked to analog mirror media. The image reflection is always produced in real-time, so there exists a synchronicity between the spectator appearing in front of the image and the production of the reflection. Synchronicity is key in establishing a person’s ownership of the mirror image. Furthermore, the analog mirror media is bound by its features—it will always produce the same kind of reflection as dictated by its physical attributes. A plane mirror surface with high quality glass and reflective coating will always produce a reflection with the same color rendering and size of the spectator, while curved surfaces will move the convergent point of beams of light either in front or behind the mirror image surface—skewing the image reflection accordingly. The same analog mirror will always produce the same reflection (under same light conditions). As such the mirror images are inherently symmetric and offer predictability. This is also a feature that promotes ownership between the viewer and her reflection. A third and equally important feature of the analog mirror image is its passive mediation. A spectator need not actively engage with the media to capture (as in either holding or generating) its reflection or presentation.

While there is a rich history of playful experimentation with the analog mirror images (variations of curved, spherical and non-reversed images), digital and sensor technologies have brought a whole new range of images into existence. Cameras and projectors, motion and body sensors, as well as rich datasets recording human activities within a given space and time period, are all becoming elements constituting the attributes of a new mirror image. This is an opportunity of investigation and experimentation that has engaged a range of contemporary artists.

Mediation of the body image

The mirror image has been with us at least since Narcissus sat by the pool and fell in love with his reflection. Today it is cultivated in a rich selfie culture and disseminated through social media. While the mythical Greek demigod failed to recognize the mirror image reflection as himself, he did recognize another with whom he identified and adored. Only a few species of animals (primarily mammals) pass this mirror-test, the ability to recognize themselves in a mirror. In psychoanalysis this is referred to as the mirror stage, first introduced by Jacques Lacan in the late ‘30s. While marking a turning point in mental development, the mirror stage is also seen as a key element in (trans)forming the self as it promises the infant it will overcome current limitations in “motor impotence” and gain body control. As Lacan proposes:

> For the total form of his body, by which the subject anticipates the maturation of his power in a mirage, is given to him only as a gestalt, that is, in an exteriority in which, to be sure, this form is more constitutive than constituted, but in which, above all, it appears to him as the contour of his stature that freezes it and in a symmetry that reverses it, in opposition to the turbulent movements with which the subject feels he animates it. Through these two aspects of its appearance, this gestalt—whose power [*prégnance*] should be considered linked to the species, though its motor style is as yet unrecognizable—symbolizes the I's mental permanence, at the same time as it prefigures its alienating destination. (Lacan 2006, 76)

It is through the investigation of the mirror image, first considered an Other, before it is recognized as a Self, that an ego forms. The mirror stage is then a question of identification and marks a point after which the relationship to our bodies is primarily mediated by the image. However, this equated relationship between mirror image, body image and identification, seems somewhat simplified, especially in terms of analyzing more abstract works of mirror art. Instead, I turn to phenomenology, where the body image is, rather than identification, considered a conscious representation and active reflection of how I perceive my body. Philosopher Shaun Gallagher has provided a well-argued and useful analysis of the concept of the body image (1986). Here he proposes that it is either in situations of forced reflection, i.e. in illness, fatigue, pain, arousal and so on (which Gallagher calls “limit-situations”), or in voluntary reflection, that we become conscious of our bodies. This consciousness is never global, we are not conscious of every part of our body’s relationship to every other part. Instead, he argues the body image as a mental state consists of three elements. It involves the body as it is perceived in my immediate consciousness, as well as my conceptual construction of the body (as it appears in my immediate consciousness and as a result of an intellectual understanding), and thirdly, it holds my emotional attitude towards and feelings of my body (546). The body image is, as a conscious awareness of our own bodies, triggered by reflection, and informed by perceptual, cognitive and emotional experience. In terms of analyzing artworks that deliberately experiment with mirror presentations, the phenomenological lens seems more beneficial than the psychoanalytical approach, as it opens up for a more nuanced discussion of the role and limitation of the body image, rather than considering it an identificator of self.

Searching for the body image

What happens when mirror mediation is no longer symmetrical, where the reflected image is not indistinguishable from the spectator, but becomes separated, distorted and even unrecognizable? What bodily reactions occur when the interactors need to actively search for their body image or its representation in the mirror image? And how does time feature into the mediation of the mirror image in terms of how we respond to delays or randomness? These are all conditions that bring us in contact with limit-situations, where we are forced to reflect upon our own expectations of body image. But there is also something else at stake in these experiences. In the active search of the body image, we engage more than conscious cognitive processes, a set of bodily responses are activated as well. But exactly what kind of processes are these?

In the following a set of artworks will be presented, which each complicates the relationship between mirror image and body image, as the mediation of the mirror image becomes increasingly asymmetric and temporarily distorted.

Passive asymmetric mediation

The first set of works deals with asymmetric mediation of mirror image, as they are split from the viewer, or distorted in terms of proportion or resolution. What they have in common is the passive mediation of the mirror image. The interactor is not required to move (or make sounds) for the mirror image to be present.

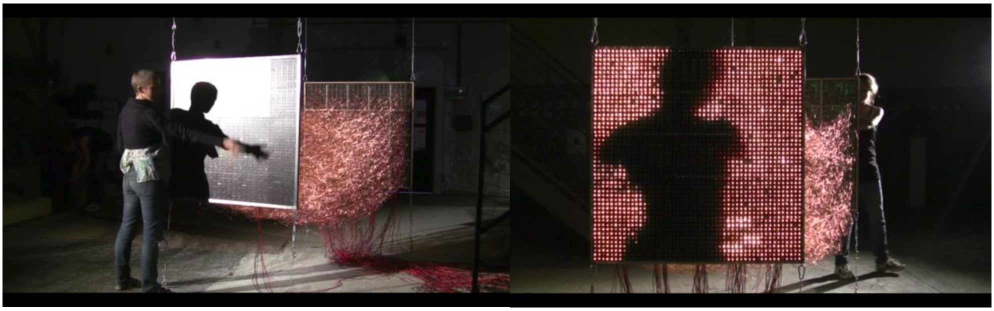

Figure 13 and 14. Screenshots from video documentation of *A Parallel Image* (2008) by Gebhard Sengmüller. Courtesy of the artist.

Gebhard Sengmüller's *A Parallel Image* is an electronic (analog) camera obscura. The real time shadow-image of any spectator standing in front of the sculpture aperture is rendered through a series of light bulbs making up a screen, situated on the sculpture's rear end. This installation differs from the classical mirror-image art works, as the interactor is disconnected from the mirror and not able to visually perceive her reflection, and never will be able to. That option is reserved for other spectators in the exhibition space. The mediation of the image happens in real-time and is symmetric to the body it maps, however, the production of the mirror image and its presentation appears on two separate surfaces that cannot be perceived at the same time, instilling a spatial asymmetry. The presentation surface reflects a mirror image as if the spectator stands behind the surface (which she does). The split image is forcing two very different processes, which both may be considered phenomenological limit-situations. On the one hand, as the presentation surface is unavailable to her, the spectator is compelled to imagine her body posture and appearance as the machine will render her, before her inner eye. Simultaneously, she will position her mental mirror image several meters away from her, dislocating an otherwise close encounter between body and its reflection. It is also important to note that the work itself seeks to make explicit the technological forces at work in producing mirror images.

Split analog mirror images may invite conscious reflection about our body position and posture at the time, but it remains largely a mental exercise, as opposed to a physical one. The asymmetric mediation of the mirror image invites us to look for ourselves, so what happens when the materiality of the mirror extends into the virtual?

This is a central theme in the works of interactive artist Daniel Rozin, who specializes in mirror-image installations. A significant part of his work focused around mechanical mirror construction and virtual augmentations, allowing almost any material to become a mirror surface. These mirrors are all set up the same way. Hundreds of small wooden bits, pieces of trash, or steel tiles make up the mirror plane. Each mirror piece is connected to a servo motor and thus movable using control software. Depending on the angle of the individual pieces, incoming light is reflected differently making it possible to indicate shadow and highlights as the key constituents of a mirror image. A camera hidden within the mirror pieces, records the spectator. The camera feed is translated by control software turning pixels into the individual pieces of the mirror image. The images are conveyed in real-time, providing the viewer with a symmetric and as such consistent mirror image, although the different images may either match the view of the interactor 1:1, or enlarge or shrink selected body parts.

Figure 15. Screenshot from video documentation of Wooden Mirror (1999) by Daniel Rozin. Courtesy of the artist.

The latter is the case with his early work *Wooden Mirror* from 1999 where the mirror image becomes a head portrait, thus enlarging and isolating the interactor's head in real-time. This framing, as well as choice of material (wood and a sepia color palette), hints to old family photographs, placing the interactor in a historical time. She is invited to inspect herself from this new perspective, as a person of the past where merely the face and head posture are mediated, rendering the body irrelevant. When the interactor moves closer to the mirror, the overall image is enlarged at the cost of facial details. This is because resolution is fixed in the material solution, not the image, yielding human strategies for inspection useless, and more specifically, the traditional act of inspecting oneself in the mirror. Additionally, as the interactor moves, the individual pieces of the wooden mirror make sharp clicking noises as they render the image anew. This auditory tracking invokes bodily attention towards the tiniest of movements and changes in posture. The virtual and material qualities of the mirror image invoke not just attention to body image representation, they also force the interactor to physically reflect on distance to and degree of movement in relation to the work.

Figure 16. Screenshot from video documentation of *Penguins Mirror* (2015) by Daniel Rozin. Courtesy of the artist.

The notion of self-recognition and image distortion in terms of resolution is taken further in Rozin's *Penguins Mirror* (2015), as the artist detaches the mirror image from the wall. Here 450 stuffed penguins on rotating motors are situated on a gallery floor, presenting a low resolution, binary (black and white) mirror image of any interactor standing in front of the penguin colony. Data from a motion detector is fed to a control software to produce a real-time silhouette of forward-facing penguins. The mirror image is simplified in terms of color and resolution to the extent that it is not possible to recognize a particular person, only the identification of a biped with two arms and a head. These simplistic representations of bodies in terms of resolution and color may hint to something original and particular to a human body, as individual features are lost. Bodily gestures and postures become key identificators of what a body is.

Active asymmetric mediation

The second set of artworks is centered around the active mediation of the mirror image, conditioning the posture and movements of the interactor. The interactive element is central to these works, as it is only through movement or deliberate inactivity the mirror image will appear.

Figure 17. Screenshot from video documentation of *Rust Mirror* (2009) by Daniel Rozin. Courtesy of the artist.

The *Rust Mirror* (2009) work projects the mirrored silhouette of the spectator onto a surface consisting of hundreds of rust steel tiles. As the viewer moves about and actively explores her mirror image, small trickles of rain will form in the image. The raindrops will increase in number as the person becomes more active particularly when getting closer to the work. Eventually the image of the body will be overtaken, in the same way raindrops distort the reflecting pool. In this screen experience, the interactor will need to make an active choice in search of her body image or its representation. The participant is conditioned to stay still if she wants to see herself with clarity. And in many ways, it distills some of the sensations provoked by Nauman's work. Distance and inactivity are rewarded with a clear mirror image. But how truthful is this representation of self as still and unmoving? The work certainly explores the assumption that an active, moving body cannot be captured in an image.

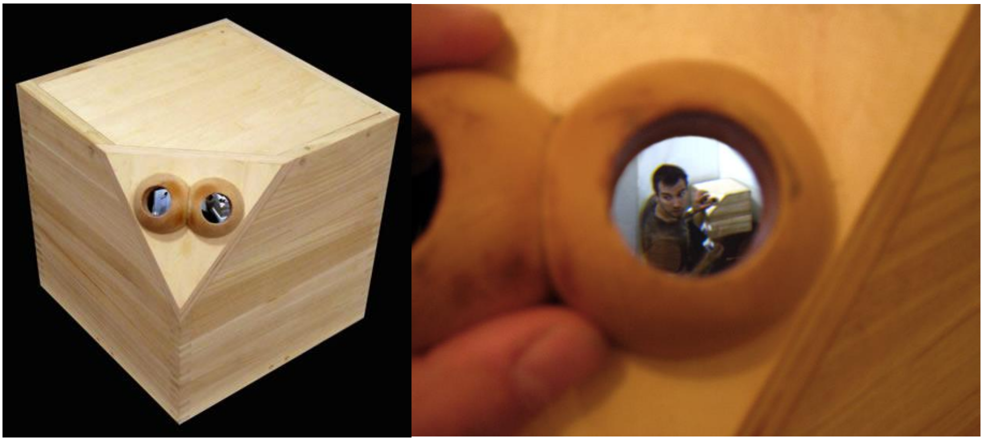

Figure 18. Screenshot from video documentation from *BoxedEGO* (2008) by Alvaro Cassinelli. Courtesy of the artist.

Many mirror artworks are occupied with the effects of dislocating the observer from her mirror image. While Sengmüller's *A Parallel Image* does this quite literally, other artists take it further. Alvaro Cassinelli's installation *BoxedEGO* appears as a straightforward stereoscopic peephole camera placed on a platform in a corner of the gallery space. Out of plain sight, two cameras are mounted in the ceiling in front of the platform. When curious observers decide to take a sneak-peak through the peephole, they see a miniature version of the platform in the gallery space. However, as soon as they breathe or talk, this first image feed is replaced with a live image of themselves operating the camera. The live image is scaled down to exactly fit the peephole camera's box interior, as if the gallery space is appearing inside it. The artist, in accordance with the title of the work, calls it the "double trap of self" (Cassinelli & Ishikawa 2008, 1), and argues that the camera first captures the curiosity of the observer—its ego, and secondly the observer himself. Only if the observer stands perfectly still, will he be slowly purged from the image. The mirror installation has an additional perceptive layer, because as the users see themselves from behind and above, at first sight it appears they are looking at someone else. As they recognize their own body posture, position and appearance in the image, the image reflection is connected to the self. This is also reinforced as proprioceptive and tactile feedback correlates with the live feed. Watching yourself touch the peephole box will produce tactile sensations. However, the process seems to reiterate, engaging the observer in a perpetual loop between light out-of-body experiences and self-identification. In opposition to Rozin's *Rust Mirror* the participant produces the mirror image through activity, not by passivity.

Asynchronous mediation—the mirror of time and collective

A third set of mirror artworks utilizes digital technologies to generate virtual layers, elements of temporal dislocation and collective representation, in the mirror image.

Figure 19 and 20. Screenshots from video documentation of *Time Scan Mirror* (2004) by Daniel Rozin. Courtesy of the artist.

In *Time Scan Mirror* (2004) Rozin experiments with the passing of time in the production of a mirror image. The mirror is a projected screen, showing a time-delayed and slightly skewed mirror image of the viewer. We see our movements over time, presented within the metaphor of the timeline. The aesthetics of a temporal body image connects present actions with a reflection of the past, forcing bodily responses beyond the conscious reflection of self-image. How did I just move, how can I move to affect the timeline differently? This is a temporal representation of an individual body in motion. But timed bodily signatures of the collective have also been utilized in mirror imagining, to produce personal mirror images of us.

Temporal representation of the collective in the mirror image is found in Chris Lee and Henry Chang's *Pulse Mirror* (2012). The work records the audience's pulse when engaging with the artwork and transforms each person's individual heart rate into a pulsating dot as a biometric record. Each of the dots, representing the timed biofeedback of the collective, make up a visual mirror-image of the current viewer. The internal state of the group is represented in the image of the one, as a temporal haptic-visual connection. My body, as represented in the image, is made up of the pulsing hearts of the group, inviting affective tactile sensations and a physical recognition and tracing of one's own body surface.

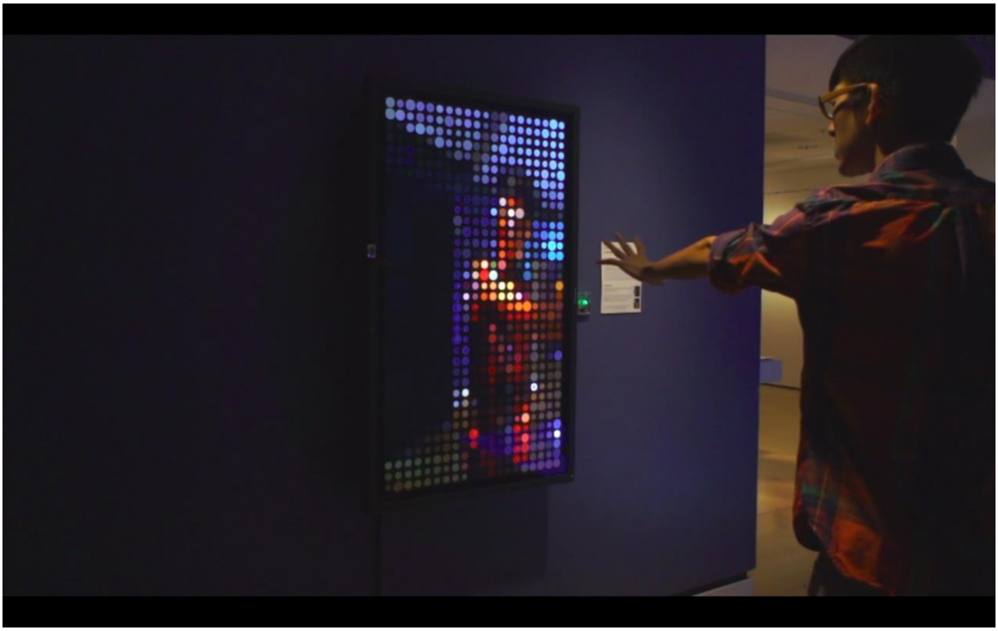

Figure 21. Screenshot from video documentation of *Pulse Mirror* (2012) by Chris Lee and Henry Chang. Courtesy of the artists.

The concept of representing a collective in the image is taken one step further in Brigitta Zics' *Mirror_SPACE* installation: the users' faces are scanned in real-time by an infrared sensor, gathering data which it then proceeds to calculate into mood values. The internal states— mood values—are translated and coupled with network data (from stock exchanges and weather forecast centers) producing an abstract virtual mirror image of the user which is presented on screen. The user is confronted with a real-time virtual interpretation of herself, an abstract mirror-avatar as such. Additionally, the avatar is semi-autonomous of the user, meaning its actions are partly mirrored by the user's movements, partly controlled by proximity to other virtual objects.

Figure 22. Screenshot from video documentation of *Mirror_SPACE* (2003/2004) by Brigitta Zics. Courtesy of the artist.

The work is occupied with the phenomenal image (an image of a reciprocal body as it experiences, affects and is affected by, the world), offering us an opportunity to reflect on not only an optical mirror image, but other forces that make up our experience of the world. She calls it a system that mirrors a space where the user becomes "a node that is networked with the whole of existence" (Zics 2005). The work confronts us with the notion of the personal mirror image (of me) versus a public mirror image (audience movements in the exhibition space merged with network data), perhaps arguing the interconnectedness between us. Equally, the body is no longer directly figuring in the image, offering a rather asymmetric representation of self. We need to connect the dots and actively search the representation to identify ourselves, but it is not the body image we will find, rather machine responses to our actions, coupled with the representation of previous interactors. The work emphasizes that we are never just an individual body, we exist in a space within a collective, and while we influence these surroundings by our being, it also shapes us in return. But with so many layers of machine translation and interpretation within this interactive space, it becomes a question of whether we agree with the image representation of our collective self, or reject it.

What all of these selected artworks offer is a chance for interactors to engage with their mirrored self, independent of real-time and place, at the risk and opportunity of exposing our bodies to ourselves. Some mirror works barely trigger more than a conscious reflection of the body image, largely as a mental activity, and do perhaps reiterate the state of self-emancipation and growth as suggested in the mirror stage. But as the mirror images become increasingly asymmetric and asynchronous, they trigger a next step of self-identification which has to do with reacquainting ourselves with inherent skills and competencies held by our bodies in engagement with tools and the environment. This also makes me question how much of ourselves we need to recognize in order to accept what the mirror presents and engage with it.

There is an ongoing, intimate connection between the body and the visual, in our tactile and proprioceptive versus visual recognition of the body. Just consider how the sense of sight helps us keep balance, as an addition to the vestibular system. What many of the artworks above do is disconnect the symmetric and synchronous visual feedback about a body’s extension and position in space, as well as tactile engagement with the environment. In doing so, they force our bodies to apply other skills to orient themselves, and consequently give us temporary access to a predominantly pre-conscious motor-control program, which often is referred to as the body schema.

Closing the perceptual gap

Vision machines have a significant impact on how we experience reality. The transformative power of these technologies seems to be neglected in the race to satisfy our hunger for them. We are mesmerized by the image, the power it has to instill in us the belief that it portrays the truth, the whole truth, or the truth that matters. Positioning the screen as the primary interface makes us forget the richness of our whole-body perception. At the same time, the roots of the screens are so embedded in our social, cultural and scientific practice that we have difficulties realizing what is left out. As such we need to be aware of what the screen is concealing, and the nature of the screen mirage. Complete media transparency is not the solution either, as it hinders critical reflection. When screen media are no longer consciously perceivable to us, we lose the ability to criticize the medium. In selected works of electronic and digital art, we are shown what kind of presence the screens have difficulties mediating, but they also present opportunities for displaying touch and proprioceptive elements of our perceptive experience, as sensorimotor responses are reflected back to us via other modalities. The ability to examine your reasons for acting and the influence of these actions, is key to critical thinking and reflexivity. Mirror works offer this opportunity for reflexivity. Pre-conscious haptic responses are triggered and made available to us through engaging with these artworks, and we are given a chance to expose and critically assess the capabilities of screen media in conveying presence. While the analog mirror is primarily engaging a body image, the conscious awareness of our own bodies, artistic experimentation realized in various mirror artwork seem to go beyond the active exploration of an individual body image. It appears to put us in contact with a particular set of skills, competences and sensations held by our bodies, that we are rarely consciously aware of in our everyday life. This skill set is governed by body schemata which are the topic of the following chapter.

2 BODY SCHEMATA

Evolution and Revolution of Haptic Repertoire and Agency

In the first chapter I unpacked how our sense of embodiment is affected by extensive screen use, which foregrounds vision in the interaction with machines. While screens and other vision technologies are very useful as surfaces for organizing thought, they are insufficient as mediators of presence. We have been identifying ourselves, seeing ourselves, and constantly re-confirming our body image primarily through ocularcentric technologies, instead of technologies that are addressing our full body schema. Experiments with mirror image, connecting haptic sensations with vision, reveal body competences and sensations we seldom engage with consciously, making us aware of the richness of body perception and our embodiment in relation to different media interfaces. Perhaps they even offer us an insight into the conditioning power of interfaces and how they dictate the terms of interaction. What is certain is that our interaction with machines is influenced by the machine's ability to address our sensory apparatus alongside any prosthesis added or used in conjunction with the body. Sensory information gathered by the haptic—the touch and proprioceptive senses—constitutes a significant component in the way we form hypotheses about what an object is, and how it can be manipulated, and is seldom recognized in our everyday interaction with computers and media technologies. This leaves much to be desired.

This chapter presents the claim that our bodies are key mediators of the actions we can perform in the world, and furthermore that this action potential is extendible as we learn skills and engage with tools and technologies. Inherent in this claim is the idea that different skills and technologies afford different actions, and as such should be regarded with scrutiny when designing media interfaces. I use the concept of the body schema, as presented by phenomenologist Maurice Merleau-Ponty, as a map for our action potential. Body schemata are preconscious knowledge pools that keep track of how a particular body can act in the world, what it is capable of doing. Furthermore, Merleau-Ponty suggests that the body schema is revised as we break habits, learn new skills or use different tools and technologies. By identifying processes governing the body schema, processes of confirmation and revision, I seek to establish the significant role of tactility and gesture, the haptic apparatus, in addressing the body schema.

The chapter is divided into four parts: Body Schemata and Plasticity, Evolution and Adaptation, Active Revisions, and finally, Haptic Repertoire and Agency. Part I presents the concept of body schemata, its connection to body image, and how these schemata are established and revised as we use and act with our bodies. Part II investigates our historical co-evolution with technology as a process that gradually extends and modifies our body schema. Part III investigates how bodily performance, technological augmentations, and telepresence scenarios may radically revise our body schema, and revisits the concept of mirror vision and screen presence pointing to the potential and limits of visual-haptic (ideal-motor) mediation. Part IV argues the unique qualities of haptic perception and the role of gesture as movement form.

2.1 Body Schemata and Plasticity

The concept of body schema (plural schemata) was introduced over 100 years ago, and has since been riddled with different meanings, and been used interchangeably with body image. The body schema/image distinction seems to be settled, in which the concept of the body image is denoting a primarily visual and conscious mediation of the body. But still, the understanding of body schema is not the same within different research fields. An important distinction must be set between cognitivists advocating the body schema as a representation of body posture, and phenomenologists presenting the body schema as a dynamic enactment of the body in space. The latter approach will be pursued in this thesis, introduced by the treatment of the term in the phenomenology Maurice Merleau-Ponty, and his suggestions for processes of confirmation and revision of body schemata.

Origin of the body schema and its connection to the body image

The concept of a postural schema was first introduced in 1911 by neurologists Henry Head and Gordon Morgan Holmes. They arrived at the conclusion that there must be a fundamental standard, a model of previous postures and movements, against which postural changes are measured:

> By means of perpetual alterations in position we are always building up a postural model of ourselves which constantly changes. Every new posture or movement is recorded on this plastic schema, and the activity of the cortex brings every fresh group of sensations evoked by altered posture into relation with it. (Head & Holmes 1911, 187)

Head and Holmes also claimed that visually acquired images of posture and movement, the body image, cannot be the source postural schema, as the visual sense is insufficient in keeping track of postural changes. Additionally, they argued that postural schema is never a conscious model or program, as opposed to body image. We might have thought that Head and Holmes' proposal was sufficient to separate schema from image. However, in 1923 Paul Schilder published *Das Körperschema: Ein Beitrag zur Lehre vom Bewusstsein des Eigenen Körpers* in which he introduces the concept of the body schema. He describes it as a mental representation of our final body's position, equating it with Head and Holmes's concept of the body image. As such, this text becomes the starting point for confusion lasting decades mixing the two concepts. Philosopher Shaun Gallagher has done significant and important work in tracking the usage of concept body schema and the body image in scholarly texts in the 20th century (1986), with the aim to propose a clear distinction and relationship between the two. He writes:

> The body schema is neither the perception, not the cognitive understanding, not the emotional apprehension of the body. The body schema, as distinct from the body image, is a non-conscious performance of the body.[34] (548)

The body schema is a motor-control program that appropriates habitual postures and movements, as well as incorporating elements of its environment into itself (i.e. tools and instruments). Gallagher summarizes the body schema as "an active, operative performance of the body," and how "the body experiences its environment" (548). In a more recent text Gallagher slightly updates his definition suggesting that:

> The body schema is a pre-noetic (automatic) system of processes that constantly regulates posture and movement - a system of sensory-motor capacities and actualities that function without the necessity of perceptual monitoring. (2001, 149)

The notion of non-conscious is changed to pre-noetic or pre-conscious, and the emphasis on independence of perceptual monitoring is highlighted. Still, the body schema is not a simple reflex, despite the automatic quality of the processes it governs. In recent years scholars and scientists have largely accepted this distinction between body schema and image, where body schema is used to identify and describe semi-automated, pre-conscious motor skills and program our bodies utilize to engage with the environment and tools.

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[34] It is important to note that Gallagher does not claim that body image and body schema are functioning independently of each other, as there are several cases of body image influencing the body schema (as suggested with mirror vision experiments), and vice versa (in cases where physical training improving body performance and capability changes our body image).

From representations to lived body

There are slight, but important differences in how the body schema is conceptualized in various fields.[35] While philosophers have been criticized for producing too abstract descriptions of body schemata to be applicable as explanations for experimental data, neuroscientists on the other hand have tended towards detailed and careful concepts that offer little new insight and perspective. One well-known proposal by neuroscientists Schwoebel and Coslett suggests body schema to be “a dynamic representation of the relative positions of body parts derived from multiple sensory and motor inputs (e.g., proprioceptive, vestibular, tactile, visual, efference copy) that interacts with motor systems in the genesis of actions” (2005, 543). It is noteworthy that they underline that body schemata are fueled by multisensory and motor input. However, the word representation is somewhat problematic as it connotes distinct mental states, rather than embracing the explicit and pre-conscious experience and action of the body promoted in phenomenology. It is this distinction that truly separates the fields. Body schemata are never mental representations of a body action potential. They are dynamic enactments of the bodies in space.

The idea that action generation is one of the core capabilities of the body schema is shared by present-day phenomenologists, and this point specifically is extended in Gallagher’s definition. He proposes that actions controlled by body schema can be “precisely shaped by the intentional experience or goal-directed behavior of the subject” (2001, 150), and in doing so he hints at the habitual qualities of the body schema as well as the potential for shaping it (through bodily articulation of a person’s intentions for actions). Still, none of the conceptualizations referenced above illustrate how these processes of shaping the body schema come into play. A starting point for the investigation of processes governing the body schema can be found in the works of Maurice Merleau-Ponty and his notion of the lived body.

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[35] A thorough treatment of conceptualizations of the body schema in phenomenology, neuroscience and psychoanalysis is provided by Helena De Preester and Veroniek Knockaert in *Body Image and Body Schema : Interdisciplinary perspectives on the body* (2005).

The phenomenal world of Merleau-Ponty

Maurice Merleau-Ponty's contribution to promoting and enriching the concept of body schema is significant, and he is one of the pioneers in describing mechanisms governing the body schema, and its inherent plasticity. In Merleau-Ponty's world the body schema is updated by acquiring new skills or using new tools to engage with the world. So, the exact nature of the body schema and the process of how the body schema is revised is worthy of exploration. At first glance this revision process appears to take the form of a preconscious conversation between the body sensory apparatus and the outside environment. Perhaps when Merleau-Ponty describes the body as "an attitude directed towards a certain existing or possible task" (Merleau-Ponty 2002, 114), he suggests that the body affords something as possible to do. What are the triggers in the environment or situations that make my body encounter something as possible? And as these processes are bound in preconsciousness, how can I get familiar with this inherent knowledge of my body? To get closer to an answer we need to dig into the world of Merleau-Ponty and key terms in his phenomenological project: The notion of the lived body, *schema corporel* (body schema), bodily space, and the phenomenal field.

In *Phenomenology of Perception* (2002) and *The World of Perception* (2008) Merleau-Ponty provides the reader with an extensive and thorough investigation of human perception. Building on the works of Edmund Husserl, especially his concept of *Leib* (lived body), Merleau-Ponty too argues that our bodies are lived—that the subject is first and foremost a *being-in-the-world*.[36] The body is the first receiver of experiences, and this experience is key to human understanding and self-awareness. We experience the world with all of our body, simultaneously, all senses are involved in participating in that which exist outside our bodies, even though we

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[36] In Merleau-Ponty's wording the lived body is neither situated nor gendered—this phenomenological worldview does not regard a particular "female body located in Dakar in the 1990s," but any body that will and has ever lived. The lived body is universal and unspecific. However, as noted by media artist Marco Donnarumma in reading feminist philosophers Young (1980) and Shildrick (2002), "female, transgender, intersex and differently abled bodies, as well as those bodies considered 'monstrous' in particular societies because of their differences and vulnerabilities" (2016, 97), are all specific bodies that do not fit well into Merleau-Ponty's notion of the phenomenal body.

might not be consciously aware of the full multisensory range. This perceiving body is the lived body. As such, our perception is active, and it is through actions/acting in the world that we become self-aware. Perception is a process of orienting oneself toward the world, and consciousness is a collection of what I can do, not just what I am thinking. Each body is unique in its action, but similar bodies share perceptive content. In the *The Cambridge Companion to Merleau-Ponty*, philosopher Taylor Carman points to this codependent coupling of the system (our bodies) and the environment in Merleau-Ponty's framework: "[m]y body is perceptible to me only because I am already perceptually oriented in an external environment, just as the environment is available to me only through the perceptual medium of my body" (2004, 68). It is also important to notice that this engagement is pre-reflective and pre-conscious. Merleau-Ponty states that "[m]y body has its world, or understands its world, without having to make use of my 'symbolic' or 'objectifying function'" (2002, 162).

Furthermore, Merleau-Ponty states that our bodies are in a precognitive, pre-representative engagement with objects in the outside world, which is an engagement that is framed by the body schema. The body schema (*schema corporel*) is "an integrated set of skills posed and ready to anticipate and incorporate a world prior to the application of concepts and the formation of thoughts and judgements (Carman 1999, 219)" and as such, the body schema is comparable to a habit, driven by a what Merleau-Ponty call a "motor intentionality" (Merleau-Ponty 2002, 117). Although he argues that the structural framework of the body schema is set in an early stage of life, he presents the body schema as a "system of equivalences" which constantly aim towards a perceptual balance between the perceptual background and changes or movements in the environment (163). We are deeply interconnected with the world we experience. Merleau-Ponty argues that we are not merely acting presently in the world, our actions are also directed by a phenomenal field, that is, the individual and personal background of experiences, training, and habits that shape our perception. And because we are set in the phenomenal field (as inherently as we are embedded in space-time) our perception is directed—we choose what to inspect, we select what to focus on. Our perception thus anticipates the future, we are existing towards tasks in a “spatiality of situation” (114). The body schema is the agent connecting the body to an environment, unifying the body proper, space and movement. This bodily space is our action space.

Confirmation and revision of the schema

The body schema sets the bodily space which is organized by a subject’s potential for action in the world. The bodily space changes when the subject acquires a skill or the body itself changes (with the use of prosthetics, tools and instruments, or through injuries). In short, different bodies afford different bodily spaces. The body schema thus appears to have plastic qualities, which suggests that it also can be revised. And there seem to be two forces present in shaping the body schema: Processes of confirmation informed by habits, training, and experience, and processes of revision primed by breaking habits, learning new skills, and changing the action potential of our bodies. Merleau-Ponty offers his own vocabulary for the difference between the two processes, as abstract and concrete movements (2002, 127-128). Concrete actions are ones that we do out of habit—they confirm the body schema. The abstract actions are performative. They are actions we perform, through play, impulse, improvisation, and prototyping—and are for this reason non-habitual. In other words, the body schema is formed by two processes: A process of confirmation by our habit-actions and a process of revision through performativity. To give an example of this, imagine a person with no physical handicaps, going through her everyday tasks in a wheelchair. How she meets the world from the perspective and restrictions of the wheelchair will force her to reconsider simple day-to-day operations usually done unconsciously, out of habit. The same restrictions will most likely let her identify other qualities of her bodily motility.

We engage with the world through body movements, in the form of gestures and postures, by directing our body towards possible actions. When we acquire new skills or introduce new prostheses we are acting in non-habitual ways. Where habitual use binds an instrument to a particular use or preferable body actions confirming the body schema—processes of play, performance, tinkering, and even hacking, invites us to revisit body potential and objects in the world.

Exploring bodily space and cues for action

The plasticity of the body schema is set by the body's ability to identify cues for action in a bodily space. The extent to which our bodies are able to investigate and extend bodily space, our potential for action, is the extent of the plasticity. So, before we look into strategies for extending bodily space or our bodies, we will look more closely into how this process of identifying action potential takes place.

From reactive to enactive exploration

Inherent in the concept of the body schema is the claim that we exist towards tasks, our body orients itself towards actions it perceives as potential for it, and downplays the importance of others, a process governed by habit as well natural limitations. We do not form mental representations of our goals before we act, nor do we simply react to our environment on reflex. There is a level of intentionality to our motor-control programs. We establish the world through our engagement with it, experience and understanding arise as we enact. This difference between representation of goals, and reactive and enactive exploration of space is investigated in Simon Penny's installation *Petit Mal: an Autonomous Robotic Artwork*.

Figure 23. Simon Penny's *Petit Mal: an Autonomous Robotic Artwork* (1989-2005). Photo credits: Jonathan Gröger.

Petit Mal is an autonomous robot which responds to the world as it finds it, but it does not create it. It is engineered in the tradition of reactive robots, and as Penny himself states: "*Petit Mal* has no memory. It makes no maps. It makes no authoritative world pictures. It just reacts to the world as it finds it every moment" (ARTE television 2006). As such it is critiquing the focus on artificial intelligence system engineering in robotics, in which the robotic actions are results of previously formed representations of goals based on environmental maps. Rather, the work underlines the claim that we need to engage the world with our bodies to understand it, by creating a robot that explores the concept of "kinesthetic intelligence"—or an inherent knowledge bodies have of the space around them. The inherent knowledge of *Petit Mal* is governed by two parameters: it is drawn to hotter things and avoids colder things, and it will not move closer than 75 cm to anything. While Petit Mal is a reactive robot, it is not curious nor does it have articulated goals (although it may appear so), but it does have behaviors that afford a rich kinesthetic repertoire, exploration of space. This indicates that mental representations of goals are not necessary for navigating an environment, and the capabilities of a body to perform independently of conscious thought. But it also demonstrates the shortcomings of the robot in forming lasting relationships and building habits for actions. Humans have this ability to revise their actions, based on perceptive experience. We act in accordance with goals, that are both informed by the capabilities of their bodies, as well as the phenomenal field of past experience, cultural preference and history. This specificity also shapes our body's ability to identify perceptual cues and recognize actions.

Perceiving cues and recognizing action potential

In 1979 J.J. Gibson published *The Ecological Approach To Visual Perception* and introduced the concept of affordances as cues in the environment that guide perception. Affordances are unchanging, invariant, and exist prior to perception. He separates affordances from properties and qualities of objects, proposing that:

> Phenomenal objects are not built up of qualities; it is the other way around. The affordance of an object is what the infant begins by noticing. The meaning is observed before the substance and surface, the color and form, are seen as such. An affordance is an invariant combination of variables, and one might guess that it is easier to perceive such an invariant unit than it is to perceive all the variables separately. It is never necessary to distinguish all the features of an object and, in fact, it would be impossible to do so. Perception is economical. (Gibson 1979, 135)

Affordances are unique to each animal, Gibson suggests, which I interpret as affordances being unique to a type of body. Having a specific body does not only determine how I can explore a bodily space, I will also read the environment in accordance as I have different means of approaching it. A door knob offers very different affordances to a fly, a mouse, a child and a grown human being. A decade after Gibson, cognitive scientist and usability designer Donald Norman took the concept of affordance into his own hands, and the reintroduction and modification of the concept presented in *The Psychology of Everyday Things* in the late '80s and throughout the '90s quickly rose in popularity in the human computer interaction community (1988). His take on affordances was and is normative, as he sought to present a model for what an engineer or designer needs to take into consideration and include for their product or service to be successfully understood by users.[37] Norman has re-engineered the concept of affordances to include only those actions intended by the designer to be performed, that are *perceived* and *recognized* by the user. As such he creates a concept catering to the developer, who opts to design a product or service for a specific user in mind. Affordance of an object is a measure of a designer's capability to present its action potential. However, this idea of affordance excludes the many unintended or unimagined actions that other people identify through their engagement, play, and tinkering with the object.[38] Secondly, his concept is very much rooted in cognitivism. Affordance is formatted from being perceptive cues in an environment that is perceived directly, to becoming a mental representation involving higher cognitive processes. For this reason, Gibson's initial take—of affordances being the perceived (but not necessarily recognized) invariants (pertaining to the object or artifact)—is more flexible. The perceptual experience of encountering an object will give rise to a specific set of affordances, that only a specific body bound by its unique bodily design and capabilities, as well as learned skills and experience, have access to. And this access is not directed by recognition, and as such, Gibson concept of affordances very much connects to the phenomenological approach proposed by Merleau-Ponty, that we exist towards

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[37] In the 2013 revised edition of his bestseller *Psychology of Everyday Things*, renamed *The Design of Everyday Things*, Norman introduces the concept of signifiers to make a better distinction between possible actions an object affords, and how these actions are discovered. Partly to mend some of the confusion that arose from the rather radical re-conceptualization of the term affordance, but also to update the design guide to better describe and tutor the developers of virtual objects.

[38] The intended and imagined functionality of an object, as proposed by a designer, often differs from the actualized functionality. Many examples of the uncommunicated intentions of the designer are found in specialized user interfaces (just consider the many attempts to make remote controls for TV's or heat pumps with too many buttons all given equal importance, or UIs for specialized appliances such as washing machines or GPS systems).

tasks. Each body has unique encounters with an environment, and affordances are actualized in this encounter.

While the autonomous robot Petit Mal perceives environmental cues fitting its robotic body's capabilities, it lacks the ability to form goals, and end up merely reacting to them. An enactive exploration of space entails that we establish our environment as we act in it. It is a dynamic process, where we orient our bodies towards tasks. But humans do not only respond actively to perceptive cues as we direct perception towards tasks, we also have a unique ability to extend our potential for action.

Techniques and tools to postulate goals

By utilizing body techniques or binding tools into our body schema, we redefine our bodily space or space for action. The notion of bodily space and our potential for *being-in-the-world* is not only a phenomenological concern, it has also been confirmed in recent neuroscientific evidence. Based on experiments, cognitive scientist David Kirsh argues that our brains construct a layered presentation of space (2013). Bodies exist in several spaces at once: the peripersonal space (near-body), the extrapersonal space (beyond the reach of our limbs) and personal space, which is the space inhabited by our body proper. Peripersonal space of particular importance as this is the space we consider within reach for action. As such, the Crab Nebula in Taurus constellation is trapped in our extrapersonal space. While we can investigate it through a telescope, we cannot (at this point) directly interact with it. This is not the case with some telepresence systems, such as selected videoconferencing systems, or tele-intimacy devices.[39] Here input and feedback loops designed for several modalities may be constructed between two distanced spaces—and for this reason must be considered part of our peripersonal space. There are not only phenomenological arguments for such a claim, this extendibility

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[39] There exists a range of telecommunications wearables focusing on communication of tactile affect, proposed in projects like the T-Jacket (http://www.mytjacket.com/) for or the Hugshirt (http://cutecircuit.com/the-hug-shirt).

of peripersonal space is also reflected in the material situation of the body. Kirsh points to empirical studies of Japanese macaques and humans by Maravita and Iriki (2004) which conclude that “neurophysiological, psychological and neuropsychological research suggests that this extended motor capability is followed by changes in specific neural networks that hold an updated map of body shape and posture” (Kirsh 2013, 3:7). Instruments extend our peripersonal space and increase our potential for actions in the world. By doing this, they also shape our goals. “In addition to altering our sense of where our body ends each tool reshapes our ‘enactive’ landscape’ —the world we see and partly create as active agents” (3:3). Our perception not only has *direction*, with the use of tools we also *postulate goals*. Tools extend what we perceive as possible tasks in a given space and situation. What is perceived as possible will affect the goals formed and activities chosen, and indirectly shape our interests and attentiveness towards the world. As a new parent, I have reconfigured my perception of public space accessibility as my body now “includes” a baby-stroller, which to a great extent defines my day-to-day goals. My peripersonal space is revised with the extension of the stroller, and it dictates what I find achievable (the set of actions I consider) within a given timeslot. We engage with the world through exploration and towards tasks, as we identify cues for actions. Our ability for identifying actions is dependent on the natural setup of a human body, the bodily space it exists in, and the techniques, tools and technology used to extend either the body or the space. While the plasticity of the body schema is substantial, there also seem to be some natural limitations to what we can do. Body schemata seem to have certain pre-noetic restrictions, perhaps coded in our DNA. As an example, we only grow bigger, never smaller, and similarly, we have five fingers and toes, and symmetric body halves. We are also always privy to a cultural and historic conditioning of body habits and techniques, stored in the body schema which is binding its subjects in a time and place, that might be difficult to counter.

This points to another insight. As Gallagher puts it, it is “not just brains, but bodies and environments, and social and cultural practices undergo interrelated reuse or plastic changes due to their on-going, dynamical interactions across all relevant timescales” (Gallagher 2018, 10). Our body schemata are never truly fixed but set in a time and place of human evolution and practice.

2.2 Evolution and Adaptation: The technical mediation of the body schema

The plasticity of the body schema accommodates for revisions, and our ability to extend action potential is closely connected to our ability to integrate techniques and tools in the body schema. I will argue that the development and use of technical strategies and tools to extend our action space is inherent in human nature. We have always explored our action potential and in turn revised our body schema in conjunction with tools and technology.

Some revisions take place over a long time, almost glacial in nature, either as an outcome of the slow evolution of the physiology and physical capability of man formed by natural selection or developed over time as result of specific cultural strategies and habits framed by technology. On the other end we have abrupt body schema revisions resulting from radical augmentations offered by diverse technology, both as temporary and permanent configurations. In this following we will discuss this first class of revisions, before moving onto the second class in part III.

The technical body and learned habits

A huge part of our day-to-day actions are automated skills or techniques governed by habits, learned or formed naturally over time, where we repeat and in turn confirm previous actions towards a task or goal. But every so often we engage in new actions to overcome an obstacle or get access to new experiences. We take that extra big step over a puddle of rain to avoid getting wet, or acquaint yourself with a friend’s SLR-camera on which all the buttons are located elsewhere than on our own.

In these moments we become aware of the bodily habits we are maintaining, but also how quick we can adapt to new situations and setups.

Following the line of thought proposed by Merleau-Ponty we are primarily engaging with the lived body through concrete movements, habitual movements. These bodily gestures are our means for acquiring and confirming habits through exploring the world and enacting intentions. These actions are also heavily influenced by culture and tradition. As already noted in the work of French sociologist and anthropologist Marcel Mauss in the ‘30s, there is an intricate relationship between the forming of habitual gestures and body language, called *body techniques*, and tradition, culture, and social interaction. Starting from the observation of various casual techniques, for example digging, running or striding, Mauss suggests that there exists a cultural conditioning of body gestures or mechanisms of the body, which are learned and consequently, have each their own specific cultural form. He points to the “the social nature of the habitus” (1992, 458), the social aspect of habits separated by education, cultures, status, tradition, and fashion, and significantly less by individuals. Techniques of the body differ from others in that they are “*traditional* and *effective,*” meaning they are “felt by the author as actions of a mechanical, physical or physicochemical order and that they are pursued with that aim in view” (461). And this is where Mauss really gets interesting. He proposes that “man’s first and most natural technical object, and at the same time his first technical means, is his body” (461), and that this is a technique we need to differentiate from instrumental techniques (how we incorporate tools into our body schemas) in understanding how bodies relate and engage with the world. Part of the body schema is conditioned by traditional, cultural, and social sensorimotor habits. Beyond the initial abilities of grasping, seizing and pointing, a lot of body movements are learned, becoming body habits, imposing ways of walking, posturing, touching, gesturing. Mauss' proposal that our bodies are inherently technical is an assumption we will bring with us through the rest of this investigation.

Technogenesis

In *Bodies in Code* Mark B. Hansen expands on Merleau-Ponty's concept of the body schema in his discussion on new media interfaces. To underline the intentionality of the body schema Hansen defines the body schema as a "flexible, plastic, systemic form of distributed *agency* [my emphasis] encompassing what takes place within the boundaries of the body proper (the skin) as well as the entirety of the spatiality of embodied motility" (2006, 38). This agency of bodily movement and position defines our prepersonal domain, the space of motor-intentionality which couples the body with the environment, an "organism–environment coupling operated by our nonconscious, deep embodiment" (20). The body schema contains knowledge not only about the action potential of the body proper (contained by the skin), but also about the peripersonal space (the space within reach of the body limbs—natural as well as prosthetic). Tool-use thus has a particular impact on the body schema. Hansen continues:

> [F]irst, the body is always in excess over itself; second, this excess involves the body's coupling to an external environment; and third, because such coupling is increasingly accomplished through technical means, this excess (which has certainly always been potentially technical) can increasingly be actualized only with the explicit aid of technics. (39)

In tune with Merleau-Ponty, Hansen claims that the body schema is always technologically mediated. Our embodiment is realized in conjunction with tool-use. In fact, we are not only *beings-in-the-world*, actively perceiving bodies that experience the world. We are also *bodies-in-code*. Integrated with, and defined by the techniques and tools we develop and use, we co-evolve[40] cognitively through our

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[40] The concept of technogenesis and co-evolution is well-developed in Bernard Stiegler's renowned book series *Technics & Time* (1998, 2008, 2010). Here the concept of *co-originarity* is introduced to define the co-evolvement of humans and technics. Much of this co-evolution happens so slowly and gradually that it may slip our attention, however, Stiegler suggests that certain technological revolutions, such as the Industrial Revolution in the 18th century, have introduced too radical conditions on humans to go unnoticed. During this time man became acutely aware of how connected his being is with technology. I would propose that the

engagement with technology in a process labeled technogenesis (Hayles 2012, 10). In this sense tools are never neutral, they are a specific historical articulation of human action potential. Equally, a tool cannot be considered separate from the body, as we shape and direct our bodies much in the same ways as we direct our tools towards tasks. This relationship between bodies, tools and time is often referred to as *technicity* signifies the tool as it emerges in situ, collectively. The technical aspects of embodiment should be understood as temporal, something that changes over time, in particular places and within certain collectives.

2.3 Active Revisions: Radical plasticity through improvisation, augmentations, and telepresence

We have discussed how our bodies engage with the environment by actively exploring, identifying cues, and generating actions. We have also seen how intrinsically we incorporate body techniques and tools to explore our surroundings. We gradually alter and extend our action space through our engagement with technology. This is an evolution that is somewhat fluid and gradual that it may almost seem invisible to us, but not always. As mentioned above, we have witnessed technological advances that have collectively revolutionized the way we use our bodies, how we communicate with each other, and explore the world, which constitute a significant and collective revision of our body schema. While many body schema revisions stem from passively acquired skill sets and tool-use, that have come into play sub-consciously over time, there are also many revisions that are introduced to us actively, where we take specific steps to extend our bodily space and action potential. These active revisions will be discussed below under the headings: The Playful Body, The Augmented Body, and the Telepresent Body.

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digital and network revolution of the 20th century has brought many similar reactions. Instead of being independent masters of technology, we again need to rephrase and re-consider the conditioning power of technology on human agency.

The Playful Body: Breaking habits and acquiring new skills

Active revisions are most often triggered through individual exploration. Returning to Merleau-Ponty, he proposes that body schemata are revised through engaging in abstract movements. Improvisation and play are key drives for bringing forth such movements. His prime example is the man who decides to take alternate routes back home from work each day. Walking home, his unconscious habit-movements are challenged by each new turn. His conscious choice to improvise, becomes a method for breaking habits and acquiring new skills. Abstract movements are also made available by resetting or changing the bodily space as we extend the reach of our bodies through the use of tools, or even altering our bodies. But what extensions in terms of body augmentations, alterations and telepresence experiences are likely to be arranged into the body schema? As we discussed above there seem to be some natural limitations to what actions a body schema may facilitate.

The Augmented Body: the potential of embodied reflection

If we alter the body (through implants and prostheses causing different augmentations and alterations), we change the action potential of that body, and as previously stated, different bodies afford the recognition of different tasks. Several media artists, Stelarc being a prominent one, suggests that bodily play and improvisation is not enough. We need to hack our bodies, which are currently stuck in the glacial slowness of evolution, to match the radical development of our thinking. In other words, we need to challenge biological evolution through hacks to match the revolution of thought, as we by altering and augmenting our bodies to give rise to new experiences. Stelarc's many art projects show his dedication to the potential of body augmentations, some more dire than others, but also to some inherent restrictions.

In the following, I will discuss two artworks that investigate the experience of having additional or significantly altered limbs, aiming to trigger novel and conflicting body sensations. I propose that these sensations give us an inkling of potentials and limitations in body schema revisions.

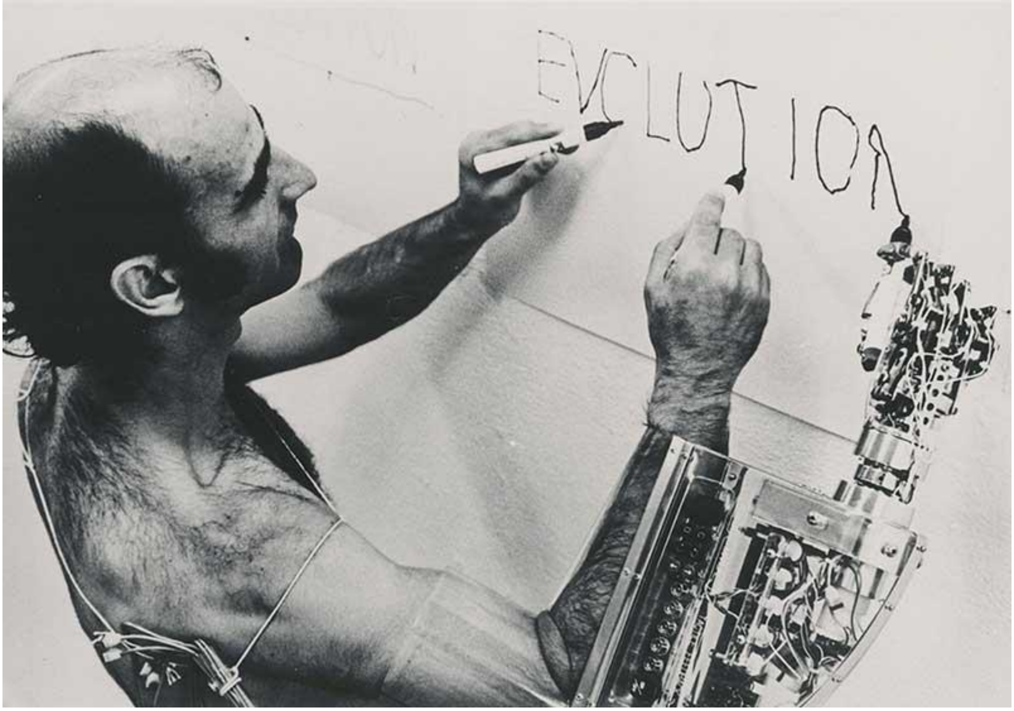

Figure 24: Stelarc performing *Handwriting* with the prosthetic body sculpture *Third Hand* in 1982 at the Maki Gallery, Tokyo. Photo by Akiro Okada.

We can all recognize the gestural and cognitive effort in coordinating two hands to write one word. In *HANDWRITING: Writing One Word Simultaneously with Three Hands*, which is one of the many performances incorporating the Third Hand prosthetic, Stelarc takes it further. Here three hands simultaneously co-write the word "EVOLUTION," the prosthetic arm being a semi-autonomous limb triggered by muscle contractions. As Goodall sensibly notes:

> The functions of pinch-release, grasp-release and wrist rotation in the third hand were controlled by electrical signals triggered from muscle contractions in the leg and abdomen. Stelarc was effectively 'writing' with multiple parts of

> his body. At the same time, the robotic prosthesis was tapping into his energy system in order to perform an action that did not entirely belong either to it or to him. He was working towards a symbiosis, and the handwriting demonstrations were, in his words, 'to do with developing a relationship with the extra limb, something traditionally connected to identity and identification.' (Goodall 2017, 78)

The work of Stelarc provides an example of the habitual relationship between body parts in coordinating actions, and the challenges in including an additional limb with some agency. In this case, the overall prosthetic design appears unrealistic. There is little linkage between the cognitive process of writing and how it is executed in the body, and contractions in middle-torso and leg muscles. Likewise, the element of robotic agency seems closer to that of a controller, executing pre-programmed tasks based on muscle contraction as triggers. However, for the audience the work has significant symbolic value, as it invites us to reflect on the action potential and control of a third arm. Haptic sensations may arise from physically imagining how this novel body extremity may be operated, enabling embodied reflection. This opportunity for embodied reflection on potential bodily augmentations, is explored in several artworks, and is elegantly presented in recent mirror work centered around the hand discussed below.

The extensibility of the hand

Augmented Hand Series (2014) is an interactive software installation by Golan Levin, Chris Sugrue and Kyle MacDonald, which investigates the concept of a hand as an interface for the world. The system allows its players to see their hands transformed in real-time beyond the (currently) possible forms, giving rise to both playful and uncanny experiences. The installation is set up as an open small box with an opening for the player's hand to be placed, and a touch screen on top which displays the projection of her hand in real-time. By sliding a finger on the touch screen, the player switches between transformations. The system captures video of the player's hand posture and its movements and displays the hand actions with various transformations. The transformations target the hand only, not the entire field of view, which is key in connecting the visual representation of the transfigured hand to your own hand.

The system can add an image of an extra digit or remove one, as well as varying the length on the fingers or giving them the same length, either by stretching the fingers or by adding a knuckle. Some of the transformations seem to imbue the digits with some independence, letting them wander off seemingly random in different directions. Others again will exaggerate or delay the movements of the digits. Some are complete transfigurations, bending and stretching the digits in impossible and somewhat grotesque directions, which in reality would mean that most of the bones were broken and the hand no longer functioning. And finally, there are transformations that are centered on the palm, emulating breath by letting the palm surface expand and retract, as though the hand is an independent being, breathing on its own.

This installation is simple in its premise, but provides a rich object of contemplation and experience, giving rise to bodily reactions and reflections on what a hand is, what we take for granted, how hands are used both in general and individually, but also how they could potentially be used if reconfigured. As such this work induces embodied reflection providing us with insights on the hand as an interface.

Figure 25, 26, and 27. Screenshots from *Augmented Hand Series (v.2), Live Screen Recordings,* video documentation by Golan Levin (2015), featuring the hand transformations *Variable Finger Length* (left), *Plus One* (middle), and *Two Thumbs* (right). Courtesy of the artist.

There seem to be two categories of transformations. One set presents hand alterations that could be possible in a future world, or which have already taken place in some of us born with genetic mutations leading to hands with more or less than the appointed five digits or finger limbs. These visual transfigurations are funny and strange as they invite the player to become perceptually aware of how their hands are operated, and in extension reconsider what a hand may reach and perform. I know I am looking at my own hand, as it is presented to me with all its familiar features (scars, nail shapes etc.), and as a digit is removed, I find myself trying to identify what finger is missing. As a digit is added, I am wondering what muscles to activate to move it. Similar perceptions arise as the fingers are added or removed, forcing/inviting the player to consider how such fingers can be bent, and in extension consider what tasks such a hand could perform. How would you use a hand with an extra thumb? The second category deals with alterations which we commonly would conceive as damaged hands—as only a hand with no or broken bones would allow for such transfigurations.

Figure 28 and 29. Screenshots from *Augmented Hand Series (v.2), Live Screen Recordings,* video documentation by Golan Levin (2015), featuring the hand transformations *Angular Exaggeration* (left) and *Vulcan Salute* (right). Courtesy of the artist.

The first category instills curiosity, while the other gives rise to discomfort, as the “damaged” hands still seem to function. As such, the artwork seems to indicate that there are body schema revisions that are very difficult to implement in finding a neural path for engaging a limb in completely non-conventional ways, while others are more likely to be accepted into a revised version of the schema.

This artwork bears close resemblance to the mirror artworks presented in chapter 1, in that the embodied sensation is promoted by purely visual means as no touch nor proprioceptive senses are actively engaged in this scenario. And while it may dictate the extent of discomfort that can be experienced during the interaction, it reiterates the potential of mirror-vision transfers.

Body transfer by mirror-vision

The *Augmented Hand Series* seems to provoke certain sensations in the interactor, and a clue to what they may be about is found in neuroscientific research. The proportional size of the projected hand image to the interactor's real hand and the fact that the image is transferred in real-time, is key in linking the player's perception of her own hand to the augmented version of the hand. The fact that it looks like your own hand and moves like your hand, binds you to the image of the hand. The installation triggers the same responses in the player as participants in various mirror-vision illusions, or body transfer illusions, which trick the brain to assume ownership for a new or different body part.

A well-researched setup is the rubber hand experiment, first presented in the late '90s (Botvinick & Cohen 1998) and continued in the early 2000s (Ehrsson et al. 2004). In these experiments the participant sits at a table with both their hands placed on top. One hand is hidden from sight behind a veil or box and replaced with a rubber hand or a mirror image of the opposite hand. As long as the illusory hand holds approximately the same position and is similar looking to one's own hand, actions performed in real-time (such as being touched or hurt) on the illusory hand will give rise to sensations in the hidden hand. Botvinick and Cohen refer to this as the "three-way interaction between touch, vision and proprioception," which features in how we identify our own bodies. In later research Ehrsson and team suggest that we have a neural mechanism for "bodily self-attribution", a system which stores the extent/reach of our bodies. This mechanism is multisensory—meaning that if one sense (i.e. the visual sense) is particularly targeted, we can interrupt the mechanism and induce body transfer illusion. However, the illusion is dependent on synchronous visual and tactile stimuli, as well as a congruent position of the rubber hand.

So, symmetric and synchronous visual feedback is key in linking a new or altered body part to your own. We can assert that the Augmented Hand Series induces this illusion in its players. However, something else is at play in this artwork. What happens to us when we are given the option to try out (at least visually) our new, augmented limbs?

Mirror-therapy and movement

Variants of body-transfer experiments have been used in treatment of people with damaged or missing body limbs. In his research on phantom limbs, neuroscientist V.S. Ramachandran works with amputee patients suffering from pains in hands and arms they no longer possess. He has developed a treatment called mirror-therapy centered around a mirror box where reflections of their healthy limb projected onto the position of the phantom limb (Ramachandran and Rogers-Ramachandran 1996). The patient is then asked to look in the mirror while moving both the healthy and phantom limb symmetrically and at the same time. The treatment has been successful in allowing patients to mentally target and move the phantom limb, and thus relieving the pain. This research seems to suggest that we have neurological maps that govern the movement and extension of different limbs. So, we have a brain map for our hands and what they can do, and another one for our feet.[41] Another key point in this research is that the effect takes place through *movement.* We need to move the limbs in order to access, activate and alter the neural map governing the limb. As such, this is a description that very much fits into the concept of the body schema, which is revised through movement. It seems fair to suggest that

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[41] The concept of neurological maps or brain maps was first introduced in the late '30s by Wilder Penfield who performed direct neural stimulation on brains to identify the location of sensory and motor systems, which are the brain centers responsible for processing input from the different sensorimotor receptors (Penfield and Jasper 1954). By the time of discovery brain maps were considered fixed. It was later, through the significant contributions of neuroscientists like Michael Merzenich, that these maps were shown not to have fixed functions, rather they can be re-wired by training the brain to create new neural pathways (Merzenich et al. 2009).

the sensations that arise from playing (i.e. moving, stretching fingers and palm) with the *Augmented Hand Series* installation are somesthetic responses making us consciously aware of the neural map and body schema governing our hand.

The nature and nurture of brain plasticity

If you ask people if they "remember" their tail, most of us can easily pinpoint exactly where it would be and how they would operate it, although it is millions of years since our ancestors lost them. Sitting here writing I instinctively know how to move it to the left and right, but I don't sense the tip of my tail. I am curious if an experience involving mirror-vision feedback would be able to trigger this sensation?

There is an element of plasticity to the work distribution of the brain. It is able to reuse neurons to represent new things—or to have new neurons take the role of previously damaged ones. This is seen in people with damages or disabilities, able to extend one sense to provide sensory input previously (or usually) handled by another sense (e.g. the developing the sense of echolocation; the ability for the blind to "see" their surroundings by emitting clicking sounds).[42] There are also those with localized brain damage which has governed particular movement or speech, who through directed treatment become able to use a new part of the brain to perform the same tasks (e.g. the success of constraint-induced movement therapy on stroke victims).[43] Both of these scenarios involve a strenuous amount of training over

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[42] A recent study published by Thaler et al is measuring the range and richness of human echolocation using eight blind expert echolocators. (Thaler et al. 2018)

[43] Constraint-induced movement therapy (CIMT) is a group of neurorehabilitation treatment procedures first proposed by behavioral neuroscientist Edward Taub. The treatment is aimed at patients that have suffered from damage to the central nervous system, primarily stroke, although treatment has also been extended to victims of cerebral palsy, MS, and spinal cord damage. The core of treatment is restricting movement in functioning body parts to force the brain into finding a new path to motor-nerves in a paralyzed limb. The treatment originates from a set of controversial experiments on monkeys led by Taub in the '60s early '70s. Paralysis was induced on the forelimbs of infant monkeys by disconnecting sensory nerve paths from an extremity (called somatosensory deafferentation). Simultaneous movement was restricted in other limbs that would otherwise compensate for the non-working limb (Taub et al. 1973). Experiment with deafferentation of extremities on monkeys was first performed by Sherrington and F.W. Mott at the end of the 19th century aiming to identify the origin of movement (Mott and Sherrington 1895). Here Sherrington noticed that the sensory disconnection of nerve path resulted in the monkeys not moving their limbs, even though the motor path was operational. From this he concluded that all movements are the result of reflexes originating in the spinal cord, and not from the brain, and pioneered a way of thinking of movement that lasted well into the second half of the 20th century. By building on the original experiment including the use constraints, Taub not only introduced the basis of a treatment method, he also proved that the reflexes are

weeks, months and years compelling the body to update its schema by rerouting neural connections. And as such it is fair to ask about the speed of brain plasticity: how quickly can this be applied? It seems that parts of the mechanism governing our body schema are protected by the slowness of evolution. The nature-nurture equation in the forming and sustaining of inherent qualities of the body image and schema is not easily unraveled. Part of the program seems hardwired in our genetic code, and as such, becomes very hard to break. We seem to have a built-in desire for symmetry, born out of an evolution of failed and confirmed designs for survival, stretching millions of years. Symmetry in bodies is found throughout the animal kingdom. The setup with sets of two limbs (arms, legs, wings etc.) mirrored over body halves, is a very successful design, shared by all mammals and birds (and many insects as well). The design specifics seem to be part of us, hidden in genes and sustained through social, cultural and technical interaction.

Other parts of the body schema will more easily form/reform through the breaking of a habit or experimental play and is primarily limited by our concept of what a normal body is and can do. It is a schema informed by a historical body image that we bring with us, and the body image of what we consider natural today. When is an extension of the body schema considered natural and when is it considered cyborgian? And how do we perceive the cyborgian? There is a stark contrast between the dystopian vision of machine-ridden cyborgs that have lost their humanity (e.g. Darth Vader of the Star Wars universe) versus the positive notion of the prosthetically enhanced individuals seen in current prostheses advertisements or in filmatic presentations of the superhumans (e.g. the Iron Man series).

Here the *Augmented Hand Series* installation seems to bridge the natural and the cyborgian, by layering our experiences of what a hand currently is, with the prospect of what it can be—independent of the interactors' utopic or dystopic view on augmentations. In this way it shares the qualities of Donna Haraway's famous concept, the Cyborg: A neither-nor creature which exists between dualities, and

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not primarily responsible for movement, our brains plays a significant part, and that depending on the capabilities of our bodies, our brains will try to find a way to get its message across.

because of this in-between position is capable of nurturing and sharing new experiences (1991). Of the two sets of transformations offered by the Augmented Hand Series system, the first set is more apt in letting us experiment with an extended body schema, triggering neurons to form new connections. Even though the experience is temporary, lasting only while the interactor uses the system, the sensation offers her new sensations and a visceral concept of what an augmented hand could be, can be, or even should be— challenging the current norm. The second set of transformations are perhaps too uncanny in their transfigurations to induce other than imagery of broken, damaged, or dead hands (although such transformations might be a desire for some).

The *Augmented Hand Series* offers the interactor a rich environment for re-conceptualizing the notion of what a hand is and can do. It promotes thinking about how a hand can be utilized if augmented, and at the same time lets the interactor revisit how we currently use hands—encouraging us to contemplate what role hands have as our interfaces with the world. More importantly, as digital and sensor technologies develop, we see works of digital art offer us a laboratory setting for exploring insight from both phenomenology, and re-staging or expanding on findings from neuroscience. We are able to simulate (with obvious limitations) the effect of altered body schemata and new directions interface design.

The Telepresent Body: Re-embodiment in remote lands

Insights from various mirror works can be re-applied in the analysis of telepresence and telemanipulation applications. These are systems set to present scenarios that extend peripersonal space, by connecting distal locations and times. However, the success of the setup is varying, much due to the insistence of strict visual representation of the remote location. The extension of the body schema happens in conjunction with extension of action space. We need to be able to act within the space to feel present, so how may embodiment re-introduced in a telepresent landscape or remote space? Mirror vision strategies have revealed that a symmetric (same position and size) and synchronous (real-time rendering) visual mediation of the body is needed to link a new or altered body part to your own. But, as the rubber hand experiment shows, not only is a symmetric visual mediation of the hand important, the hand must be moving synchronously in order to induce a sense of ownership, or else the body image/body schema correlation will break. Interestingly enough, research suggests that this does not hold true for all full body illusions, the sensations of transfer of the full body into virtual or telepresence environments. An insightful literature review and analysis by Lesur et al. on body illusions (2018), suggests that asynchronous visuo-tactile stimulation (the temporal mismatch between the presentation of visual and tactile sensory input to a participant), is only sufficient to induce a break in body image-body schema interactions such as rubber-hand experiments and similar mirror vision setups involving limbs, but not necessarily in first person perspective full-body illusions (1PP FBI). How come?

Findings from several experimental setups, particularly the work of Maselli and Slater (2013, Maselli et al. 2016), suggest that there is a "link between head-related visuoproprioceptive coherence during 1PP FBIs[44] and the integration of sensorimotor signals" (2018, 102). In other words, breaks in body image-body schema integration during asynchronous visuotactile stimulation, only occurred when head-related movements were not permitted, proposing the importance of mediated head-movements in establishing and maintaining body ownership. Additionally, the survey reveals that sensations of body transfer of limbs, as opposed to first person perspective full-body illusion with optical flows matching head movements, are more prone to body image-body schema breaks as a result of asynchronous mediation of visuo-proprioceptive and visual-motor cues. Head-related sensorimotor signals are key in mediating body schema revisions in first person virtual or telepresence scenarios for the full body. There is still a lot of work to be done here, but these initial findings are important, and may provide a sharper understanding of the potential of head-mounted displays in mediating experiences of presence, at least sensations of body ownership.

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[44] 1PP FBI = First person-perspective full-body illusions

From sense of ownership to sense of agency

A sense of ownership, in which one experiences the body part or body as one's own, may be introduced by visual mediation. But it is not sufficient on its own for inducing a sense of agency, understood as the experienced possibility of generating actions (Gallagher 2000). In everyday interaction we do not experience these two sensations apart, but in virtual reality as well as telepresence environments, these to sensation requires different means of mediation. Body schemata are, as previously discussed, are the main control program for guiding action, and must to some extent be acknowledged, to induce sensations of agency in the interactor.

A way to connect ownership and agency of action in telepresence systems is through the visual mediation of haptic feedback, recounted in the work of Luna Dolezal. She lists a set of criteria for phenomenological re-embodiment, based on Dreyfus's analysis of embodiment in telepresence scenarios (2000) and findings from experiments with telesurgery. In accordance with phenomenological thought the key aspect of embodiment is the mediation of motor-intentionality and ability to apply sensorimotor control programs, i.e. body schemata. While visual representation is important, it is the "transfer of the body schema, motor-intentionality, and perception, where successful intentional action would induce a transparency of not only the technological interface with which one engages, but also transparency of the body in the remote environment" (Dolezal 2009, 220). Technically speaking, the interactor's body must match the remote body visually. Secondly, the system must support rich sensory feedback. In addition to corresponding and seamless visual feedback of the environment, visual mediation of proprioceptive sensations, as in the perception of position of limbs, posture and movement, must be supported. The ability of the system to support proprioceptive awareness is key to induce a sense of agency.

There is no need to perfectly emulate physical worlds for the feelings of presence to take place. The mediation of intentional actions is sufficient for the experience of embodiment in telepresence scenarios. To explain this difference, Dolezal presents two sides of embodiment, the intentional body and the sensory body:

> These two aspects of the body, that is, the intentional body and the sensory body, are described in a distinction offered by Tsakiris and Haggard (2005, p. 389) between the "acting self" and the "sensory self." The acting self is "the author of an action and also the owner of the consequent bodily sensations," whereas the sensory self is "solely the owner of bodily sensations that were not intentionally generated, but … passively experienced" (p. 389)." (221)

The sensory body will always be here, but it is possible that the intentional body, the acting self, could be transferred there. This distinction is also what sets the limitations of telepresence scenarios, as the transfer of full corporeality or the element of risk will never be fully possible, because the sensory body is stuck here. This shows that visual technologies are sufficient for mediating sensation of body ownership, and that matched with corresponding visual mediation of haptic sensation may promote a sense of bodily agency, allowing the interactor to engage in intentional actions, and experience feelings of re-embodiment in remote locations.

The potential of extending embodiment by utilizing corresponding visual mediation of proprioceptive awareness appears to be extensible into virtual worlds as well. Media researcher Rune Klevjer proposes the concept of prosthetic telepresence in gaming environments utilizing player avatars, as a means to induce sensations of embodiment in virtual and telepresence scenarios. He argues that "[t]he prosthetic avatar functions both as the player's bodily extension into screen space and as a proxy or replacement for the player's body as an object in external space." (2012, 21). This experience is embodied in contrast to cinematic experiences where "there is no actual space to be inhabited, only images, and there is nothing off-screen except our own mental projections'" (22). The reasons for embodiment are threefold; not only does the avatar resemble the physical likeness of the interactor and thereby "evok[e] familiar body schemas", the games also offer an simulation of tangibility through the "conceit of continuous materiality" as the avatar at all times is capable of manipulating and traversing the gaming environment, through mediated experiences of *agency*, *intentionality*, and *locomotion*. Finally, the character is projected as a humanoid in the fictional narrative, strengthening the bond between avatar and gamer.

Klevjer claims that the sensation of embodiment is mediated via the body image, through the visual presentation of the capabilities of the avatar for spatial, task-oriented actions (8). I note that he separates proxy embodiment from interfaces promoting direct interaction (using hand and fingers to manipulate and navigate virtual worlds and objects) and what he labels as “mirror” interfaces, where the interactor’s movements and shape are mapped into the gaming environment (14). This, I would guess, is due to the lack of body proxy as the interactor directly mediates her embodiment. The remote body or avatar is both an extension and a relocation of the body, that engages the interactor's "locomotive vision"(1)—the sense of moving through the images, connecting the sense of ownership and agency.

Klevjer claims that mirror vision strategies may produce sensations of body transfer, but only when mediated through an avatar. This line of argumentation frames a consistent and ongoing insistence that visual representation in key inducing bodily sensations of presence and telepresence, specifically when mediated via the body image.

Potential and limits of visual representations of haptic actions

A neuroscientific argument for the potential of screen-based mediation (particularly in scenarios where the user shall learn new skills), has been promoted through the research on mirror-neurons initiated in the early ‘90s led by neurophysiologist Giacomo Rizzolatti at the University of Parma. It proposes that we inhabit a mirror system (Rizzolatti and Craighero 2004) where neurons governing our sensorimotor system fire when we observe an action.[45] This research suggests that seeing enables

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[45] Mirror neurons were first identified by and presented in *Understanding motor events: a neurophysical study* by Di Pellegrino et al. in 1992. A common misunderstanding is that mirror neurons fire by all kinds of actions recognized by the viewer. However, the study suggests that mirror neurons only fire by particular actions, object-directed actions. It is not sufficient to see someone grasping non-existing objects, or moving towards objects, for the mirror neurons to react and fire (7).

action learning to some extent.[46] Neuroscientist Vilayanur S. Ramachandran's work on phantom sensations and mirror visual feedback (MVF)[47] is providing a more nuanced view of the importance of sight in adjusting the body image, the plasticity of brain maps and congenital aspects of the body schema. The case of the 3-finger digits amputee (McGeoch and Ramachandran 2012) provides a powerful example of this, and involves a woman born with one hand missing two fingers, the thumb being one of the missing digits. Following an accident where the whole hand was amputated, the patient grew a phantom hand with the full five digits—suggesting that we have a hardwired, as well as culturally sustained schema for a hand consisting of 5 fingers including a thumb. This suggests that the brain from birth includes a representation of a complete hand. However, the phantom hand was not fully developed when it first appeared (two of the digits were half normal size), and the woman reported a sustained pain in the phantom hand. It was through mirror visual feedback treatment that the phantom hand grew into a normal, proportional hand, at which point the phantom pain receded. This example stresses the potential of visual feedback in forming and sustaining the body image, as well as its part readjusting inherent qualities of the body schema.

Nevertheless, there are significant shortcomings in acquiring skills through purely idea-motor representations, proposed in the theory of common coding by (Prinz 1997) and motor resonance theory (Agnew et al. 2007) as they primarily promote the power of affordances recognized visually. Tactile (touch based) or proprioceptive (movement and position based) affordances that are first revealed

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[46] It is important to realize that both cognitivists and phenomenologists have used mirror neuron research to front their respective arguments. The reason is that current mirror-neuron research does not clearly propose the order in which we come to recognize the goal of an action. Following the logic of the phenomenology of Merleau-Ponty it is the identification with another body action towards an intentional object, that engages my body. I recognize the goal of the action only after my body has identified the behavior of the other body. On the other hand, advocates from a stronger cognitivist tradition will argue from the concept of mental representations, stating what mirror neurons do, is allowing us to identify an action after we recognize the goal of it. See De Preester (2005) for a longer treatment on different phenomenological logics in mirror neuron theory.

[47] Mirror visual feedback is a technique developed by V.S. Ramachandran where one body limb is reflected and superimposed onto another limb or even phantom limb, where the stimulation of the former body parts is felt/sensed in the latter. This technique has particularly been utilized in the treatment of phantom pain in amputees.

through overt, physical involvement (such as gravitational pull, pain, resistance, pressure), are not recognized and acquired through idea-motor representation as they are hidden from sight and mirror cognition. While visual mediation of proprioceptive awareness might mediate a limited form of embodiment in scenarios where an avatar or remote body can act as a body proxy, there will still be a range of perceptive cues the avatar can't mediate as the interactor never perceives them. Unseen haptic affordances, that may only be detected by tactile and proprioceptive senses, are underestimated as parameters for fully engaging with the environment.

2.4 Haptic Repertoire and Agency

We have presented the body schema as a motor control program that is constantly identifying possible actions the body can make based on its layout, posture, skills, and tools equipped. As such it directs world exploration with agency, as an intentional force that generates actions, not merely a sensory one that experiences them. And the activation of the schema is specifically related to movement. As we move, the body schema is revised. Perception is inherently active and multisensory, but each of the senses carry their own ability to explore and engage with the environment.

Philosopher Alva Noë provides a powerful insight into why this is so, in his notion of *sensorimotor contingencies*. He proposes that there are patterns of dependence binding each sense modality, suggesting there are patterns in the environment that appear specifically to the sense of touch (e.g. , while others appear to the sense of sight (e.g. color), but that is not all. Each sense modality is directed by movement, as what we perceive is influenced by our movements. He states: "the ground of our encounter with these different objects—appearances in one modality or another—is sensorimotor skill," which entails that "how things look, smell, sound or feel (etc.) depends, in complicated but systematic ways, on one's movement. The sensory modalities differ in distinctive forms that this dependence takes" (2006, 107-109). This seems reasonable, but it also carries some compelling implications.

For Noë, as shared in an interview, "the difference between seeing touching and hearing, is that these are all activities of exploring one and the same world, but making use of a different repertoire of sensory-motor knowledge, a different body of sensory-motor skill" and that this constitutes a "difference at the level of consciousness, a difference in the nature of the quality of experience" (History of Distributed Cognition 2014, 56.50-57.10). This also reiterates the claim that the extent to which a body is engaged in an interface, will influence the hypotheses we can make about the world and object we interact with. But there is more.

The unique role of haptic sensation in sensorimotor coupling

Our sensory apparatus, managing the full range of multisensory input, is deeply connected to our motor system by means of sensorimotor coupling. Just as there is a strong sensorimotor coupling between vision and motor control, as discussed above, our haptic sensory apparatus is deeply connected to our motor system and culminates in sensorimotor coupling as tactile and proprioceptive sensations are delivered through touch and proprioceptive gestures. However, the haptic sense, proprioception specifically, has a unique role in our motor system, unmatched by other senses, as it participates in all sensorimotor couplings, by means of guiding movement both internally and externally (Riemann and Lephart 2002). In relation to external environments proprioception is the quickest and/or most accurate means to adjust motor programs as unexpected changes occur, proprioception has even been proposed as "essential during the movement execution to update the feedforward commands derived from the visual image" (81). Internally, proprioception assists the motor system in planning joint movements, as it is superior in providing "the needed segmental movement and position information to the motor control system" (81). As such, we can establish a strong connection between haptic perception and motor control, coupled by means of our embodiment through our active and goal-directed exploration of our environment, which is inherent in all sensorimotor couplings. The head-movements that extend visual perception within a space is equally a sensorimotor coupling between motor system and proprioception governing posture. Even mediated vision may introduce novel sensorimotor couplings that introduce certain body schema revisions, however, it is largely due to a visual representation of motor and haptic sensations, which trigger haptic sensations in our bodies.

Haptic gestures as movement form

The haptic senses offer specific opportunities for addressing the body schema, not only through the assistive role of proprioception in all sensorimotor couplings, but also because the role of the haptic apparatus in actively perceiving spatiality, posture, and motion. The deep connection between the haptic sense, particularly the sense of proprioception, and movement, is articulated in gestures. Gestures (both tactile and proprioceptive) are significant movement forms that activate the full range of haptic perception, forging sensorimotor links between tactility and proprioception, postures, and body movement. Gestures are a significant contributor to all sensorimotor engagement with the environment, as a navigational strategy for traversing a space, but also as intentional movements connecting a body and tool, as gestures that shape our bodies into tools, or makes it possible for us to grasp and wield them.

Engaging our inherent perceptive curiosity

In this chapter the body schema has been presented as a significant contributor to human embodiment. It is contrasted to the notion of body image, which is conceived as primarily conscious and visual representation of a human body. Body schemata on the other hand are pre-conscious motor control programs that set the extent of the bodily space, the action potential of a body. The plasticity of the body schema is governed by processes of confirmation and revision. The confirmation of schema is framed by genetic predispositions of humans as a species, but also by habits informed by cultural conditioning of body techniques and training skills. Revision processes, made possible through broadening the prepersonal domain, are related to the ability of engaging in abstract actions, by breaking habits, learning new skills, as well as extending the peripersonal space through tool-use, specifically because it makes possible the postulation of new goals.

The body schema is enactive, directed by goals and existing towards tasks, and is the domain that generates bodily actions. Perception, directed by the body schema, is an active and pre-conscious activity, and not a mental representation or a map of possible actions we can take to reach a goal (as proposed in cognitivism and some directions of robotic research). There is an intimate connection between the haptic apparatus and the visual sense, and a symmetric and synchronous visual mediation of tactile and proprioceptive awareness may induce feelings of presence in both telepresence and virtual environments. Still, each sense has its own access to the environment which cannot be duplicated by another. Haptic affordances may not be perceived by sight alone. So, while the body schema is *informed* by multisensory input, ranging from haptic, auditory, to visual, it is *activated* through movement and bodily gestures. It is by moving that the body perceives cues in the environment that afford tasks it can perform. This underlines the importance of utilizing the haptic senses in our exploration of worlds as it has a unique ability to not only identify perceptual cues, but also direct and orient our bodies within the space.

We must keep in mind that all activity shapes our body schema and bodily space. While eyes and fingertips currently are key players in interactive experience, by engaging more of our bodies, we can expand our perceptive landscape and enactive landscape—our awareness about the world, our potential for action, and our potential for thinking about the world. This proposal, that we think with the world and environments as we actively explore them using our bodies, is central to the next chapter. Here the theoretical framework of the thesis is further strengthened as the concept of physical thinking and the enactive embodied cognition thesis is put into play. While the enactive position has already been introduced to explain the ability of the body schemata in directing actions towards goals, there are additional implications that become profound when we consider the possibilities inherent in new digital and sensor technologies in extending sense of ownership and agency, specifically centered around the formation of novel sensorimotor couplings and extending the haptic senses.

3 EXTENDED EMBODIMENT

Thinking Through Body-World Transitions

Body schemata can be revised and extended as we acquire new body techniques, skills, and tools, and moreover, this technical engagement with the world is inherent in human evolution. In the following, I will expand on this principle by interrogating the potential of digital and sensor technologies in activating the plasticity of body schemata. Several theorists, Mark B. N. Hansen among them, have claimed that these technologies have a unique ability to extend these schemata, either by broadening the range of a given sense or even extending it onto other modalities, and as such re-distributing the individual sensory weight of our multisensory and often technologically mediated perception. The ability to extend haptic senses and gestures provide us with a richer haptic vocabulary that can be utilized in personal computer environments, as we are able to articulate and execute haptic actions specifically to solve tasks. This, I will claim, not only provides us with richer interactive experiences, it also extends our cognitive apparatus. My claim is based on the assumption that cognition is always mediated through matter, it is articulated through our embodiment and formed by the capabilities of our bodies. Engaging with and reading material signs. To think otherwise would appoint us to be mind readers.

In the following I will present the insights from the embodied cognition thesis as a continuance of the theoretical framework established in chapter 2 and connect it to the haptic. I will investigate how the haptic senses may be extended through digital and sensor technology, by analyzing selected works of digital art that target touch and proprioception. I will primarily be concerned with touch and proprioceptive input, and its translation into a broader sensory field, as machine mediation of haptic feedback is addressed more specifically in the fourth chapter. I will apply the findings within the framework of enacted and extended embodied cognition thesis and theorize what effect it might have on our cognitive faculty.

The chapter is divided into four parts: Thinking with the World, Embodied Cognition, Extending the Haptic, and finally, The Expanse of the Body. Part I present extends the argument formed in chapter two, that bodily space sets our action potential, to suggest that our embodiment frames our cognitive ability to form hypotheses, our thinking about the world. Part II presents the embodied cognition framework as a continuance of the phenomenological premises, situating the role of the haptic in cognition. Part III discusses the promise of digital and sensor technologies in extending haptic sensations into other modalities, through the analysis of several digital works of art. Part IV examines proposed borders for embodiment and cognition, and the difficulties in setting them.

3.1 Thinking with the World

Cognition is not merely an isolated event in the brain, it is deeply and closely connected to our embodiment. We use our bodies to trigger and shape cognitive processes.[48] As proposed in chapter 2, when we use tools and techniques we are not simply solving a given task, instead we are given particular opportunities to perceive the world, identify actions and form goals. When we extend our sensorimotor perception, we increase or alter the reach of objects we can engage with and in turn influence its goal-directed behavior. We not only extend our body schemata through the use of tools, we also extend our cognitive capacities. We think *with* the world.

The idea is not a new one. In 1991 Francisco J. Varela, Eleanor Rosch and Evan Thompson presented their take on the nature of experience in *The Embodied Mind*. It presented an important critique towards methods developed and utilized by existing disciplines of cognitive science, psychology and branches of philosophy, in understanding human consciousness. Even though the main research object in phenomenology is human experience, it too, the authors suggest, is centered on

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[48] The close connection between the haptic senses and cognitive faculty is demonstrated in the touch-based language of Braille. The tactile recognition of texture (tactile acuity and texture perception) has an immediate semantic correlation—there is a direct translation between haptic input and mental processing of haptic sense data into meaning.

theoretical reflections, lacking “a pragmatic dimension” (2016, 19). This critique is primarily extended towards Husserlian approaches, but also Merleau-Ponty’s project is called into question as an insufficient method for grasping the richness of human experience. Instead they look at non-Western approaches to philosophy of experience, particularly Buddhist practices and tradition of mindfulness meditation, to arrive at a new concept of theoretical reflection, promoting “a change in the nature of reflection from an abstract, disembodied activity to an embodied (mindful), open-ended reflection” (27). Mind and body work in conjunction to arrive at theoretical reflections and these reflections are embodied. This is the pragmatic dimension needed to enrich our understanding of human experience. We use our previous experience to identify potential actions in our surrounding milieu, and this is a significant trait of the embodied mind approach. Departing from the theory of self-organizing systems which are systems that have *operation closure* (have autonomy) and are capable of *structural coupling* with the environment,[49] characteristics shared by all living systems, the authors argue we are neither closed-off minds operating independently of the world around us, nor are we slaves to each and every aspect of our environment. Rather, we are initiating our surroundings based on skills and experience, and in turn get shaped by them. But even more significantly, this very design proposes that our actions in the world, specific to our biology and culture, are highly influencing cognitive processes, we create our own “cognitive domains.” As an example, the categories of color are not given a priori, rather they are “experiential, consensual, and embodied: they depend on our biological and cultural history of structural coupling” (171). Cognitive content is shaped by the kind of experiences a body may have. This enactive approach by Varela, Rosch, and Thomson, presenting cognition as embodied action, is two-parted: “(1) perception consists in perceptually guided action and (2) cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be

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[49] The concepts of operational closure and structural coupling are two critical design criteria of self-organizing systems, and key in Maturana and Varela’s autopoietic theory presented in *Autopoiesis and Cognition: the Realization of the Living* (1972). This work became one of the key texts defining the second wave or order of cybernetics thinking concerned with the concept of reflexivity in systems, running from the ‘60s to mid-80s.

perceptually guided" (173). With these two statements, the authors formed the first proposal for the embodied cognition thesis, which later has developed in several directions as will be discussed below. But before we head into the present-day application of the thesis, we need to present two additional contributions to the framework of embodied cognition, namely the concepts of epistemic actions and extended minds.

Epistemic Actions

The concept of epistemic actions was first presented in the article "On Distinguishing Epistemic from Pragmatic Action" by Kirsh and Maglio (1994). Here they differentiate between pragmatic actions that change the world and epistemic actions that change the mind. Pragmatic actions "actions whose primary function is to bring the agent closer to his or her physical goal" (515), and epistemic actions "—physical actions that make mental computation easier, faster, or more reliable—are external actions that an agent performs to change his or her own computational state (513). While pragmatic actions simply are means to perform a physical task, e.g. lifting a rock, epistemic actions aim to reduce the cognitive load of solving a problem or task, by means of using the body. These actions improve (easier, faster, more reliable) cognition by "1. reducing the memory involved in mental computation, that is, space complexity; 2. reducing the number of steps involved in mental computation, that is, time complexity; 3. reducing the probability of error of mental computation, that is, unreliability" (514). We utilize our bodies to find and gather information that is hidden or hard to detect, reducing strain on memory and planning processes, but the strategy is also perpetualized internally in sensorimotor processes, as proprioceptive information is gathered to prepare the motor system for actions to come. Kirsh and Maglio's position is well summarized by Simon Penny stating that "[t]hey assert that thinking is enhanced or made possible by the manipulation of things in the world and identified with artifacts (and associated sensorimotor procedures) as *epistemic action*". These are actions that allow an "offloading of cognition into the external could simplify or speed the task at hand" (2017, 201).

And while Kirsh and Maglio uses cognitivist terminology by presenting the brain as a computer and thinking as computation, the idea that vi use our bodies to aid and even improve cognitive processes, has been adopted into a wider embodied cognition framework.

Extended Minds

Building on the concept of epistemic actions developed by Kirsh and Maglio, a theory of the extended mind was formulated by professor of philosophy Andy Clark and David Chalmers in 1998. The extended mind argument holds that when we are physically performing a problem-solving task, we do not only use physical actions to solve the task, but our motor actions also to determine *how* the problem is solved. Clark and Chalmers suggest that epistemic actions promote a coupling between the body and the world, and through that coupling "that part of the world is (so we claim) part of the cognitive process" (8). They call this outward directedness *active externalism* which is achieved when "the human organism is linked with an external entity in a two-way interaction, creating a coupled system that can be seen as a cognitive system in its own right" (8). Clark and Chalmers suggest that it is not just selected cognitive processes, rather the mind that is extended beyond the borders of the brain into the environment incorporating non-biological resources.

Both the concept of epistemic actions and the extended mind thesis has heavily informed the framework of embodied cognition. But as already encountered in the above recollection, the notion of an embodied mind is not clear cut, as there are diverging ideas on the ability of cognitive extension into the environment, and the role of embodiment. These differences will be explored in the next part, presenting various positions within the embodied cognition thesis, and specifically, the enactive position.

3.2 Embodied Cognition: from representation to enactivism

The embodied cognition thesis proposes that our bodies and our interaction with tools both initiate and advance our thinking and knowledge about the world. Support for the view is found in various experiments investigating how animals (primates primarily) and humans (children and adults) interact, solve tasks, identify and use tools. The embodied cognition framework is increasingly included in robotics, artificial intelligence, as well as social and cognitive psychology research, but there is far from a consensus among the different fields. What separates the different positions in the field is to what extent embodiment is proposed as involved in cognition—what cognitive tasks are embodied?—and secondly, the extent to which mental representations feature in cognition. Shaun Gallagher has provided an extensive and rich overview (2011) of the many different variants and directions in embodied cognition.[50] He points to the very different positions theorists hold in terms of understanding the role and influence of embodiment in cognitive processes, as well as what part mental representations play in these processes.

On one end of the spectrum we find the proponents of the minimal embodiment position, such as Alvin Goldman and Frédérique de Vignemont (2009), who hold that the brain is significantly separated from both the body proper and its immediate environment. Body actions and postures are as such insignificant constitutive contributors to cognitive processes. The body is primarily a biological brain host,

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[50] Margareth Wilson has also offered a well referenced overview of the diverse research field of embodied cognition. She states that while the different positions all agree that "cognitive processes are deeply rooted in the body's interaction with the world" and that "the mind must be understood in the context of its relationship to a physical body that interacts with the world" (Wilson 2002, 625), there are also significant differences between them. Wilson continues to present six distinct claims held by individual and distinct advocates.

1. Cognition is situated (connected to tasks)
2. Cognition is time pressured (bound by real-time environment)
3. We off-load cognitive work onto the environment (using the environment as an archive and external memory)
4. The environment is part of the cognitive system (cognition is distributed among the entire interactive situation)
5. Cognition is for action (no representations for representation sake, only for priming actions)
6. Off-line cognition is body based (make use of sensorimotor functions covertly)

and the extent to which its embodiment interferes with cognition is via body formatted representations; mental representations of selected body actions and postures. Embodiment via body formatted representations are reduced to neuronal processes, such as mirror-neuron activity. And it is only the body representation in the brain that plays a role in cognition. Goldman and Vignemont argue for their position using the neural reuse hypothesis. This hypothesis proposes that neural circuits can be reused as "neural circuits originally established for one use can be reused or redeployed for other purposes while still maintaining their original function" (2018, 9). However, as Gallagher proposed, this hypotheses actually promotes a stronger view of embodied cognition, than furthered by the minimal embodiment proponents, as even mirror-neurons activations are exapted deployments of previous motor function (and as such bodily functions), that originated in the body and not the brain (10).

So, if embodied qualities are inherent in neural activity, it seems appropriate to investigate other positions of embodied cognition that increasingly consider the role of embodiment in cognition.

Extended functionalism: body neutrality and representationalism

The extended mind perspective, the proposal that we extend our minds into the world as we engage with it, was later developed by Andy Clark to include the notion of cognitive technologies. This position was first presented in *Natural Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence* (2003), and later elaborated and defended in *Supersizing the Mind: Embodiment, Action and Cognitive Extension* (2008). Clark's particular take on embodied cognition—labelled as extended or functional cognition—argues that by solving a task, we engage in body-world cycles, an action of supersizing the mind. A body-world cycle is a "set of problem-solving state transitions whose implementation happens to involve a distributed combination of biological memory, motor actions, external symbolic storage, and just-in-time perceptual access" (Clark 2008, 69). We extend ourselves into the environment when we engage with it to solve a problem or task. This process is furthered through tool-use, not only because we extend our reach within an environment, but the tool itself may hold opportunity for use that is only revealed as we engage with it. A tool is presented to us with a given function, but as we interact with the tool and allow our body to wield it, modified uses, new uses or even new tools may arise. Through exploring our relationship with technology and tools we are shaping new thinking systems and new design environments that further invites thinking processes. Simply glancing at something is insufficient for coupling with an object in our environment, coupling is a real-time event, that intends to turns "some object, which in and of itself is not usefully (perhaps not even intelligibly) thought of as *either cognitive or noncognitive*, into a proper part of some *cognitive routine*" (87). This is what separates us from animals, our inherent cyborg-hybrid nature formed by what Clark calls "cognitive technologies." And cognitive technologies are particularly open for coupling processes. We engage in loops with these cognitive technological environments. Clark offers a broad definition of what constitutes such technologies, ranging from language, counting, writing, number systems, printing, digital encodings "to the digital encodings that bring text, sound, and image into a uniform and widely transmissible format" (2003, 4). Even non-biological elements (instruments, media and notation), are part of creating extended cognitive systems. The system of exchange is described by Clark as a process of *continuous-reciprocal-causation* (CRC) which "occurs when some system S is both affecting and simultaneously being affected by activity in some other system O. Internally, we may well confront such causal complexity in the brain since many neural areas are linked by both feedback and feedforward pathways" (1998, 356). With CRC Clark seeks to describe how bodies and tools figure in cognitive processes, in that it is a mutual influential relationship between physical gestures and tool use, and thinking, in that they both affect one another. As he exemplifies it: "Think of a dancer, whose bodily orientation is continuously affecting and being affected by his neural states, and whose movements are also influencing those of his partner, to whom he is continuously responding!" (356) The concept of CRC is very much in line with phenomenological thinking, which promotes consciousness as an embodied experience resulting from engaging with the world. The being-in-the-world is a reciprocal relationship between body and environment driven by intention.

Functional embodied cognition, or extended functionalism, proposes that most cognitive processes can be run fully in the brain, without the aid of the body or external world, but it will not necessarily run as efficiently. As an example, Clark argues that tactile engagement with cognitive technologies is more prone to system coupling, than engagements that are purely visual in nature, because the haptic apparatus more actively engages our problem-solving capabilities. The CRC process considered a *sufficient* structure for forming extended cognitive systems, but not a *necessary* one. While CRC is prone to occur when the product of the task is cognitive (forming an argument, solving a task), Clark also claims that we extend cognition when we access the memory of our smartphone, which are processes that do not involve CRC (Gallagher 2014, 46.01). The cognitive system starts with the brain, then body, then environments, but it is not always extended outwards, and cognition need not include bodily processes to be extended. The body is rather the first extension, before continuing into the world through equipment, tools and technologies.

Another key aspect with functional/extended embodied cognition is the concept of body neutrality. This proposes that the physicality of the system that supports cognition is not relevant, it could be biological or artificial or even multiple. The key is the function of the system. It has been argued that there is an element of representationalism present in the position, inherent in the claim that different bodies may produce identical experiences if higher representational processes adjust the sensory input through a process of "compensatory adjustments" (Gallagher 2014, 46.34). As Gallagher notes, Clark's proposal "allow[s] the possibility that the cognitive system will provide "compensatory downstream adjustments" that would, so to speak, even out differences in the experiential aspects that accompany cognition (2011, 64). The concept of body neutrality inherent in functional embodied cognition and later formulations of this proposal is in significant disagreement with the phenomenological position of Merleau-Ponty and later enactive positions of embodied cognition, in that *unique bodies produce unique experiences*.

Enactivism: sensorimotor contingencies and environmental cues

In the previous chapter we introduced the notion of enactive exploration as a process of establishing our environment as we act in it. We also discussed how we may reshape the enactive landscape, the world we perceive and partly create through actions, as we extend our bodies through techniques and tool-use. The core idea of enactive embodied cognition or enactivism is well summarized by one of its proponents, Shaun Gallagher:

> [E]nactive theorists claim that the (human) bodily processes, as well as environmental factors, shape and contribute to the constitution of consciousness and cognition in an irreducible and irreplaceable way. Specifically, in the enactive view, biological aspects of bodily life, including organismic and emotion regulation of the entire body, have a permeating effect on cognition, as do processes of sensory-motor coupling between organism and environment…[S]ensory-motor contingencies and environmental affordances take over the work that had [in functional embodied cognition] been attributed to neural computations and mental representations.” (Gallagher 2011, 65)

The enactive position in embodied cognition discards the functional position of body neutrality, as it almost eradicates[51] the notion of mental representation in cognition. Rather cognition is shaped by sensorimotor contingencies, the patterns of dependence which binds each sense modality to specific environmental affordances. These contingencies are unique to each body, the body's ability to move and to extend its perceptual range and cannot be replaced by another body. Furthermore, the enactive position holds that not only unique sensorimotor contingencies, tools

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[51] There are proponents of a radical enactivism (REC) in which argues that the mind is embodied to the extent that the constitution of cognition is non-representative. This view is presented in Hutto and Myin's book *Radicalizing Enactivism: Basic Minds without Content* (2013).

and cognitive technologies form shape and extend cognition. Several additional biological functions and affective aspects of embodiment shape perception and in extension cognition, such as hunger, fatigue, emotion, and mood, both autonomic and peripheral factors. As cognition arises from an active and directed engagement with the world, intersubjective interaction is also embodied. Facial expressions, posture and gestures from other humans, also engage embodied responses that direct perception and affect our postulation of goals.

Both extended functionalism and enactivism are positions that are hard to quantify in neuroscientific research, in fact there is no consensus within the scientific research community on the border of cognition and peripersonal space (Rowlands 2010, 210). While theorists of all the positions present well-structured arguments and empirical evidence to strengthen their claims, none of it is decisive, as exemplified in the presentation of mirror-neuron research and neural reuse hypothesis to both support a cognitive and enactive view simultaneously! Yet, there is an increasing emphasis on embodied and distributed cognition, e.g. in robotics research, in understanding and developing intentional agents. And the idea that bodies, tools, and body techniques shape cognition, allow us to think with our bodies, is powerfully demonstrated in the case of physical sketching as a tool for learning and remembering.

Physical thinking: the promise of gestural shorthand and physical sketching

> The dwindling importance of the makeshift organ that is our hand would not matter a great deal if there were not overwhelming evidence to prove that its activity is closely related to the balance of the brain areas with which it is connected...Not having to 'think with one's fingers'' is equivalent to lacking a part of one's normally, phylogenetically human mind.
>
> Leroi-Gourhan in *Gesture and Speech* (1993, 255)

By engaging the sensorimotor apparatus in performing tasks, our ability to acquire new knowledge as well as to remember it is increased, and the importance of body enactment in grasping and learning should not be underestimated. An experiment run in 2010 by David Kirsh notably underlines this point. Here he measured professional dancers' ability to learn a part of dance routine, either mentally (by imagining the routine), through "marking" (a gestural shorthand where one is modelling key elements/phrases of the dance routine using the body), or full-out practice of the routine (Kirsh 2012). The results suggest that marking proves most efficient in learning and remembering the routine, even better than the full-out practice of the routine. The poorest results occurred when the dancers solely practiced by mentally simulating the dance. Kirsh suggests that marking or body modelling is so successful because this allows us to physically connect a dance concept to a more ideal movement. In other words, marking allows us to anchor a mental image onto a physical structure, what Kirsh labels "projection" (2013, 3:18). Kirsh claims that the physical act of sketching (the act of marking or similar methods of projecting) activates analogous cognitive processes as playing with a physical models in that they both "drive(s) our perceptuo-motor system into a state of expectation, and we tacitly assign probabilities to outcomes conditional on what we might do ourselves" (3:25). This process of engaging tactile and sensorimotor apparatus in human activity is what Kirsh labels physical thinking. He proposes that "when people think with things they rely on the world to simulate itself and in so doing they stimulate themselves" and continues: "[Humans] use their bodies not just to act on the world and enact or co-create a personal world, they use them to represent, model and ultimately self-teach. They use their bodies as simulation systems, as modeling systems that make it possible to project onto unseen things" (3:26). This proposes that memory and learning, clearly cognitive processes, are very much influenced and improved by involving the body in process.

Kirsh definitely includes the notion of representationalism in his take on embodied cognition, as we utilize mental images to connect and enhance cognitive processes with physical actions. Kirsh's main hypothesis extends minimalist approaches to embodied cognition position, which propose that our cognition in great part depends upon internal simulation of how things work, to include the notion of external simulation as a means to activate motor-intentionality enabled through physical thinking, particular to the extended and enactive views. Furthermore, he seems to exist between an extended and enactive position within embodied cognition, arguing for both situatedness and distributive qualities of cognition. Arriving from the concepts of epistemic actions, as physical actions that offload cognitive processes into the external physical realm, Kirsh has called for a perspective on cognition as is *situated*—bound by the actions in which a problem or task is performed or explored. This position appears closer to enactive than extended functionalism, in that specificity of the situated body—without overtly stating the different bodies can't produce the same experiences. His proposal for establishing research on situated cognition, pushes the need for a broad analysis of the role of "hints and scaffolds, symbolic affordances and mental projection, thinking with things, self-cueing and metacognition, and an enactive theory of thought" (Kirsh 2009, 303). In line with extended views he argues for *distributed* qualities of cognition, suggesting that it may be socially distributed within a group, extended beyond biological systems into non biological resources by means of causal coupling, or distributed over time within a culture (Hollan et al. 2000). The degree of situatedness and the distributive range of cognition is not fixed between embodied cognition researchers and theorists. While there is evidence that cognition is both situated in the body as it performs actions, and distributed beyond the skin border, we do not have neurological evidence that can precisely set this border. An overall claim in this thesis departing from phenomenology—namely that any engagement with the world, machines and environments, is framed by our embodiment—is best supported in a strong embodied cognition perspective, and perhaps most accurately in enactivism with its emphasis on the specificity, the situatedness, and uniqueness of the body in perceiving and experiencing the world.

The haptic in embodied cognition

The extended functionalist perspective proposes the haptic apparatus is more efficient in causal body-world coupling, as it more actively engages problem-solving capabilities. This is literally demonstrated by Kirsh in the process of physical sketching. While we may perform certain processes of learning and memorization by mental imagining aided by visual representations on a screen, we optimize the results by remembering and organizing thought through physical sketching. We think with our hands. The potential of physical sketching as gestural shorthand directly underlines the significance of gestures as movement forms and as epistemic actions that aid cognitive processes, and simultaneously the limits in visual presentation of cognitive tasks. The enactive view holds that bodily actions influence and extend our thinking, fueled by a process of movement as sensorimotor couplings are formed. Each sense has an inherent ability to identify environmental cues, guiding perception, but the haptic sensation of proprioception is involved in all motor activity, and as a result in all sensorimotor couplings.

Haptic technologies differ from screen technologies in an extended-enactive embodied cognition perspective, for several reasons. First, we have noted the limitations of visual representation of cognitive tasks, in processes of learning and remembering. But more so haptic technologies allow us to extend the haptic senses, either by means of reading haptic gestures as input, or by mediated haptic feedback from virtual or telepresence environments. As the haptic apparatus is involved in all sensorimotor coupling, these technologies are capable of introducing novel sense experiences which in turn shape consciousness and cognition. In the following, we will discuss this potential of digital and sensor technologies in extending the haptic senses.

3.3 Extending the Haptic

We have several technologies that are specifically aimed at extending sight, and we are increasingly developing technologies that target other aspects of our multisensory perception. And a particular promise for sensory extension identified in new digital and sensor technologies. Media theorist Mark B.N. Hansen claims that these technologies are in a unique position to grant us conscious access to our body schema and broaden the prepersonal domain, as they make possible interactive scenarios where our sensorimotor responses are reflected back to us via other modalities (2006, 20). This is the case with many interactive mirror artworks, but the potential of these media technologies is considerable. Digital and sensor technologies provide us with extraordinary means to obtain new experiences, as we can extend and augment the sensory range (color space, auditory range, spatial distance, and touch experiences) by layering the virtual onto the real, translating sensor data into formats specific for one modality or mapping content from one modality into another.

Mechanical and electrical[52] technologies have also provided us with interactive scenarios that extend our sensory apparatus. Every so often you will find mechanical gear exhibits in science museums where children input kinetic energy to power a greater machinery. Also, consider the tradition of hand-cranked music boxes, where regular hand movements power the instruments to produce and adjust the pitch and

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[52] With electrical technologies I refer to technologies made with analog electronics that utilize the continuous range of current to represent signals and information. This is opposed to digital signals that have a set range between two values, 0 and 1, depending on sample rate (resolution). Very often computers and other electronic devices are made with both digital and analog circuits, e.g. the old-style electric radio with digital display.

presentation of the sound.[53] Similarly, electrical technologies have offered a range of sensory extensions, early telecommunication being a key candidate. However, the interactive experiences made possible with digital technologies are ever more nuanced, particular and explicit in what kind of human sensory expression these systems process and utilize. The opportunity for explicit and accurate tracking of such a wide array of sensory and motile articulations has grown with the development of sensor technologies. And with digital technologies we are given the ability to take analog measures and translate them into precise digital values that can be mapped to literary anything, making bodily events such as muscle movement, skin friction, heartbeat, pulse, moisture, temperature, and similar, input factors in interactive scenarios offering novel sensorimotor experiences. Inherent these technologies lie the opportunity to induce temporary experiences of synesthesia—a technologically mediated synesthesia, coupling previously unmatched sensory experiences. We are part of revolution in terms of interactivity, as our sensory repertoire is expanded. While all senses are potential targets for extensions, we will pay particular attention to haptic sensory extensions.

In the following I will demonstrate how touch and proprioception may directly be targeted and probed by media technologies, extended into audio-visual sensory realms. These are areas of novel sensorimotor coupling that are currently most explored. Relevant and useful scenarios are found in the artworld, in works of digital art, which are much less dependent on commercial success, public recognition and acceptability to be considered relevant and important, and thus inclined to follow artistic curiosity and consequence to its own end. This combination of creative and independent exploration and media critique provides unique insights, exposing media potential.

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[53] A unique example is found in the *Marble Machine*—a musical device consisting of several instruments, whose main engine is a crankshaft that when turned will push 2000 marbles through the device playing a score (Ferreira 2016).

Extending tactile sensation and the moment of touch

While there are many projects aiming to present you with a feeling of touch in virtual or telepresence environments,[54] these devices are most often designed with the intention to mimic and emulate touch experiences of the physical world, allowing an interactor to touch and feel virtual objects. The promise of touching the virtual or telepresent is rarely problematized beyond syntax as an engineering problem of mapping haptic input and mediating haptic feedback. The translation of any touch experience into an electrostatic or vibrotactile pattern, is as much a semantic and even affective exercise, as a syntactic one. As mediated haptic feedback is problematized in chapter 4, in the following we will be concerned with haptic, touch and proprioceptive, input, the moment of touch, and its translation into a broader sensory field. The artist duo Scenocosme has made several works of art that aim to make visible and audible the moment of touch, as reflected in their mission statement:

> We suggest to seek out the hidden, to feel elements of reality which are invisible or to which we are insensitive. We use the idea of the cloud as a metaphor of the invisible because it has an unpredictable form, it is in an indeterminate status of metamorphosis, and because its process escapes our perception. […] If we take as an example the energetic clouds of living beings, the physical boundaries of their bodies can become permeable through the usage of sensory technology and we take advantage of this permeability in order to design extraordinary relationships between humans, living beings and the surrounding environment. (Lasserre and Ancxt 2012, 142)

The metaphor of the cloud as a domain of potential relationships is present in most of Scenocosme's work. With sensor technologies they seek to form novel connections between us extending the border of our body. In the interactive artwork *Urban Light Contacts* the notion of relationship is particularly emphasized as it

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[54] TeslaTouch (Bau et al. 2010) or Tactai Touch ("Tactai Inc." n.d.) are two projects particularly aimed at emulating tactile sensations.

demands two or more people for the experience to become perceptible to the interactors.

Figure 30 and 31: Scenocosme's interactive installation *Urban Light Contacts* connects sound and visual scenes as mediations of different tactile interactions (left). The work encourages social interaction, here demonstrated at the Festival Les Nuits de Lauzerte in Lauzerte, France in 2016 (right). Courtesy of the artists.

The artwork consists of a central pedestal with a metal ball on top of it. The spectators are invited to touch the ball and as such become the mediator of the interactive experience. However, nothing will happen until a second interactor touches the person touching the ball. The moment of human touch is made audible and visible, and the soundscape and coloration will "vary according to the intensities of bodies' electrostatic energy" (Lasserre and Ancxt n.d.). One the one end the work is turning the interactors to human instruments,[55] but more importantly it is inviting spectators to engage in new bodily relationships as we caress each other, extending a tactile space often reserved for intimate and personal, to an urban one. The sensory extension is bound in a semantic and affective dimension, which is seen and

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[55] A commercial application of these principles is found in devices such as the midi controller TouchMe which, when coupled with standard musical software, allow users to play back beats and soundscapes by touching one another or objects ("Playtronica TouchMe" n.d.).

heard. The richness of tactile actions and the notion of proximity are further explored in Scenocosme's *Phonofolium* which investigates a potentially communicative and affective relationship with plant life (Scenocosme 2011). Interactors are invited to engage with a tree, by getting closer to and finally touching its leaves. Both the process of closing in on the tree, and the moment of touch are sonified, allowing the interactor to engage in novel haptic conversations. Both of these artworks show how touch may be extended and give rise to novel and significant experiences. Specifically, they demonstrate that the moment of touch is not just a temporal physical encounter between two bodies, it is an equally a moment of meaningful and emotional exchange, that can be experienced and explored across modalities.

Extending proprioception by stretching time, mapping posture and gestural control

Our perception of movement is very much bound to the experience of time. The notion of stretching time is a well-explored strategy in film media and comedy, by speeding up or slowing down the playback, accentuating or arresting movements and gestures.

Figure 32. Screenshot from the work *Unnamed Soundsculpture* (2011) by Daniel Franke and Cedric Kiefer. Courtesy of the artists.

With motion capture and digital rendering in 3D we are offered additional opportunities for stretching time and presenting movement *over* time, unveiling proprioceptive and motor qualities specific to a body. In the *Unnamed Soundsculpture* artwork by Daniel Franke and Cedric Kiefer (2011), the movements of a dancer are captured by a motion sensor and rendered as a digital body made up of 22000 different points. The digital body is caught in a visual lag as movement points are distributed in time. The effect is intriguing, allowing the viewer to become consciously and physically aware of the minute postural and gestural changes in a body movement, which are otherwise too fast for us to notice. The motion points appear as a textural skin of the sculpture, akin to grains in an hourglass. This directly corresponds to the temporal theme, the slowing down of time, the seeing movements in time, over time, caught in time. The perceptive experience may be compared to the one achieved by asynchronous mediation in mirror works—such as the *Time Scan Mirror* by Daniel Rozin discussed in chapter 1—but not quite. In the latter work, the body in the image is not yours, but rather a body. And while both works experiment with the passing of time, the movement of the digital body is not initiated by you. Rather than functioning as a coupling mechanism extending presence into the screen, the *Unnamed Soundsculpture* invites the viewer to reflect on bodily movement in general, consciously reflect on the proprioceptive and motive abilities of the body. The purely visual mirroring of temporally hidden body postures and movement is nonetheless an example of how proprioceptive qualities may be extended into other modalities, to produce novel experiences and insights.

From temporal to habitual recognition of posture

The extension of proprioception is further demonstrated in works centered on postural mapping, the capturing and active representation of body posture in time. In Rafael Lozano-Hemmer's interactive installation *Body Movies* (the sixth work in the Relational Architecture Series), images of individual body postures are matched by the active positioning of the audience bodies. In advance, over one thousand photographic portraits taken of people in the streets of several major cities, which are later grouped into several scenes, before being projected one-by-one onto the outer wall of a building. A second projection layer produced from several bright xenon lamps completely hides the portrait layer, as the wall surface is cased in white, bright light. However, as people walk in front of the building they are caught in the light and their bodies cast large shadows onto the wall. The silhouettes range between two and twenty-five meters depending on the interactors' position from the light source. The audience can embody the portraits by moving around to match them. When all the portraits are matched in a scene, the installation blacks out before presenting a new scene for the audience to match.

Figure 33. The *Body Movies* installation by Rafael Lozano-Hemmer, presented as part of Sapphire '02, Atlantico Pavilion, Lisbon, Portugal (2002) where the projected shadows are matched by passers-by. Photo available under a Creative Commons Attribution -Noncommercial-Share Alike 3.0 Spain License.

The matching of silhouettes is present in early shadow theatre, from which this installation is inspired, and is certainly a trigger for proprioceptive awareness, as you play with the scaled reflection of your own body. However, something more is at play in this work. The photographic portraits offer a visual presentation of specific and even individual postural forms, beyond the contour. I can move myself and position myself to map a another's person's posture producing an awareness around my own habitual postures as well as exploring the gestural poses of others, and secondly, there is a collaborative effort involved in matching the scene in its entirety. We need to relate to others and position ourselves within a three-dimensional space to match the imagery of the two-dimensional surface.

Both Lozano-Hemmer and Franke and Kiefer's works are exploring the potential and qualities of postural mapping, as a means to let us physically or mentally match another body, and contemplate our own embodiment—the specificity and generality of our own habitual gestures and postures. They also demonstrate the power of extending proprioceptive qualities into the visual realm. However, it is but one of many opportunities inherent in mapping proprioception.

Proprioception and gestural control

The demonstration of proprioceptive mapping at its core is demonstrated in several works by Marco Donnarumma, where proprioceptive sense data is mapped and wielded through gestural movement and control. In the visceral performance Ominous (2012), Donnarumma uses the strain and delicate movement of the body to incarnate a sound sculpture. Sensors attached to the artist's arms register the sound of muscles as they are flexed and relaxed, truly recording the proprioceptive activity of his body. The muscle sound sensors are accurate and minute, recording each minuscule movement, from the bending of the little finger to the intense flexing of upper arm muscles. The artist calls it *biophysical music*, as the sound produced from moving and straining the muscles, is amplified and made audible to the spectator. The technology involved, the Xth sense muscle sound sensor, is developed by the artist and collaborators (Donnarumma 2011). It is conceived and intended as an extension and augmentation of the body mediating proprioceptive sense data directly from the body, rather than a controller for an interface capturing control data. Microphone sensors attached to upper arms capture low frequency sound waves originating from muscle movement and blood pressure. This sound information is given to a computer in real-time which analyzes and identifies specific sound gestures and patterns. These sound patterns are amplified algorithmically and distributed via a multi-channel sound system.

Figure 34 and 35. Screenshots from video documentation of *Ominous* (2012) by Marco Donnarumma. Courtesy of the artist.

The *Ominous* performance starts with the artist standing almost completely still, curving his hands in front of him. In the background one can hear a silent humming. It is not unwelcome nor uncomfortable, actually it feels rather familiar. Like the embrace of a close friend. What we hear is the amplified sound of Donnarumma's body, relaxed, except from maintaining the posture of the curved hands. Eventually his hands start to move—outwards as in pulses, and in circles, as if stroking a growing round object. Visually, we are given enough cues to imagine the object at hand, but what makes the experience complete, is listening to the strain of the artist's muscles as he forms the object, proprioceptive data is resonating, allowing us to feel the weight and shape of the object. We are experiencing a perceptual coupling between the imagined object formed by the gestures of the performer, and the sound, as proprioceptive and auditory sense data are linked. As the performer molds the sculpture with his hands, we get to know the material it is made of. It becomes incarnated, of matter. We see it, we hear it, and we feel it. The notion of affordances comes into play, beyond the concept of visual cue recognition as presented by Gibson and Norman. Instead Donnarumma appeals to our tactile and proprioceptive sense recognition. We perceive the strain, through the indication of gesture and sound, and immediately know what force is required to produce that strain. Through the experience we are offered bodily sensation previously unavailable to us. While Donnarumma's own intent and interest with the Xth Sense technology is centered on the artistic experimentation of body augmentation and biophysical music, he acknowledges its many potential areas of use. The technology can readily be applied as a traditional instrument where one maps a range of individual muscle gestures to a tone scale making it possible to play chords and melodies, or as gestural controller where individual gestures and postures can work as input patterns for close to any computation task.

The *Unnamed Soundsculpture, Body Movies*, and *Ominous* all present opportunities for novel sensory experiences as proprioception is extended into the visual and auditory realm. Donnarumma's work not only argues for the novel sensorimotor coupling occurring as proprioception is made audible, it demonstrates the potential of proprioceptive activity to be utilized for gestural control.

Extending embodiment

The artwork presented above offers a modest and surely incomplete demonstration of the potential of new digital and sensor technologies in extending embodiment via the haptic senses. Understood from an enactive perspective engaging with these interactive scenarios—experiencing the moment of tactile and proprioceptive activity as it is captured and extended—will promote novel sensorimotor couplings, as additional environmental cues and affordances are made available to us. These novel cues and affordances guide perception, allowing us to identify new opportunities for action. Our embodiment is extended means extending action potential, which influences our thinking processes and hypotheses about the world. The enactive approach is also reiterated in the artwork's proposal that tactile and proprioceptive sensations, as they are extended into audiovisual realms, may mediate affective and semantic content, experiences of emotion and meaning, as embodied cognitive processes.

But what are the limits of extension? When is a tool, technology or technological mediation of me no longer considered a part of me, but something else? New digital and sensor technologies present endless opportunities for translating and mediating bodily engagement, to the extent that we no longer recognize our own contribution.

And secondly, what may be considered the final limit of cognitive extension beyond the body border?

3.4 The Expanse of the Body

The body is extendable, and we think with our bodies. Within this claim lies the assumption that our embodiment may be extended, extending action potential, and with it the ability to form new hypotheses about the world. While enactivism is concerned with the embodiment of cognitive processes, extended functionalism takes this premise further. As we engage in causal coupling with cognitive technologies proposed by Clark, cognition may be extended way beyond our bodies and bodily space. So, what are the limits of cognitive distribution? And how is it mediated through technology? From skull border, to skin border, to the extent of human agency in encounters with autonomous technical systems, the full expanse of the human body is not fixed.

The border of the skin

> [The skin] is the oldest and the most sensitive of our organs,
> our first medium of communication, and our most efficient protector [...].
> Even the transparent cornea of the eye is overlain by a layer of modified
> skin [...]. Touch is the parent of our eyes, ears, nose, and mouth. It is the
> sense which became differentiated into the others, a fact that seems to be
> recognized in the age-old evaluation of touch as 'the mother of the senses'.
> Ashley Montago (1971) cited by Pallasmaa in *Hapticity and Time*
> (2000, 79)

What is the role of the skin in an embodied cognition perspective?
In disagreement with Andy Clark and the formulation in extended functionalism, I am not certain there is a fluid transition of cognitive processes between subjective self and the objective world, between the brain and skull, the body, and the world.

We are not the same as the world, there is a border that separates the subject from the object: the skin. The skin is a border in that it mediates the transitions between the external and the internal, as a connector between the extrinsic world, the body proper and the mind.

This emphasis on the specificity of skin and tactile sensation, presented by Montagu, above, resonates in Merleau-Ponty's phenomenological position of perceiving the world. Perception is a reciprocal relationship between the perceiver and that which is perceived, and this event is taking place on the skin surface: To touch is to be touched (Merleau-Ponty 2008). The world rubs on us as we engage with it, proposing a twofold role of the skin as border and mediator. The skin functions as a self-identifier, of me as an individual, and as a member of humanity. But it also serves as a potential (although not exclusive)[56] identificator, in the biometric reading of exterior body features to identify a body, as fingerprints and retinas are scanned. The role as an identifier or self-container, is reiterated in psychoanalyst Didier Anzieu's work. He argues that the skin itself is an ego, a skin ego that fulfill three main functions:

> [A]s a containing, unifying envelope for the Self; as a protective barrier for the psyche; and as a filter of exchanges and a surface of inscription for the first traces, a function which makes representation possible. To these three functions, there correspond three representations: the sac, the screen, the sieve…[and] that as a mirror of reality. (1989, 98)

The skin functions as a container and a protective shield for body and mind, but perhaps most relevant for our discussion, Anzieu considers the skin a surface for inscription (for affective touch, as well as the reading of expression and body language). For these reasons, he proposes that the skin is crucial in constituting cognitive functions and structures. So, while there are specific functions of the skin

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[56] We have other means of identification besides skin readings. In addition to DNA-testing, we see an increase in machine reading of body signatures, e.g. motion, face and gesture recognition, that become increasingly suitable for identification.

as a border in terms of identification, protection, its function as a surface for socio-affective communication that mediate cognitive processes reiterates the twofold role of skin. The border is not fixed, nor absolute. So many things do transition through the skin—moisture, temperature, pulse. But as we have argued, so does embodiment. As established in the introduction, there is a gradual transition from internal to external haptic sensations, as proprioception folds tactile sensations inwards and outwards as gestures and movements. And furthermore, these haptic sensations may be extended, as we utilize techniques, tools and technology to extend peripersonal space, and into other modalities.

Technical mediation and extension of cognition

> ‘Red or white, Carrie?’
> I opened my mouth as if to answer him, but nothing came.
> Normally, in that instant between the question and the response,
> the AM would have silently directed my choice to one of the two options.
> Not having the AM’s prompt felt like a mental stall in my thoughts.
> Alastair Reynolds in *Zima Blue and Other Stories* (2009, 437)

Significant processes of cognition include the ability to form hypotheses about the world and recording it to memory. While we use our bodies to organize and strengthen thinking processes, and record memories for later recall, we also use storage devices to help us remember names and numbers, events and deadlines, as placeholders for thoughts. Increasingly, we use these technical memory systems to make decisions based on previous preferences, as seen in increasing use of information retrieval and recommendation algorithms which “remember what you like, have liked, and what other people who like the same as you, also like.” Bernard Stiegler takes this premise to its full extent in his notion of technogenesis, human co-evolution with technology. Human memory is inherently technical, he claims, and always has been. We have exteriorized ourselves into artifacts since our ancestors wielded the first stone tools two million years ago. In the construction of *hypomnemata* (technical memory aids or technological exteriorizations of memory) whether the manuscript, the photography, digital encodings or the Internet, these systems frame and embody the act of remembering (2010, 67). Stiegler argues this process is set in time and space, our evolution is essentially technical, in a history of memory. We have increasingly moved from exteriorizing memory with techniques, to sorting memory through technology, and with the digital revolution we have departed “from individual exteriorizations of memory functions to large-scale technological systems or networks that organize memories” (67). Stiegler labels these technological systems cognitive technologies (in accordance with Andy Clark), which increasingly partakes in human cognitive processes.

The effect of technical memory devices on decisions-making, is explored by science fiction author Alastair Reynold in his short story *Zima Blue* cited above. In this fictional world, most people use neural implants to record memories as an inherent and inseparable component of cognition, however, some still use *Aide Memoires*, AMs for short, that are external memory recorders hovering around the body, that may be turned off. The story presents a connection between technical memory storage and decision-making processes, made notable once the AM is removed. The lack of assisted memory causes the character to sense holes in her knowledge, coinciding with Stiegler’s claim that “[t]hese cognitive technologies, to which we consign a greater and greater part of our memory, cause us to lose ever-greater parts of our knowledge” (2010, 68). Our ability to make a choice is highly influenced or even lost in an algorithm rendering of historical preferences. But as the story continues, the AM in contrast to neural memory implants, may be turned off, leaving the recording and recalling of memory to the organic brain. This, the story asserts, may present novel opportunities from ever arising. As events are recorded to memory, unassisted by algorithmic organization, emotions and specific meaning may be attached to the memories, presenting an opportunity for the weight of a choice to be redistributed when recalled to make a decision based on preference. If the technical mediation of memory and related cognitive processes becomes direct, we lose the critical distance needed to become aware of the function and conditioning effect of the technical system. While Stiegler appears skeptical to the opportunity for technical media distance, as vi inherently condition and are conditioned by technical media, he does not consider us slaves of technology, rather our contingent relationship with technics is an essential human quality. As we create new technical systems, we also make critical decisions and intentional designs about its use, whether or not those become facts.

In the extended mind thesis promoted by Clark and Chalmers (1998) the authors distinguish memory from beliefs and assumptions about the world embedded in memory. So, while extended memory may be temporarily inaccessible, as we turn devices off or move beyond the range of communication, or even sleep, we still have our beliefs. Clark and Chalmers propose that temporary inaccess from the cognitive extension is irrelevant for convictions and assumptions about reality embedded in extended memory to exist, rather the causal coupling is contingent on its ability to be available on-demand (15). It appears that the link to a memory, knowing where something may be found, becomes the new set of memories that we need to keep in our minds and bodies.

Distributed agency—cognitive technologies and assemblages

But the technical mediation of cognition might even be more severe. What if we consider these technical systems and cognitive technologies that assist and extend human cognition, semi-autonomous agents with their own set of cognitive processes and sense of agency? This assumption is central to the recent research of N. Katherine Hayles. Hayles distinguishes between thinking and consciousness as higher-level cognitive processes, from nonconscious cognition which is not specific to the human species, but may exist in other biological organisms as well as computational media.

> Cognition is a much broader capacity that extends far beyond consciousness into other neurological brain processes; it is also pervasive in other life forms

> and complex technical systems. Although the cognitive capacity that exists beyond consciousness goes by various names, I call it nonconscious cognition. (Hayles 2017, 9)

Examples of nonconscious cognitive functions are pattern recognition, body representation, information processing, and perceptual adjustments (2019). Hayles suggests that we extend our agency through interaction with technical nonconscious cognition. Nonconscious cognitive processes "occur[] at multiple levels and sites within biological life forms and technical systems[,]" and "[c]ognitive assemblage emphasizes cognition as the common element among parts and as the functionality by which parts connect" (2016, 32). It is through cognitive assemblages, network system structures, that human agency and technical cognition coincide and influence each other. She proposes that these technical systems or cognitive technologies, induced with their specific capacity for non-conscious cognition, run with an increasing level of agency. Trading algorithms, self-driving cars, and autonomous drones, are examples of systems which extend human cognitive capabilities, that run with a significant level of agency (45). With the considerations of Stiegler and Hayles, it becomes difficult to discern where human embodiment and cognition ends, as well as our agency, in our encounter with increasingly capable, intentional and cognitive technical media.

The extent of the intentional agent

So where do I end? Or begin?

Within the enactive perspective I find a simpler and perhaps a more practical proposal to frame embodiment and cognition. The extent of cognitive distribution is matching the extent of embodiment, framed by the domain of ownership and agency. The reach of a body and bodily intent, the intentional agent, is defined by a sense of ownership coupled with a sense of agency. Gallagher presents this distinction elegantly.

Ownership is framed by the “sense that I am the one who is undergoing an experience” and agency as the “sense that I am one who is causing or generating an action, for example, the sense that I am the one who is causing something to move” (2000, 15). When mediated and extended sensory experiences no longer are experienced as your own, or you no longer experience yourself as the intentional agent generating these actions, the border for bodily and cognitive extension is reached. And perhaps this makes more sense. As I walk from home, disconnected from the Internet, I realize that there are limits to my reasoning, there are hypotheses and plans I can’t finalize as I lack information stored in an external database. I don’t feel my agency stretching all the way throughout the Internet into the storage vaults holding the insight I need, but I feel connected to it. The link is mine, a part of me.

From extensions to communication

We have the opportunity to extend our embodiment through new technologies, as new sensorimotor couplings are formed. The haptic senses are unique in this context as they partake in all sensorimotor coupling: Proprioceptively, as an inherent contributor to the motor system, and by the power of tactile skin sensations that cover the full extent of our bodies. The potential of any individual body is unique, however similar bodies (e.g. species-specific bodies) might share similar experiences. As we extend our embodiment, we also redefine the action space, allowing us novel experiences that influence the hypotheses we make about the world. This is a cognitive process, suggesting that cognition may be extended throughout our bodily space as well. The process of using movements (gestural shorthand) or physical objects to strengthen cognitive processes of learning and remembering is an example of how cognition is offloading into the environment. We have found evidence that cognition may be distributed beyond the body proper, through the application of tools to extend peripersonal space, but also that sensory extensions into other modalities are likely to affect and influence cognitive processes. The scientific research has not settled, neither in theory of empirically, the extent of embodiment, nor what kind of cognitive processes that may permeate skin and skull, ranging from sub/nonconscious functions to higher level conscious thinking. While there is no doubt that we are exteriorizing memory and offloading selected cognitive processes into technical media, and that this shapes and informs our thinking, we have not set the expanse of the human body. For the purpose of the discussion ahead, the enactive approach seems to be the most beneficial track to follow, namely that the extent of the intentional agent is set by her sense of ownership of experience, and agency of actions.

There is a special role reserved for the skin as a communication surface and mediator of semiotic and affective content, extending from the tactile to the proprioceptive through haptic interactivity. We have discussed how haptic sensitivity may be mapped, extended and distributed across spaces, and modalities, but less about the machine mediation of haptic feedback made possible through haptic technologies. Inherent in the haptic connection lies the opportunity for meaningful and emotional messages.

The facilitation of haptic communication, by extending the sense of ownership and agency, is most often reflected in the material solution, but we must also consider the semiotic and affective dimensions of machine mediation and communication. But what exactly are the semiotics of haptic interactivity, and what is the role of affect? In the following chapter I introduce the concept of the haptic figura as an analytical tool to identify and qualify the material and semiotic solution of haptic devices, and the potential of affect in haptic interactivity.

4 INTERACTIONS

Haptic Figura as Material Signs for Communication

In the previous chapter we discussed how the haptic senses can be extended into other modalities or telepresence situations, presenting the rich world of mediated haptic sensuality. In this chapter we will develop this discussion to investigate the notion of haptic communication. Media artists and scholars use the word haptic to denote everything from touch technologies to media that respond to people's gestures, it becomes difficult to understand what haptic media are or can be, and the term is as such in need of clarification. This chapter investigates the intimate relationship between touch, tactility, proprioception, and gesture, and proposes the concept of the haptic figura to describe the material and semiotic qualities of haptic interaction, as an attempt to provide the reader with a tool for analyzing and differentiating various haptic media artifacts. The recognition of haptic input in computers is becoming more commonplace, particularly when considering touch screens, biometric sensors, and motion capture devices. However, the commonly available haptic feedback repertoire is still rather limited. In the following, I aim to give the reader an overview, if not a complete taxonomy, of significant material and semantic parameters of haptic interaction, and the central role of affect in this kind of communication.

The chapter is divided into eight parts: From Haptic Extensions to Communication, The Capability of the Haptic Senses, The State of Haptic Media, The Scope of The Haptic Figura, Haptic Materiality, Haptic Semiotic, Haptic Figura and Affect, and The Haptic Figura and Interface. Part I outlines the backdrop for understanding haptic communication, as consisting of transmissive, interpretive and interactive elements. Part II presents the capabilities of the haptic senses in consideration of interfacing with machines. Part III discusses the present-day application of haptic technologies. Part IV introduces the concept of the haptic figura as a means to evaluate machine-mediated haptic communication in terms of its material solution, and ability to mediate semiotic and affective messages. Part V offers an overview of haptic hardware and areas of use as a means to frame the material solution of a system and what kind of haptic perception it supports. Part VI discusses potential and challenges in designing haptic signs, alphabets or even languages, to be utilized in machine mediated communication. Part VII investigates the close connection between haptic perception and affect. And finally, part VIII discusses the role of the haptic figura in interfaces, and the notion of a haptic interface.

4.1 From Haptic Extensions to Communication

Haptic communication: transmissions, interpretation and interactivity

We use the words *communication* and *interaction* quite loosely in everyday conversation, without there being any need to clarify to one another what we mean by it, specifically. However, to have a useful discussion on haptic communication a rudimentary working definition is in order. Communication theory has fronted three important aspects of communication over the last 70 years, viewing communication respectively as transmissions, as acts of interpretation, and as interactions. In framing haptic communication we need a model that can take a whole range of communicative items into consideration, the qualitative aspects of transmission, messages of meaning, and interactivity—ranging from non-verbal signals, signs, symbols, icons, gestures, motions and proxemics, and even vocal language into consideration. All of these aspects have a role in haptic communication.

The transmission model of communication was first promoted by Shannon & Weaver (1949). It was based on telecommunication studies, which analyzed how signals were being encoded, transmitted, and lastly, decoded. Communication was understood as the successful transmission of messages. This framework was later refined in the 60s by David Berlo proposing the sender-message-channel-receiver (SMCR) model of communication, which is today known as linear models of communication. It is an important contribution, because it underlines the role of the media platform in conveying and forming messages, which is relevant when discussing machine-mediated haptics. What it doesn't take into consideration is the challenges connected to an "objective" encoding and decoding of signals. We all know that the person next to you may fail to grasp the intention of your statement even though it is articulated to perfection and rendered perfectly in the receiver's ears. The fact that we do not necessarily interpret signals identically at any given time or place, is one of the significant shortcomings of the transmission model. To mend this an information model of communication was developed in the field of semiotics, seeking to understand the production and interpretation of meaning in acts of communication. Here one considered pragmatic (relationship between sign and interpreter), syntactic (relationship between signs) and semantic (relationship between sign and object) rules of communication, a distinction first noted by Charles W. Morris in *Foundations of the Theory of Signs* (1938). The role of semiotics in haptic communication will be further investigated later in the chapter, with a particular emphasis on the role of tactile and gestural signs, symbols, icons, and figures.

But communication is more than the transmission and interpretation of messages. If not always, then very often we do something when we communicate—we act. John Austin (1962) theorized the element of actions in communication as speech *acts*, a work that was continued by his student John Searle who identified five classes of speech acts: declarations, commissive, expressive, directives, and representatives (1969). These communicative acts are interactive, some even collaborative: they present relationships between two or more bodies, and they can be more or less successful. The extent to which media environments we act within promote social actions, they will have a significant effect on communication and interactivity. In terms of machine mediation of haptic sensations, what form would a haptic "speech act" take, and how are these kinds of social acts connected to affect? The activities and tasks a haptic media environment supports, will influence social interactivity.

So, how do these three understandings of communication, the transmission model, semiotics and speech act theory, relate to haptic communication? We need to interrogate haptic interactivity through all of these lenses. I find it problematic that haptic communication between human and machine is often described in terms of how the machine can detect and convey touch, postures, positions, motion, and forces, in a primarily transmissive manner. Much research is centered on the description and understanding of the encoding and decoding of signals, while very little attention is given to semiotic qualities, and the role of the machine as a platform for (inter)actions.

This is not a purely theoretical issue. We are starting to see machines that are capable of interpreting haptic input and that can propose relevant haptic output based on the reading of the situation and environment, as well as rendering affective responses, so we need a broader scope to grasp the essence of haptic communication. In the following we will look at some noteworthy attempts to understand haptic interactivity in human-machine communication.

Embodiment in human-computer interaction design

To arrive at a model of interaction that specifically deals with embodiment (and the haptic senses in particular) as well as the relationship between human and machine/system, there are several well-established theories to consider, each emerging from its own specific field of research. From the mid-60s to mid-80s the theoretical framework and mindset of designers and developers was rooted in early cybernetic reasoning (as discussed in the chapter 1), which came to influence the development of the personal computer environment we work with today. The graphical user interface (GUI), the introduction of the desktop metaphor, as well as the hardware interface of the desktop itself (screen, mouse, keyboard)—all limit the role of the multisensory body, with their focus on screen-based mediation of visual content and limited physical manipulation and interaction. In the early ‘90s the field of human-computer interaction (HCI) research grew. This was a cross-disciplinary research field connecting principles and findings from cognitive psychology, engineering, industrial design, computer science and humanities, exploring and theorizing the intricate relationship and exchange between men and machines.

An important insight that came to shape both industrial and web design was introduced in the pioneering work of Donald Norman: *The Psychology of Everyday Things* (1988). This work (re-)introduced the notion of affordance (inherited from psychologist J.J. Gibson) to explain how we perceive possible ways to interact with physical objects and interfaces, providing developers with basic design and usability principles for physical interaction. His principles have later been applied in screen-based graphical user interface design with varied success. Ultimately, the concept of affordance became too vague and nonspecific to offer a clear direction. In a later edition of the book (2013), Norman introduced the notion of signifiers, to limit his guide to the design of actions that are intended by the developer, as well as perceived and recognized by the user. At this point the design guide entered a closed-loop relationship between the intentions of the developer (as limited or directed as they may be), and her success rate in terms of communicating this intention to an end-user. Furthermore, the tactile component in identifying and manipulating objects as part of how a body can interact with the world, is no longer given particular consideration in the design guide. This makes Norman’s contribution insufficient for understanding how we engage the world with the haptic senses.

Embodied interaction

On the path towards a model which is simultaneously dealing with the haptic experience as well as the machine medium, there are important findings in Paul Dourish’s concept of embodied interaction. In *Where The Action is: The Foundation of Embodied Interaction* Dourish investigates the relationship between action and meaning, and the mechanism of coupling (2004). He extends Heidegger's theory of equipment (the concepts of *present-at-hand* and *ready-to-hand*) and the hermeneutic circle of interpretation, both outlined in Heidegger's foundational *Being and Time* (1927). Dourish defines embodied interaction as "the creation, manipulation, and sharing of meaning through engaged interaction with artifacts" (Dourish 2004, 126). Dourish's proposal is more an argument for the benefit of including tactile cues and physical manipulation in interaction design, without positioning it or connecting it to the embodied cognition thesis or similar theoretical or experimental research on the active role of the body in perception,[57] which would offer that argument more weight. Still, Dourish managed to re-introduce the importance of haptic engagement and response to a human-computer research community much centered on visual representations. He also reiterated the significance of interpretation and production of meaning in embodied interactions, beyond written and vocal communication.

Haptic interaction: from HCI, HRI, to HMC

From the late '90s and into the '00s, the term human-computer interaction (HCI) has gradually been replaced by more specific concepts of interaction, often relating to a particular field (e.g. human-robot interaction or haptic interaction). The concept of haptic interactions appears on first glimpse to perfectly denote perspectives on interaction suited for this discussion. However, from the early 1990s the term haptics has been closely connected to devices and interfaces that relate to the haptic senses, and haptic interaction has become a terminology and discipline mostly associated with technological development in engineering and computer science research (Kajimoto et al. 2015) primarily directed at the sense of touch, and detached from the broader aspects of haptic experience. And as mentioned above, it is a research field primarily concerned with describing the transmissive qualities of haptic communication.

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[57] See chapter 3

Human-machine communication[58] as a research field, combining insights from earlier human-computer and human-robot interaction research, has been established the last five years, as a reminder that we need to extend our analysis from mere interactivity to communication. HMC understands communication as the "creation of meaning among humans and machines" by "focus[ing] on people's interactions with technologies designed as communicative subjects, instead of mere interactive objects" (Guzman and Lewis 2020, 71). Here they present the machine as a subject, highlighting the significance of the semiotic qualities of human-machine interaction, as well as presenting the pressing need to understand machine communication as something other than human-to-human communication.

We need to expand our understanding of human-machine interactivity, to include both parties, if we are to grasp the versatility and extent of haptic communication, and a good place to start is by unveiling the plentitude of the haptic senses.

4.2 The Capability of the Haptic Senses

I will start from a definition of haptic interaction as the study of machine recognition and interpretation of human touch, proprioception (and even affect) in the form of postures and gestures,[59] as haptic input, and machine mediation of tactile and proprioceptive responses, in the form of haptic feedback. So, a thorough understanding of the haptic senses is critical in both understanding and designing rich haptic environments. While a history of the term haptic and haptics was presented in the literature review, we will need a closer physiological understanding of the haptic senses for the discussion ahead.

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[58] The website for the Human-Machine Communication (HMC) Interest Group of the International Communication Association (ICA). https://humanmachinecommunication.com/

[59] I will primarily be discussing machine recognition of haptic input and output, and only briefly discuss haptic media, e.g. gesture controllers, utilizing machine vision analysis of gait, gestures and posture.

From touch to gestures

The sense of touch is elementary and vast. Touch is the first sense to develop in a fetus, enabling it to separate self-touch from external touch, and it covers our entire body. Touch is a complex sense, offering us the ability to recognize texture, temperature, pressure, and pain. We also have different modes of interacting with the touch sense, as we can distinguish between passive touch where a moving object touches our skin, and active touch which describes our ability for texture recognition, grasping, and manipulation of objects. The sense can also both work in proximity with objects, as well as at a distance in recognizing heat, gravity and static electricity (some people tagging themselves as highly sensitive, state they can sense other types of radiation such as magnetism and x-rays, although there is insufficient scientific evidence to support such claims).

In my discussion of the haptic senses in the literature review, I noted that touch is deeply connected with proprioception (and the vestibular senses), to the extent that it is difficult to state where tactile sensations end and proprioceptive sensations begin. So, the haptic domain clearly extends beyond the sense of touch. The haptic sense is a common denominator for proprioceptive and tactile sensations, where proprioception is responding to sensations in muscles, tendons and joins, and involves bodily movement (kinesthesia) and gestures, and tactile sensations are indicating sensations in skin, such as vibration, pressure, and skin deformation (stemming from skin stretch and skin slip).

The common conception also suggests a deep connection between the haptic and gestures. When describing John Carpenter's interactive screen projections,[60] Willis presents haptic art as "artworks that respond to people's gestures: pointing, pushing, waving, touching" (Willis 2014). In line with this, I consider both tactile and gestural interaction as haptic, as the proprioceptive feedback from gesturing directly responds to and shape our tactile sensations, and as a result are so deeply

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[60] Willis discusses Carpenter's *Dandelion Clock* (n.d.) and *Trailer's Anemone* (2013), two interactive wall projections where the interactor uses her hands to interact and shape the projection.

interconnected that it makes little sense to consider them separate interactive categories when evaluating haptic media.

Haptic sensitivity and sensorimotor control

Tactile and proprioceptive sensitivity

Our tactile sensitivity[61] is primarily in debt to mechanoreceptors. Mechanoreceptors are sensory receptors recording mechanical pressure, stretching and rotation, typically measured as frequencies of vibration between 0,4-1000Hz, and are found on the nerve fibers and nerve endings (corpuscles) in the skin (Jones and Smith 2014). They are distinguished by their receptive field (size of field that is activated when receptors are stimulated) and rate of adaptation (how fast receptors adapt to the transition between active tactile stimulus, and static, nonactive, stimuli, or said differently, how fast the receptor change their response based on the state of tactile stimuli). In terms of tactile sensitivity it follows that if the receptive field is small (type I), the tactile sensation is high and more specific, whereas larger receptive field (type II), will yield less sensitivity over a larger skin area, proposing that certain skin areas are better at detecting specific and pinpointed tactile input. In addition, the rate of adaptation (slowly adapting and fast adapting) will dictate how fast and specifically different types of tactile input can be recorded, or in other words, how well it records movement. As a result, we have four different types of mechanoreceptors (FAI, FAII, SAI, and SAII) distributed throughout the skin on our bodies, offering different kinds of tactile sensitivity, responding to vibrations of various frequencies. As an example, our hands (fingertips in particular), lips, and foot soles are densely populated by FAI mechanoreceptors, which are fast adapting with small receptive fields, and respond well to frequencies between 1,5-100Hz ,

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[61] While the sense of touch is used to describe more than strict tactile sensations, such as sensations of pain, temperature, and itching, our discussion on haptic interactions are first and foremost concerned with haptic (tactile and proprioceptive) sensitivity. That said, we are already seeing haptic media interfaces that experiment with stimulus of pain (nociceptors) and thermal receptors to create plausible virtual environments.

meaning these areas are better suited at detecting precise and dynamic tactile stimulus, such as skin deformation, and, in consequence, direction, as two or more points of touch can be applied in sequence within a short time frame. The sensation of motion is essential to grip/grasp moving objects.

On the other hand, our hands also have slowly adapting receptors with small receptive fields (SAI), sensing frequencies of vibrations between as little as 0,4 up to 3Hz. These are essential in identifying objects, as they sense precise spatial details, curves and object edges. Fast adapting receptors with large receptive fields (FAII), are the largest receptors and also the ones found mostly distributed over the body and is for that reason the most studied. These receptors respond to frequencies between 10-100Hz, but are most sensitive to frequencies between 250-500Hz. These receptors are fast adapting in that they are very sensitive to changes in force applied to the skin, recording transitions very well. (Jones and Smith 2014, 280-281). Slowly adapting receptors with large receptive fields (SAII) are key in detecting skin stretch (not so much skin indentation) and are thought to work in conjunction with other fast adapting mechanoreceptors and proprioceptive receptors to detect movement of grasped objects (Fleming and Luo 2013). A separate kind of nerve fibers, called C-tactile afferents (CT afferents or C fibers), have more recently been identified, responsible for the sensation of pleasant touch, achieved via slow, gentle movements e.g. experienced when petted or caressed. (Jones 2018, 17), suggesting that we have a particular sensitivity directed at affective touch.

We can measure tactile sensitivity in the skin in terms of spatial and temporal resolution. Spatial resolution calculated from the two-point threshold method[62] which the minimum distance two stimulated points in the skin before they are experienced as one point. In fingertips that distance is 1 mm. Spatial resolution is also measured based on how well we detect unevenness, during static touch and strokes. As expected, we detect smaller bumps if when stroked/stroke the object. On the fingertips a difference in sensitivity of 13 nm as opposed to 0,2 has been

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[62] As presented in the literature review, the two-point threshold method identifies the threshold for discriminating between two individual points of touch, formulated by Ernst Heinrich Weber in 1851.

measured (Skedung et al. 2013). The temporal resolution is measured in the length of time between pulses applied/delivered to the skin, for the sensation to be perceived as following one another and not as simultaneous. Currently this is measured to be 5 ms, which is better than vision, and less than audition (Jones 2018, 48). To summarize, signals from mechanoreceptors are responsible for recognizing location of points (spatially and temporally), orientations of objects, and pressure of force.

Our proprioceptive sensitivity is situated in the muscle spindle receptors (which record changes in muscle length), Golgi tendon organs (which record changes in muscle tension - the perception of force), and joint receptors. Together with tactile sensory signals from mechanoreceptors, these spatial and motor signals allow us to sense the direction, amplitude and velocity of the movement of the limb and changes in limb position.

Tactile perception plays a key part in proprioceptive sensing and vice versa. For this reason, it truly makes sense to talk about haptic sensitivity, as opposed to either tactile or proprioceptive sensitivity, when discussing tool use and interacting with haptics. It also becomes apparent that the extent to which a haptic media device is able to track and map these variances in sensitivity will dictate what tasks and actions it can mediate. As an example, vibration feedback at 100Hz (which is the average feedback frequency of a touch screen phone) can only be recorded by some fast-adapting receptors, mostly FAII, and therefore only suitable for specific types of tactile notifications.

Sensorimotor control and active touch

Our haptic, and tactile perception specifically, is also greatly interwoven with our ability for sensorimotor control (Jones and Smith 2014, Johansson and Westling 1984). The tactile apparatus detects a range of sensory signals, which allows it to perceive and recognize texture/roughness, pressure/weight, edges, curvature, and surface slip. These are qualities that are sensed passively, e.g. when an object is pushed against the skin. By actively exploring our environments with our haptic senses, we utilize the tactile and proprioceptive sensitivity in conjunction with our sensorimotor control. This allows us to experience sensations of shear, friction, compliance (the softness/hardness or elastics of an object), larger shapes, and inertia (Jones 2018, 18), as it is first when we manipulate objects, certain tactile qualities are available to us. In our skin lies tactile signals that are key in “encoding the magnitude, direction, timing and spatial distribution of the fingertip forces” (40) which appear to us during active exploration. This sensorimotor contingency entails that the range of our haptic sensitivity will depend on whether we are actively or passively engaging with the world, which again is another parameter to consider when designing haptic media devices that accommodates haptic input and haptic feedback.

From haptic sensitivity to haptic perception

Haptic perception is vast and complex as noted above, and in terms of interacting with objects, and, in extension, machines, there are specific qualities that inform this interaction. Human haptic receptors respond to three main categories of sensory input: namely vibration, force (sensation of pressure and resistance), and motion (sensation of movement and, in extension, duration). These sensations allows us to perceive geometrics (size, shape, orientation, curves), material (surface texture, temperature), compliance (elastics or how fast/slow an object/substance is displaced), and viscosity (how much force must be applied to an object/substance for it to gain velocity) (Jones 2018, 52-58). We also distinguish between passive and active sensing, in which active sensing allows us access to a whole new range of perceptions, as we manipulate objects. A subset of active sensations is called exploratory procedures (Lederman & Klatzky 1987). These procedures denote simple haptic gestures we perform to reveal certain properties of an object, e.g. squeezing a ball to confirm how hard it is. Later developed by Jones & Lederman in *Human Hand Function*, the authors list six different procedures performed to relevant properties. We utilize lateral motion to perceive texture, unsupported holding to identify weight, we apply pressure to uncover the hardness of an object, we enclose object to identify volume or global shape, we apply static contact to sense temperature, and finally, contour following to grasp global shape or exact shape (2006, 77). We often use these procedures in conjunction to identify objects.

No doubt the haptic apparatus is complex and versatile, and as we have seen above there are several parameters that need to be considered when designing precise and meaningful interactions utilizing haptic input and haptic feedback functionality in humans and in machines. We have a long history of designing tools and media interfaces that recognize our tactile and proprioceptive capabilities, allowing for a range of haptic input. I am especially thinking of tools made for our hands, in the shape of pins, levers, buttons, and wheels. But as we also have a highly developed sense for responding to tactile and proprioceptive feedback, and while there are devices offering machine mediated feedback, the repertoire is still rather limited.

4.3 The State of Haptic Media

From tactile media to haptics

The go-to haptic media of today are different touch screen devices that recognize a set of haptic inputs and provide a limited repertoire of haptic output.[63] There are also specialized and customized devices and biometric sensors for health monitoring, gaming, music performance, experimental art, that consider more varied bodily input (pulse, heartbeat, temperature, moisture) and haptic feedback (pneumatic or electric vibrotactile pulse patterns in seats or wearables) than handheld commercial communication devices. These provide us with an idea of how

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[63] Developers who seek to implement tactile feedback in touch screen devices are offered many applications where they can test different feedback patterns. In running the apps like *Haptic Effect Preview* which later transitioned into the *Haptic Test Tool* app (downloaded August 2016 and October 2018 respectively, both for Samsung Galaxy S7), a repertoire of haptic feedback patterns that can be produced with any present-day Android or Apple device, is made available. Both apps suggest a rather optimistic range of vibro-tactile patterns - all buzzing with approximately the same Hz frequency, categorizing the patterns types with ambitious names such as Collision, Engines, Textures, Alerts, Pulses and so on. However, the perceived feedback is not very varied, and in many cases indistinguishable from one another.

much richer day-to-day computing can be. We also have many gesture recognition systems which primarily track haptic input: motion tracking devices (utilizing camera and depth sensors) such as Kinect, data gloves (equipped with accelerometers, gyroscope and bend sensors), or controllers (e.g. Freespace or Wii). Machine mediated force feedback provides the interactor with tactile and proprioceptive sensations in the form of vibrations, electrostimulation, and sometimes heat. Previously most feedback devices were mechanical grounded (to a surface) to offer the force necessary, but the most common feedback devices are embedded in mobile devices, providing simple buzz-feedback.

If we consider all of these media systems, it is clear that haptics can and should be understood as more than tactile screen devices. Media theorist Mark Paterson discusses how the concept of haptic media has been understood as interfaces that only target the sense of touch, and suggests an expanded sense of haptics that includes a wider set of the somesthetic senses: "one that spans across bodily surface (especially cutaneous pressure, 'mechanoreceptors'), bodily interior (especially muscle-based stretch receptors necessary for proprioception, 'proprioceptors') and the touchable and manipulable parts of an object (e.g. the touchscreen, the button, the lever)" (2017, 1548). It is such a view of haptics through which examples of haptic media that will be discussed.

Sensory emulation, semiotics, and affect

There appear to be at least three levels for haptic technologies to engage and interact with users, often working in conjunction. First, we have technologies that specifically aim to emulate sensory experiences, such as temperature, surface textures, and forces, and in a way “fool” our haptic sense to accept these as real. A prime example is haptic clothing, i.e. the TeslaSuit[64] (which will be discussed more thoroughly in the final chapter), that aims to produce complete virtual sensory experiences for the wearer, most often coupled with AR/VR-glasses to fully immerse

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[64] The TeslaSuit is a full-body wearable utilizing biometrics, motion capture and various haptic feedback technologies to emulate virtual sensory experiences. https://teslasuit.io

the interactor in a virtual environment. A key feature of many of these technologies is that the interactor does not need to be consciously aware of the sensory stimulation provided to be effective. In fact, these technologies benefit if the sensory stimulus is seamlessly incorporated into your experience without you thinking about it, as you would everyday life sensory experiences. You are rarely consciously aware of the hardness of your bike seat or surface texture of your keyboard, unless you are forced (either by discomfort or conscious choice) to pay attention to this. This type of haptics gets a lot of commercial attention, particularly fueled by the promise of immersion offered by the second coming of VR.

A second type of haptic technologies aims to facilitate the communication of meaning and intention, providing the interactor with an interface for receiving and transmitting signs and messages. These technologies need to be specific in when and where (on the body) they are applied, as they need to capture the interactor's attention, either by offering event notifications or more cognitively demanding operations, such as interpreting incoming and composing outgoing messages. We see a lot of development in haptic warning and assistance systems (most commonly designed as simple buzz notifications, alerting the user that something has happened, or is about to). From event confirmation or event notification desaturating screen interaction, to assisting operating different vehicles or aircrafts (force feedback in steering wheels/sticks, belt, pedals and seats) or even guiding orientation, positioning, and direction (force feedback in wearables indicating when the user is off-track, e.g. in telesurgery, racing games or navigation). A third type of technology aims to interpret and communicate affective content. These are technologies that aim to identify particular emotional states based on haptic input from the user (caring strokes versus violent beatings) and in return offer different responses based on that input. There is an increase in the development of social touch and affective touch systems within robotics.

While the first type of haptic technology is the most developed at this point, with its ubiquitous qualities, this chapter also seeks to investigate the potential of haptics as an interface for communication of signs, messages and emotional content, that can function on its own or as part of a mixed reality setup including screen interfaces. Many researchers and engineers working with haptic interactivity are primarily focusing on the structure and sophistication of the encoding/decoding method of touch data (mapping and tracking of different parameters and modalities) promoting a rather reductive view of haptic communication. Despite there being a range of devices that were designed with primarily encoding/decoding parameters in mind, it is still useful to analyze the interaction these devices offer through a broader scope.

I argue we need to move from a purely transmissive understanding of haptic communication to include interpretation and interactivity. Specifically, I seek to interrogate haptic media interactions for their material, semiotic and affective qualities, and in the following I will introduce the haptic figure as a means to frame this analysis.

4.4 The Scope of the Haptic Figura

The haptic figura is an analytical tool that addresses both the material and semiotic qualities of haptic interaction (machine rendering of haptic input and machine mediated haptic response/feedback). As we shall see, in the heart of haptics we also connect with the affective dimension of haptic interactivity.

From iconography to material sign

The range of sense impressions we are able to recognize and interpret is vast. In addition to harboring complex parameters for recognizing and reading haptic signals, we produce haptic postures and gestures that form meaning clusters (signs), either to present concrete words in an alphabet (a non-visual alphabet or sign language), or tactile metaphors that trigger our ability for abstraction. This shows that we have rich potential for reading and communicating using our haptic sense. By turning haptic cues into haptic signs, we can extend our human-machine communication significantly, we may even teach our bodies to interpret a new language. Previous and successful interface design, e.g. the GUI/WIMP[65] framework, introduced the desktop metaphor which utilized communicative vehicles such as icons and symbols to bridge human intention and machine potential. This type of interface is, as discussed in the early chapters, a primarily visually centered interface, carrying components that are less relevant when considering haptic interactivity. Icons are graphical, related to the image, a pictorial likeness to the things they represent, and as such binds it to the visual representation of the reference. Symbols on the other hand are culturally specific and conventional and prove for that reason difficult to be utilized in interface design.

So, we need an alternative to analyze the flow of signals between humans and machines. Signs function as signals (which may take the form of bodily gestures), communicating a meaning. Signs in interface design have been heavily related to icons and sign processes (reading/writing via engaging with icons). To offer a move beyond a purely iconographic thinking in haptic interface design, I propose to use the metaphor of the figure, and consider signs as figures, that is, as expressions that combine aspects of meaning, reference and affect. The figure is versatile as it may simultaneously symbolize a fact or an ideal. That is, the figure is weighing the materiality of the sign equal to the idea it represents. Let's dig into this and allow me to use Auerbach's notion of the figure as a starting point. In his well-known essay "Figura" he proposes the following:

> Figural interpretation establishes a connection between two events or persons, the first of which signifies not only itself but also the second, while the second encompasses or fulfills the first. The two poles of the figure are separate in time, but both, being real events or figures, are within time, within the stream of historical life. Only the understanding of the two persons or events is a spiritual act, but this spiritual act deals with concrete events whether past, present, or future, and not with concepts or abstractions; (1984, 53)

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[65] Graphical user interface with the window/icon/menus/pointer setup.

With figural interpretation Auerbach proposes a new way of reading and interpreting religious (primarily Christian) texts (which really is proposing a new way of interpreting reality). A person or event prefigures another in history, and the latter is a fulfillment of the first (e.g. Joshua is a figure and Jesus the fulfillment of the figure). The figural relationship between the two is what will bring forth the full significance of the story. As such the figure signifies itself and what it represents (point towards), and what it represents is a realization of the signified.

What I bring with me from this perspective is that the figure exists between eidos (idea) and schema (forms perceivable by the body), it is both an idea and flesh, and the sensuous aspect cannot be reduced to a sign. The meatiness of the figure is significant. I suggest that by moving from *icon* to *idea-form* thinking, the concept of a *haptic figura* has the ability to function as a liberating metaphor in interface design, freeing us from strong iconographic representation when developing haptic media technologies. Instead we may aim to identify, capture and emphasize inherent qualities of the haptic sense. The haptic figura promotes the intrinsic value of the communicated sign, as both form (the haptic gesture itself) and idea (what it refers to) are of equal importance.

Metaphor and methodological tool

I see the haptic figura function as a metaphor that reminds us of what is important to consider when involving haptic senses in personal computing environments. The haptic figura emphasizes the material and semiotic qualities of human-machine interaction, as it emphasizes the materiality of the sign, the embodied quality of communication between bodies. But I also see it is a methodological tool for analyzing haptic interactivity, by putting individual attention to the haptic gesture as a material and visceral act, as well as the sign itself as a bearer of a particular encoding that may be exchanged and possibly interpreted (be a bearer of meaning). The haptic figura captures the message-carrying gestures in human-machine interaction. While the haptic figura offers insight on the overall haptic communication between man and machine, as an investigative metaphor and tool for understanding tactile and gestural input signals and signs, it will be directed more specifically towards haptic feedback, as this is the field of haptic communication that is most lacking.

The haptic figura addresses two aspects of haptic communication—the physical expression (haptic gesture) and the communicated sign. I will discuss these two aspects under the following headlines: haptic materiality and haptic semiotics, in a first attempt to sharpen the analytical tool.

4.5 Haptic Materiality

The material solution of haptic media defines and frames the support of haptic perception, the active exploration arriving from tactile and proprioceptive cues. As an example, tactile systems will not acknowledge proprioceptive signals, and may only simulate force feedback sensations. Likewise, full material support is not necessary for all kinds of interactions. So, to arrive at an understanding of how the material solution influences haptic communication, we need to distinguish tactile and haptic media, input and feedback solutions, to the extent it interfaces with a body-part of the full body.

Haptic technology can be distinguished in several ways. Generally haptic technologies cover all kinds of systems that mediate real or emulated haptic sensations, perceptions and interactions between man and machine. There are systems that are specifically designed to decode haptic input, others that encode and apply haptic feedback, and some do both. We can also distinguish haptics for robots (machine recognition of haptic sensations), invasive haptics (e.g. brain stimulation), and non-invasive haptics. This chapter is most concerned with non-invasive haptic feedback technologies, as that is where the potential of haptic technologies is least understood and theorized. For this reason, the section on materiality is primarily focused on the encoding and application of haptic feedback, although there will be cases where the machine recognition of human touch is part of the haptic systems discussed.

Haptic systems exist in many shapes and relationships to the body, ranging from hand-operated surface technologies (tactile and haptic displays) to full-body wearables (exoskeletons or suits). An important distinction is made between purely tactile systems and devices that engage the full haptic sensory apparatus (proprioception included). While tactile systems primarily target sensations in the skin, such as vibration, skin stretch and skin slip, fully haptic systems can also utilize sensations of force and motion. Traditionally, systems that offer force feedback sensations have required heavy actuators that dictate the design solution terms of size, degree of freedom (DoF),[66] and mobility.

There are many proposals for organizing haptic feedback technologies, and a useful distinction is introduced by Culbertson et al., contrasting between graspable, wearable and touchable haptics (2018). Graspable haptic devices are grounded and specifically targeting proprioceptors (utilizing force-feedback and sensation of motion). Wearable haptics are primarily tactile (targeting sensations in the skin via vibrations, skin stretch, and deformation), and may be both grounded and ungrounded.[67] Touchable systems can target tactile, proprioceptive or our full haptic sensitivity, and either be grounded or ungrounded (mobile). Another proposal for classification separates devices targeting proprioceptors that are body-grounded or world-grounded, and devices that are purely tactile and ungrounded (Pacchierotti et al. 2017). Others again propose a division between passive devices (systems utilizing passive actuators for force sensations, such as a break, and hence offer low DoF), rigid haptic controllers (grounded haptic systems with active actuators), and ungrounded systems (primarily tactile systems, or haptic systems using tactile actuators or gyros (Yano et al 2003)).

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[66] In mechanical engineering and robotics, DoF or degree of freedom, denotes the mobility of a rigid body. A highly mobile body has 6 degrees of freedom, as it can move: Left, right, up, down, forward, backward, pitch (tilt forward and backwards), roll (pivot from side to side), as well as yaw (turn left and right). In the design of haptic feedback systems, the DoF is measured in terms of many kinds of movement the device may offer feedback for.

[67] Culbertson et al. also include exoskeletons in this category, which being body-grounded (but not world-grounded) will be able to provide proprioceptive cues to the wearer.

The distinction between grounded and ungrounded is particularly relevant for haptic feedback devices, in terms of how force-feedback may be applied, as grounded devices can utilize the natural resistance of a body or environment (world) in generating forces. This brings us to another important design choice, namely the decision of utilizing *admittance* or *impedance* control to determine how haptic feedback forces are applied and controlled. In admittance devices the system detects the movement (as in force) applied by the user and offers (or controls) resistance according to the object or surface it simulates. As such it applies forces onto the user. Admittance systems are great for emulating stiff surfaces, but not so much low inertia (Keemink et al. 2018) nor offering forces in multiple directions (low DoF). Admittance devices are therefore useful for applications where significant force needs to be applied in a specified direction. Impedance devices, on the other hand, reflect or resist forces, and take the position of the user as a starting point for the force response. For this reason, they struggle with emulating stiff surfaces, but are great for rendering low level sensations of inertia. Due to the cost and ease of design, impedance systems are also the most common, and it is the control solution used in most tactile and haptic surfaces, as well as displays for teleoperation.

To be able to navigate the many different haptic technologies, I have suggested some categories to distinguish between them. We need to consider the machine mediation of haptic input and haptic feedback apart, and also between full-body interfaces and haptic media directed at particular limbs or areas of the body.
But perhaps the most important distinction is made between tactile, proprioceptive and haptic devices, and the ability of the different systems in supporting haptic perception, as it frames mobility, force representation, and tactile sensitivity.
In the following we will take a closer look at a set of different systems, affording tactile, proprioceptive, and haptic perception, respectively. Namely, tactile displays, selected haptic surfaces, and controllers.

Tactile displays for the skin

Tactile sensations in haptic feedback systems are mostly presented as tactile displays and surfaces, which offer sensations of static pressure (skin indentation), skin stretch/skin slip, and vibration, by stimulating mechanoreceptors in the skin. The most common delivery methods for these sensations are static tactile, electrotactile, vibrotactile stimulation giving the interactor a sense of geometric and material qualities, as well as a sensation of force (primarily through the use of small tactile actuators applying pressure against the skin).

Figure 36. Press photo of *Haptic Edge Display* which utilizes static tactile stimulation. Image sourced from project website.

Systems utilizing *static tactile stimulation* are most often pin based arrays where linear actuator motors (LRAs) or piezoelectric motors (which are utilizing mechanical motion to charge the motor) in the form of mechanical actuation that indents the skin, presents the touch sensation. Braille displays or tactile arrays are common systems utilizing this kind of tactile stimulation, but we also find novel mobile controllers, such as the Haptic Edge Display,[68] where an array of linear actuators, placed in a single direction on the device, can be arranged to present different buttons and controllers for the user (Jang et al. 2016).

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[68] The *Haptic Edge Display* was first developed at Tangible Media Group at MIT, later continued by Sangjune Jang. http://www.sjjang.com/haptic-edge-display

In *electrotactile* or *electrocutaneous stimulation* electrical charges (formulated as brief and constant pulses) are presented to the nerve endings in the skin directly via arrays of electrodes. A design advantage in using electrotactile stimulation is there are no motors involved, ergo the component contains no moving parts, which makes it robust and less prone to adding unwanted vibration/noise. On the other hand, moisture is needed for conductivity, which makes the solution less versatile. Another disadvantage is the small dynamic range of the sensation, meaning that the range of stimulation from it being perceptible to becoming painful, is small. Some systems utilize combinations of electrotactile stimulation, to better emulate the sense of force. One example is transcutaneous electrical nerve stimulation (TENS or TNS/EMS) which combines electrical muscle stimulation (EMS) with transcutaneous electrical nerve stimulation (TENS).[69] Finally, electrotactile stimulation requires little power, and is therefore relevant for wearable systems running on batteries.

Vibrotactile stimulation can be achieved in several ways. The most common method is in combination with electrostatic tactile actuation, where the skin vibration is achieved mechanically as motors transferring electrical charges are causing the perceptible mechanical motion. There are mainly two types of motors commonly used to produce vibration sensations, electromagnetic and piezoelectric vibration motors.[70] Vibrotactile stimulation can also be achieved without motors using electrical charges, but in contrast to electrotactile solutions, stimulation from

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[69] This type of combined electrotactile stimulation is utilized in several haptic wearables, among them the full-body Teslasuit (https://teslasuit.io/)

[70] Of electromagnetic motors, eccentric rotating mass vibration motors (ERM) and in linear resonant actuators (LRA) are the most common. In ERMs vibration is created by rotating, uneven centripetal force, and delivers vibrations above 100Hz. This means they primarily target the Parcinian corpuscles (which we remember fast adapting receptors with large receptive fields), meaning this kind of vibration will be sensed by a larger skin area, and therefore not be very specific. While these motors are cheap and have been used extensively, they have been gradually replaced by LRAs and piezoelectric actuators. In LRAs and solenoids, there are no external moving parts, and vibration is produced from a linear motion (up/down or back/forth) from a central mass. Inside the LRA a spring is tensed from the pressure from central magnetic mass that is set in motion by an electrical signal via voice coils. Both of these vibration motors convert electricity into kinetic energy via electromagnetism, but the LRAs are more efficient (both energy and timewise) and responsive (less latency from activation until the vibration starts).
Piezoelectric actuators generate electricity which causes vibration when a material stressed by mechanical motion, such as bending or pressure. In addition, they can vibrate in several directions, as opposed to LRAs and ERMs, and as LRA's they require less power to run. Piezoelectric actuators can come in many different sizes and layers, in addition to offering vibration at many different frequencies, making them incredibly versatile and relevant when designing haptic feedback solutions.

electrovibration is indirect as no charge passes through the skin. Mechanical skin deformation is caused by electrostatic forces which arise when fingers slide over display. So, fingers need to be in motion and function as the actuator, to produce the skin deformation effect. This technology has been successfully implemented in several tactile displays.[71] Electrovibration is generally a great solution for surfaces as the technology is easily scalable, there is no noise as no motors resonating causing unwanted frequencies, the feedback potential is instant and even across the entire surface. However, it affords only one tactile signal per surface.

Force touch

Vibration sensations derived from vibration motors are good for several types of sensation, and have been key in creating experiences of texture, as well as illusions of motion, strokes, and pulling. However, vibration is not particularly useful in creating sensations of force. As Culbertson states in an interview with Phys.org: “With vibration, you can create the feeling of motion, but it doesn't feel like you're mimicking a human touch—it just feels like buzzing," she said. "It's also very hard to isolate vibration, so people just tune it out" (Dawson 2018). Emulating the sensation of force (e.g. sensing weight and stiffness) is the most challenging aspect of purely tactile surfaces, and beyond vibrotactile vibrations, tactile actuators[72] have been the main method to deliver force sensation in the form of skin pressure. In addition to the delivery methods discussed above, we also see novel development in the field of microfluidics,[73] where arrays of pneumatic actuators and air produce suction and pressure. However, not all experiences of pressure are generated by actuators

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[71] TeslaTouch (Bau et al. 2010) is a tactile feedback technology derived from electrovibration labeled Electrostatic Friction, which has also been utilized in the Revel project by Disney Research (Bau and Poupyrev 2012). Similarly, Apple has developed their own version of electrovibration for the touch surfaces, labelled Taptic Engine, combining a static force sensor with a lateral vibrator, which is customized for different Apple devices.

[72] Tactile actuators include LRAs (primarily used in pin-based displays), solenoids, piezoelectric actuators, pneumatic actuators, ultrasonic transducers, and microfluidics.

[73] The wearable HaptX glove (https://haptx.com/technology) and NewHaptics’ Holy Braille project (https://www.newhaptics.com/holy-braille-project) offering full-page tactile displays for graphics are two recent devices utilizing microfluidics.

physically touching your skin. There are also projects, such as UltraHaptics,[74] which present mid-air haptics via non-contact displays, where various pressure sensations in the skin, allow the user to feel shape and texture, even 3D images in the form of haptic holograms. What is agreed upon is that we need to move beyond buzz sensations generated from vibration methods, to actuated force feedback to produce authentic force sensations.

From tactile, proprioceptive to haptic devices

So, we have tactile displays and wearables[75] that deliver tactile sensations, including emulated force sensations from different kinds of actuator technologies. Another field of haptics is primarily directed at proprioceptors (often called kinesthetic devices), which are mostly good at presenting deep force sensation, and little tactile feedback. In kinesthetic devices force feedback is primarily offered via bigger actuators in combination with position and force sensors to deliver precise sensations. These devices are therefore good at presenting sensations of stiffness/hardness, movement, and weight, but offer very little information of surface texture and local geometry. Haptic devices, on the other hand, aim to combine the best of worlds, by offering both tactile (relating to the skin) and proprioceptive (relating to muscle movement and posture) sensations. In these devices, forces recorded by proprioceptors are delivered in conjunction with tactile feedback, to successfully combine both types of haptic feedback. Furthermore, they have a greater potential for active haptic perception, where we explore and manipulate objects and virtual worlds with our full haptic apparatus. As we discussed earlier, these are actions that allow us to experience sensations of friction, shear compliance, inertia, and larger shapes. Sensation of shear and friction are key

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[74] https://www.ultrahaptics.com/

[75] One example of tactile wearables are haptic armbands, where the most common ones are smart watches and heath monitors offering haptic feedback in the form of vibration (i.e. Fitbit). However, we also see the development of haptic armband utilizing tactile actuators to produce more natural force sensations. By adding single rows of actuators in the arms, these are devices which may be able to target social and affective touch sensations, emulating strokes and pats, by activating actuators in a given direction.

in emulating the feeling of contact or impact. Impact sensations have generally been the most challenging to produce in haptic devices and have usually been solved using vibration to emulate feelings of texture and contact (Hannaford and Okamura 2008, 730). The facilitation of haptic perception is essential in teleoperations or virtual environments where the interactor needs to be able to manipulate virtual objects and recognize surfaces. But the more complex the haptic media system, the less mobile and versatile they are.

Haptic surfaces and controllers

Haptic surfaces typically utilize pin arrays controlled by actuators to emulate stiffness, shape, and ideally, the texture of surfaces. These are most often designed using large pin arrays, that instead of just offering force touch sensation in single direction as is the case with linear arrays, they emulate real-life surfaces that we can explore actively. For this reason, they are also often big and cumbersome, with fixed surface resolution. We haven't made a comprehensive haptic surface, so far the devices are either offering little in terms of texture representation, or the haptic interaction is one-way, as is the case with visuo-haptic environments. One example of this is the inFORM project developed Tangible Media Group at MIT. InFORM is a haptic shape display consisting of an array of actuators that is rendering three-dimensional content over distance. This display allows users to create shapes, as well as manipulate physical objects over distance. The system can change its surface based on shapes, gestures and postures mapped from the interactor (Leithinger et al 2014).

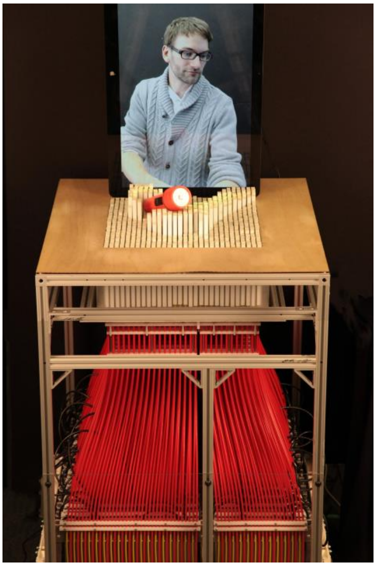

Figure 37. Pressphoto of developer Sean Follmer interacting with the inFORM device. Downloaded from Tangible Media Group, MIT, under a CC-NC-ND license.

However, inFORM is merely mirroring gestures and postures virtually before translating this data into actuator positions on the shape display. The machine is not really interpreting and responding to a human gesture. The interactor will also only experience a visual feedback of the tele-touch. There are also haptic surfaces made with pneumatics (often called deformable crusts), where the sensations of shape and stiffness are achieved by controlling the surface (and not by forming the surface with pins underneath). These soft robotic solutions only offer stiffness control. However, in conjunction with electrostatic stimulation or ultrasound vibration, more tactile sensations such as texture or friction may be applied.

Haptic controllers (specifically for hands) are becoming more commonplace and have found their use in virtual and augmented reality settings. In contrast to haptic surfaces, haptic controllers are not aiming to represent real-world environments. Instead they aim to emulate sensations in a specific area (a hand, or selected digits), or represent virtual objects for the hand. The latter approach is becoming more common in haptic controller design, as simulating objects, as opposed to simulating hands, is less complex. One example of this is the TORC (TOuch Rigid Controller), a grounded haptic hand controller designed to understand objects in terms of compliance (sensation of elastics), texture, shape, and size. The TORC targets the thumb and two index fingers, in the thumb operates a track pad which ensures texture sensation, the two index fingers are coupled with vibration motors, and between the index finger and thumb you find a pressure sensor (Gonzales Franco and Ofek 2019).

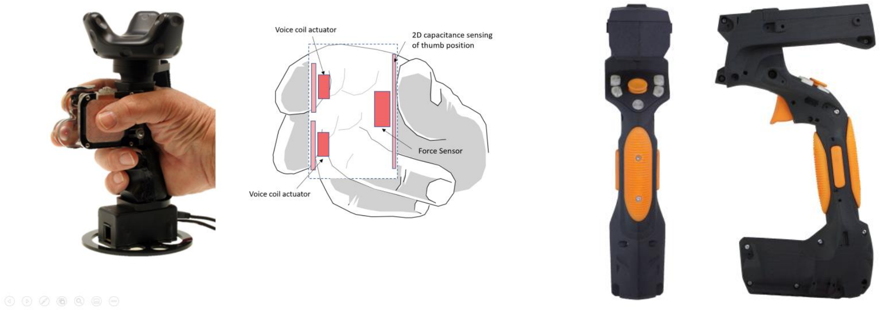

Figure 38 and 39. Screenshot of *TORC (TOuch Rigid Controller)* by Microsoft Research (left). Pressphoto of *Reactive Grip Motion Controller* by Tactical Haptics (right). Both images courtesy of the developers.

Controller application is very much influenced on them being rigid or grounded, as in the case with TORC, or if they are ungrounded, such as the Reactive Grip motion controller.[76] This controller is also novel in how actuator technology and sliding plates are applied to produce more natural force feedback, specifically mimicking forces of friction and shear, the detailed sensation of strain on impact with an object or surface (Provancher 2014, 19). A general insight is that haptic controllers supporting haptic force feedback easily become cumbersome, and rather specialized, designed for certain tasks at the cost of others. With haptic surfaces that are inherently grounded, the specificity of the interfaces becomes even more pronounced.

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[76] The Tactical Haptics Reactive Grip is a mobile haptic controller specifically designed for VR environments that supports sensation of shear and friction. https://tacticalhaptics.com/

The role of materiality in the haptic figura

I have proposed haptic materiality as one analytical aspect of the haptic figura. Haptic materiality is a measure of authenticity—the extent to which active haptic perception, our intent for action, is supported in the material solution. Authenticity does not entail an exact duplication of real haptic sensations. Rather, it is understood as the extent to which the perceptive opportunities we expect when manipulating objects or navigating an environment with our bodies, is translated when interacting with virtual objects or worlds. The potential for haptic perception (achieved when combining passive tactile and proprioceptive sensations, with sensations derived from engaging our sensorimotor apparatus by manipulating and actively exploring objects and environment) in communication is significantly influenced by material qualities. This entails the support of physical sensations of force, as well as detailed tactile sensations of surfaces. The degree of authenticity in haptic communication is a measure of the successful implementation of these two parameters, both when passively and actively experiencing an environment.

But haptic communication is more than a measure of hardware platform and functionality in terms of authentic mediation. Haptic media devices also afford the opportunity to establish a connection between sensation and meaning, which leads us to the second aspect of the haptic figura—haptic semiotics.

4.6 Haptic Semiotics

We have discussed the significance of material choice and design of haptic devices in terms of mediating authentic sensory experiences, also in virtual worlds or tele-environments. We still need to steer clear of a reductionist view, where haptic sensing is reduced to a grammar of signals (the receptors and emitters of signals, the signal to the skin system and back, and so on), when we already know that haptic communication may offer so much more. If we are to understand haptic communication beyond the purely transmissive qualities, it is fruitful to consider the interpretative qualities of haptic interaction, where we may view haptic signals as messages sent via and from machines that carry meaning and intention. Can we even think of these haptic technologies as giving us access to a new language of touch and proprioception that is constructed and learned or is it more useful to consider this exchange on its own terms?

In the following I discuss the concept of signs and messages, and connect it to the idea of haptic iconography, a current direction in interaction design for the sense of touch, to present a framework for haptic semiotics. I consider haptic semiotics to be the second significant part of the haptic figura, emphasizing message-carrying qualities in haptic communication.

Haptic signs and semiology

Contemporary linguists Charles Sanders Pierce (1839–1914) and Ferdinand de Saussure (1857–1913) marked the beginning of a theory of semiotics, the study of sign processes in the production of meaning. Pierce, who coined the term semiotic, understood this process as triadic, analyzing the relationship between sign, object, and the interpreter, including both the external world (the object), and the internal representation (within the interpreter). Saussure chose instead a dualistic approach, understanding meaning to be a relationship between *signifier* (the word uttered) and the *signified* (the mental concept), proposing no necessary link between signifier and signified. Pierce and Saussure mainly considered symbols and signs to be visual and linguistic (written or spoken words) and paid less attention to meaning and interpretation of touch gestures. So moving beyond Saussure's and Pierce's contributions, I find a valuable insight in Lazzarato's *Signs and Machines: Capitalism and the Production of Subjectivity*, where he (building on Guattari's work) proposes 3 classes of signs: a-semiotic encodings, signifying semiologies and a-signifying semiotics. He distinguishes between semiotics and semiologies, where semiotics is the study of signs that are being exchanged before or beyond the realm of interpretation (e.g. human DNA and crystalline structures (a-semiotic encodings) or machine code (an a-signifying semiotic). Signifying semiologies are the study of the interpretation of signs or signs that are becoming semiologies (these are symbolic, able to produce meaning). Haptic signs fall under a symbolic signifying semiology, which includes all “pre-signifying, gestural, ritual, productive, corporeal, musical, etc... semiologies” (Lazzarato 2014, 67). He continues arguing that “[s]ince symbolic semiotics are 'transitional, polyvocal, animistic, and transindividual,' they are not easily assigned to individuated subjects, to persons ('I,' 'you')" (69), which suggests to me that haptic signs may have a broad cultural and social applicability. The claim that certain haptic gestures and postures are more or less universal, is not new.

Figure 40. Illustration from John Bulwer's 1644 book *Chirologia*, a compendium of manual gestures from religious, social, literary and medical contexts, e.g. the gestures of Applause, Honor, Admiration or Invitation. Public domain.

As early as in the 16th century, physician and natural philosopher John Bulwer argued for a natural hand language of gestures which was closely connected to the faculty of reason. He collected manual gestures and gestures of speech and discussion in the two books *Chirologia* and *Chironomia* published together in 1644.

Although many of the gestures are recognizable to me now, I also find many of them difficult to interpret or distinguish from one another, proposing that haptic gestures and postures are not completely resistant to cultural change.

Haptic alphabets

We already have dedicated alphabets for reading and writing with the haptic sense. Some of them are purely tactile, while others are based on sign-gestures directed at the sense of sight. Sign languages for hearing impaired and deaf are developed for many languages (e.g. Norwegian sign language, ASL etc.) where gestural signs make up individual letters, words, and concepts, and they come with their own grammar ("Om tegnspråk" 2016). Similarly, we have hand alphabets such as LORM[77] developed for the deaf-blind, where reading and writing is conducted through a set of touch signs presented as points and stroked patterns on the receiver's palm.

The Braille language, developed for visually impaired and blind people, is built of cells of up to 6 dots to make up letters, punctuation, numbers, mathematical signs and some contractions. Braille can be read and written, and is, as such, a complete tactile alphabet. Sign languages, on the other hand, are not considered written languages. I would argue that the potential for inscription is present in all of these languages, even though the LORM and sign languages initially don't provide a permanent written record. How different then is the process of writing with a pen or typing on a keyboard from touch and gestural signing if the signs could be stored or directly transcribed? So, we know that we may learn new haptic alphabets with relative ease, that information can be read and written (provided that the signs are stored). How can this help us understand and develop a richer human-machine interaction which better addresses our haptic senses?

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[77] The name of the alphabet arrives from its inventor Hieronymus Lorm, a pseudonym for philosopher and writer Heinrich Landesman (1821-1902) who himself lost his hearing and sight at an early age ("Landesmann, Heinrich; Ps. Hieronymus Lorm" 2003). The LORM alphabet has its primary user base in Europe, Germany specifically.

Towards a haptic language? From signs to message

There is no doubt the haptic repertoire is rich and diverse, and in considering haptic semiotics when designing communication signs in interactive scenarios, we might move beyond simplistic mappings of touch and proprioceptive signals to communicate specific functionality and intention. As presented earlier in the chapter there are several distinctive features relating to haptic sense. We may actively explore objects and environments, or passively receive sensations, we can sense objects over distance or in proximity. Sensation may be directed at the skin only or the full haptic apparatus. Equally the intensity or force, as well as the duration and movement of the haptic sensation will dictate the potential of different haptic signs. Beyond this, the location of the touch on the body (in terms of sensitivity), emotional intent, cultural background, and content and prosody of any concurrent speech all feature in when interpreting the sense of touch. So, where to begin?

In her work with human-machine interfaces and haptic perception Hong Z. Tan and team identified and evaluated five different parameters to be considered in interfaces directed at the haptic sense: pressure, stiffness, position, resolution and force magnitude (Tan et al. 1994). These are parameters we utilize in our interaction with people and objects, and they can similarly be considered parameters of a rich haptic input and feedback repertoire, as well as in the construction of haptic signs. For tactile sensations based on vibration, amplitude, frequency, rhythm, and envelope, have been considered the most significant feedback parameters (Culbertson et al. 2018, 394). Insights in preferred input and feedback methods for handheld devices may be hinted at in an experiment aiming at creating and representing haptic messages using a handheld device (Rantala et al. 2011). The participants were asked to deliver their preferred haptic input methods (stroking, moving or squeezing), for different types of messages (e.g. agreeing to a text message, alert a friend, a message to a loved one) to a haptic device, and later rate the same message, synthesized and rendered with haptic actuators. The participants reported that primarily tactile input (squeezing and stroking gestures) was preferred input methods for more affective content. Moving (and thus engaging proprioceptors) was considered a less precise input method to specify message intent. And most importantly, the interactors sought a common haptic lexicon to "define the meanings of different messages" (303).

From binary cues to vibrocons, tactons and haptic icons

Application of haptics semiotics have been primarily utilized in information displays (mostly utilizing vibrotactile stimulation), offering the message carrying signals in the form of binary cues, signing on/off states, correction of direction, or notifications (of events or teleoperation presence). But haptic interaction may afford so much more, and there already exists a significant body of research on haptic interaction design, particularly haptic feedback and sign design. In 2001 Van Erp and van Veer presented a basic set of tactile coding principles for the design of tactile navigation symbols, labelled *vibrocons*, to aid car driving, particularly to aid information relating to direction and distance. Direction was coded using body location (tap on either shoulder) and motion (simulating movement towards left or right using several actuators), and distance was coded using rhythm and intensity. Their experimental setup using vibrocons showed an increase in reaction time and reduced mental effort when responding to incoming data from driving. A couple of years later, computer scientist Karon Maclean introduced the concept of *haptic icons* defined as "brief computer-generated signals, displayed to a user through force or tactile feedback to convey information such as event notification, identity, content or state." (MacLean & Enriquez 2003, 352). Their early studies were primarily for passively presented icons (not actively explored by the user), and with single parameter stimulus, before aiming for more complex interactive environments. One significant finding from the studies was that haptic stimulus must be sequenced in time, as humans otherwise have difficulties distinguishing them from one another, and that beyond frequency, wave shape and force magnitude were the most important factors perceptually. In later more comprehensive studies on rhythmic touch the MacLean research team created a set of 84 distinguishable tactile stimuli, concluding that subjects were most likely to respond to unevenness and note length

(Ternes and MacLean 2008). The research of MacLean and team suggests that sequence, signal difference, and signal length are the parameters that are most easily recognized by users.

At the Multimodal Interaction Group at the University of Glasgow, Lorna Brown produced her dissertation on haptic sign design. In her dissertation work, Brown introduced the concept of *tactons*, an abbreviation for tactile icons, which are structured vibro-tactile messages. Her research concluded that six design parameters can be utilized in presenting vibrotactile messages: rhythm, spatial location, roughness, intensity, and intensity change overtime, and secondly, that such messages can be learned by users (Brown 2007). Brown's research introduces spatial location and roughness to the overall parameters introduced earlier by MacLean, and also highlights the potential of rhythm when creating haptic messages. I do find the notion of haptic figures as rhythm to be particularly intriguing as I associate rhythm with often subconscious creative processes, as well as and pattern recognition processes, but I still need to connect this personal association to a larger picture coupling the sense of touch and creative/abstract thinking. Brown's second conclusion, that haptic messages are readily grasped by users is corroborated in a recent study with vibrotactile stimuli conducted by researchers at the University of Tampere. They found that both primed and unprimed subjects evaluated the stimulus almost equally, suggesting the potential and intuitiveness of meaningful haptic signs (Lylykangas et al. 2013). In a 2008 study where haptic icons were used to assist subjects collaborating remotely in a single-user application taking turns, the participants reported that 1) haptic icons were easy to learn and recognize even under high cognitive workload and 2) that they preferred the multi-modal setup with the haptic component to a purely visual one (Chan et al 2008). This last study underlines the potential of using haptic technologies (particularly feedback) to ease day-to-day computer interaction, not only because they are easy to learn, but also preferable to a non-haptic setup.

The role of semiotic in the haptic figura

Semiotics in haptic communication is primarily demonstrated in binary signs (on/off, yes/no, day/night, more/less etc.) featured in various notification features. But there are several fruitful approaches to frame and mediate haptic sensitivity and intent, beyond binary cues. The haptic sense allows for a range of parameters to be utilized in forming more nuanced signs and messages, as demonstrated in several experimental setups. While we might arrive at haptic alphabets that are shared across culture and times, linguistics, the study of language, has shown that the form, meaning and context is not set in stone, and too complex and culture-specific, to function as a suitable end-goal for haptic communication. But, if not a shared haptic language, there is a worded need for a shared glossary or dictionary to guide machine mediated haptic interaction to remove ambiguity from haptic messages.

I have proposed haptic semiotics as the second analytical aspect of the haptic figura. Haptic semiotics is a measure of the potential for sending (encoding) and receiving (interpreting) messages via the haptic senses, where the facilitation of semiotics, the ability of a technology to both present and interpret concrete haptic signs, icons, messages, and even full alphabets, is studied. It investigates the potential for conversation, in terms of how messages may be exchanged, the challenge or ease in learning the alphabet or haptic language repertoire in question, as well as the potential for producing written records by means of storing conversations.

Wielding the tool

I have proposed the concept of the haptic figura as an analytical tool that addresses both the material and semiotic qualities of haptic interaction. Haptic materiality is really a *degree of authenticity* in terms of how well the technology can emulate real tactile and proprioceptive sensation, and facilitate active haptic perception. While tactile sensations are primarily related to stimulation of the skin (cutaneous), such as vibration, skin stretch and skin slip (friction), proprioceptive sensations are concerned with feelings of force-feedback and motion (sense of inertia, pressure, or compliance). Haptic semiotics is a measure of the conversational qualities of the technology, where the element of interpretation and meaning production in tactile-gestural communication is analyzed. There will be many haptic media devices that have strong and many-faceted material features, but hardly any semiotic qualities worth discussing, and vice versa. However, looking at both aspects when analyzing interactive qualities does illustrate potential and shortcomings of the haptic media in questions. Also, the analysis will not cover a fully fleshed general purpose interface that accommodates and facilitates a range of actions and tasks, rather I wish to present specific interactive expressions and messages within a haptic media that are of particular relevance and importance, as a means to reveal basic interactive devices and methods for haptic interaction design. In the following I will use the haptic figura to present the mobile LORM glove.

Tele-tactile conversations

The LORM glove is a tactile tele-communication device developed at the Design Lab in Berlin, that lets interactors communicate with each other over distance using LORM.

Figure 41 and 42. Press photos of the *Mobile LORM glove*. Left image shows how a user can input haptic data on the LORM glove. Right image shows how the user receives haptic output/feedback. Courtesy of developers.

The LORM alphabet is a tactile language where letters and words consist of touch gestures made out of points and lines, written on the receiver's hand palm. The mobile LORM glove allows deaf-blind people to send and receive messages written in this sign language, functioning as a simultaneous translator. The gestural signs are either transferred from a touch screen device to the glove, or from a second glove palm to top of the glove, while the user sends their messages via the palm of their gloved hand. The haptic input is controlled by pressure sensors in the glove palm, and haptic feedback is delivered via vibration sensors at the back of the glove. As such, the mobile LORM glove offers the users a direct, symmetric dissemination of touch and touch gestures - as both input and feedback are communicated haptically, although rendered via text.

The material and semiotic solution

The glove is equipped with flat pressure sensors for input, that allows for continuous gestures, and the glove material and the sensors are elastic supporting a tight fit for each wearer. Haptic input is read via 35 fabric pressure sensors that correspond to the letters in the LORM alphabet, in addition a tactile guidance system is embroidered onto the glove to help the wearer trace the lines of the LORM alphabet. As some LORM letters require two taps on the same letter space, the designer added an extra sensor at the wrist area which functions as an ENTER key, signaling when a letter pattern is finalized. This is to ensure that LORM speakers with different writing speed can use the same glove and hardware configuration.

The top of the glove hand is equipped with 32 vibration motors for haptic feedback which produce buzz vibrations similar to those found in mobile phones. The feedback application is designed to confirm that outgoing messages are sent, as well as rendering incoming messages into LORM patterns. The wearer may adjust the sensitivity of the pressure sensors and feedback to fit their need, but neither the pressure sensor will record nor the vibrotactile motor will render variations in force of a push or (simulated) stroke. By using a technique of linear cross fading, by gradually decreasing the force of one vibration motor, and gradually increasing the force of next motor, an illusion of “funneling” is generated (Gollner et al. 2012, 130), giving the wearer the sense of motion (and not a point-by-point tapping sensation). Both tactile input and feedback is administered by a control unit attached to the forearm. The case holding this unit also contains the power cell and coupled with a power cell and switch to toggle the device on/off and between input and output states.

The haptic feedback solution of the glove makes it suitable for notification, not so much to emulate real life touch. More importantly, the device only delivers passive buzz stimulation in the form of vibration and has no support for active (as in exploratory and manipulative) sensing. In terms of semiotic qualities, this device is specifically developed for LORM users, who already know this haptic language. For LORM users the learning curve is therefore not too steep. For other users the haptic sensation will most likely be experienced as random. Considering alternative sign mappings, the glove is equipped with pressure points, as well as a tactile guidance system to facilitate stroke movements, that correspond with the letters in the LORM alphabet, in a fixed setup. As neither haptic input (via pressure signals) nor haptic feedback (via vibration) supports variation in intensity of stimulation, the device offers little flexibility in terms of presenting a sign, beyond a fixed palm position. The glove offers written records of the haptic gestures it mediates, as messages sent and received are rendered via a text message engine. The control unit both translates sensor data provided by the LORM glove wearer to text, as well as receiving text messages and translating them into LORM glove sensor data. One could, given alternate mappings of hand position, easily imagine this device being able to record any tactile conversation (beyond the LORM language), and replay them over distance at a later point. The mobile LORM glove project truly demonstrates the potential of rich tactile and gestural communication. And while it is a case where the semiotic qualities of a haptic device are demonstrated in a rather strict linguistic fashion, as a touch gestures is bound to a particular sign or gesture, it also has the potential to support a wider range of applications, if coupled with a richer material solution, and a more flexible semiotic mapping of touch gestures.

From semiotic to subliminal and affective messages

Considering research in the field of human-computer interaction in terms of haptic input and output streams, we note that haptic technologies are more developed in terms of haptic input, and that the coupling of tactile and proprioceptive sensations in haptic feedback is challenging, both for passive and active sensing. There exists valuable research on how to construct and present haptic messages that users understand and find easy to learn, as well as limitations to such design, and that we are far from uncovering a haptic language for interaction that is general and versatile. There is a huge jump from designing haptic feedback that is static, simple and pre-programmed, to supporting more complex and saturated messaging systems. Is it even possible to define and settle on fixed parameters for building complex haptic messages?

To classify the potential various haptic media, I have presented the concept or the haptic figura, as an analytical tool scrutinizing material and semiotic qualities and shortcomings of the interactions offered. It seems that media that offer realistic sensory emulation do not require the interactor to be conscious of the stimulation for the interaction to be successful, whereas semiotic transactions, on the other hand, seem to depend on an element of conscious processing for the message to be received and interpreted. At the same time, we are privy to a range of non-conscious messages that are delivered via the haptics sense, affective sensations. We easily and unconsciously differentiate between caresses and slaps and will automatically suggest that there are contrasting intentions behind the two haptic messages. Both kinds of messages may be represented through haptics, but they don’t seem to belong to a dimension that is purely material nor semiotic, but highly influenced by both. I call this dimension affect. And in the following I will discuss how the affective dimension fits into the concept of the haptic figura.

4.7 Haptic Figura and Affect

Affect as a haptic coupling mechanism

The mediation of affect seems to be an implicit possibility inherent in material solution. The haptic material may facilitate and/or influence affective sensations depending on the setup. That said, very little may be needed for the interactor to recognize emotional messages mediated through the machine or device. A single tap may be enough.

However, the word *message* is essential here, as it suggests a communication of information, although not necessarily meaning. For this reason, affective messages most certainly have a semiotic quality/dimension, independent on whether the meaning of the message is conveyed. To further look at how affect is connected to the haptic figura, I turn to Massumi and Flusser who both offer insight into the bodily aspects of affect, particularly touch (the dynamic event of touching and being touched) and the role of gestures (as an active representation of states-of-mind).

Affect is a twofold concept. We have the ability to affect and be affected. This distinction was first introduced in Spinoza's *Ethics* published in 1677, where he differentiated between AFFECTIO (affection/to affect) and AFFECTUS (affect/be affected). English translations made the distinction less obvious, by translating both terms to affection. This significant point is scrutinized in Deleuze's published lecture on Spinoza (Deleuze 1978), where he concludes that "[a]ffectio is a mixture of two bodies, one body which is said to act on another, and the other receives the trace of the first." (1978). As such, to affect is to blend with another body. In a more recent interview with Brian Massumi on his reading of Deleuze and the twofoldness of affect, Massumi presents two important and relevant insights. Namely that our ability for affect is dynamic. In fact, we are oscillating between being actively influencing (affecting) and passively receptive (being affected)—it is a relational tension between the two states. Secondly, he suggests that the transition between the two states can be felt (perceived), but it is not a subjective emotion (Massumi 2009). Here Massumi points to the visceral and bodily sensation of touch (tactile and/or haptic sensations) as key in affective relationships, and that affect is a quality of general embodiment, not subjective, individual emotions. The relational tension between affecting and affected is an event or process. The event is felt (and has to do with embodiment as such, as bodies blend into and rub off on each other). What is felt is the affecting body connected with the body that is affected. Affect is therefore a coupling mechanism. This suggests that in a successful meeting between human and machine, primarily mediated through the interface, the machine capability for affect is of significance. The machine needs some ability to feel and be felt - to touch and be touched - to successfully partake in an affective relationship with the user. It also proposes that if one of the parties do not have the ability to touch or be touched, the affective connection is disrupted.

So, we need to touch (to feel) to be affected, but as we have discussed previously, touch is involved in all stages of haptic sensation (from inward haptic sensations to gestures and movements, as we consider the role of proprioception in folding tactile sensations inwards and outwards our bodies. Similarly, haptic sensations can be mediated by other means than direct touch. Besides more rare synesthetic experiences coupling touch and other senses, people generally report that looking at e.g. brocade patterns or the tracking decorative ribbons and ornaments on various tapestries, wallpaper and curtains, produce haptic sensations. As such, seeing can be a haptic experience. I want to continue these thoughts as we turn to Flusser and his work on gestures.

Gestures as vehicles for intent and affective content

In *Gestures* Vilém Flusser presents gestures as an expression of affect and meaning-bearing actions that can be recognized (through interpretation) by others. Affect is a subset of bodily movements represented through gestures and is a particular expression (in fact a symbolic representation) and articulation of state-of-mind. Flusser proposes that this recognition of gestural intent is sub-conscious and rather automatic, although it is possible to analyze it retrospectively. Flusser distinguishes between reactions, which are passive expressions of state-of-mind, from gestures, which are actions; active and symbolic representations of state-of-mind. It follows that gestures, as active and symbolic representations, can be interpreted. Furthermore, Flusser suggests that "[a]ffect releases states of mind from their original contexts and allows them to become formal (aesthetic)—to take the form of gestures." (Flusser 2014, 6). Affect is then what guides the gestural performance, and also it is what can be recognized by others. Affect-driven gestures are separated from other bodily movements that are automatic reactions, and directly linked to a causal relationship. The Interpretation (the uncovering of meaning) of gestural actions are affective, as opposed to explanations of reactions.

Affect is closely connected to both the material and semiotic qualities of haptic interaction. According to Massumi, affect is the event of touching and being touched, a haptic event. On Flusser's note, affect is a symbolic expression of state of mind represented through gestures. As such, haptic interactions will always provide an opportunity for affective transmission, as long as the machine is able to recognize and mediate affective content.

Affective content and the interpretation of touch

When are haptic sensations experienced as affective?

A tap on the body by another person, can mean so many different things depending on location of the touch on the body, when it is given, and how. The identification of different contexts governing touch communication, is also becoming important in human-robot interaction research, as we aim to teach robots to correctly label different kinds of touch. Human-robot interaction researcher Silvera-Tawil and team have identified four factors as significant when interpreting socio-tactile communication: namely touch modality, the location of touch, cultural background and communication context. Touch modalities are the "basic form of touch in which a tactile gesture is differentiated only by the spatiotemporal characteristics of the touch itself. Consequently, touch modalities are characterized by attributes such as intensity, movement and duration" (2015, 234). They are simple tactile patterns helping us separate a pat from a scratch or a push, but carry no particular message on their own. To further identify the tactile message, the three other factors are taken into consideration. It is not enough to recognize something as a hit or stroke on a given part of the body, we also need to take cultural and communicative preferences of the sender and receiver into consideration. These are criteria we subconsciously consider when we touch and are being touched, to be able to differentiate between an unintended, random physical encounter from a lover's touch.

In terms of creating haptic interactions that support the mediation of affective content, it follows that we need a rich material and semiotic solution that can support this kind of mapping and representation of the haptic event. But obviously there are additional concerns involved the moment a machine enters the equation of mediation and interpretation. There are challenges connected to the machine mapping and representation of affective, haptic content, that we would take for granted in human-to-human touch, namely that of resolution and fidelity, sensitivity, and balance of touch. As such, the technological solution we arrive at may support or disrupt the affective connection between two bodies.

Resolution and fidelity of material solution

Just as we have listened to music in the form of digital audio files with low resolution, tried to decipher facial features in low-res photos or videos, we also have poorly nuanced and simple haptics. We know that this impairs the quality of the experience, to the extent that the affective exchange is disrupted. But equally important to high definition is the ability to support haptic experiences that are seamless and continuous. Digital noise and temporal hick-ups are effectively blocking affective exchange. However, while high resolution and fidelity are important factors, we know that the successful mediation of affective content is dependent on more than the free, flowing distributed application of nuanced and flexible touch sensations.

Pattern recognition and sensitivity

The affective relationship between the two bodies may become desensitized or even hypersensitized, as specific areas are stimulated similarly and repeatedly over time, or if only a few types of skin receptors are stimulated. Humans also have a gift for pattern recognition which works on a subconscious level, allowing us to identify repeating behaviors and common denominators. This has implications for haptic media that seek to mediate affective haptic sensations. In 2002 CuteCircuit designed the HugShirt,[78] and although presented as the first wearable haptic telecommunication device, what it really afforded was the machine mediation of a hug, by recording the strength, location and duration of the (self-)embrace on a shirt, and transferring those values to another shirt. There is little flexibility in terms of delivering affective content, beyond the extent of self-embrace or actively targeting pressure sensors in the shirt. The device even comes with a HugShirt software which allows you to send pre-programmed “hugs” to another shirt. Similarly, the haptic feedback is delimited to specific areas of the body, in which may easily become repetitive and singular, and therefore losing its affective quality over time.

Balance of the touch

There are many examples of machine mediation imposing imbalances between receiving and delivering tactile messages, and this is of consequence when it comes to the successful transmission of affective content. As we discussed above, affect is the ability of a body to rub off on another, suggesting that any machine mediation of touch, will need to be two-sided. The machine needs to be able to recognize haptic input (the location, and its significance, as well as touch modalities), it needs to recognize the communicative and cultural context of the haptic event. But it also needs to be able to disseminate these tactile messages. If these criteria are in place, haptic interactions may be both distal and atemporal, without losing its communicative and affective value. This challenges another idea, namely that

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[78] Cutecircuit gives no mention of what kind of sensors they use to record the parameters of the touch, nor the nature of the actuators delivering tactile sensations to the receiver. https://cutecircuit.com/the-hug-shirt/

affective transmissions and connections are governed by proximity as a means to ensure intimacy, a claim that will be investigated more closely below.

To touch and be touched: Proximity, intimacy, and affect

Proximity Cinema is a performance work by Tiffany Trenda, that explores the relationship between proximity and intimacy (and potentially affective event of touching), in relation to digital technologies. I will consider the tactile and gestural communication, and present and discuss the imbalance and uneven mediation of touch and gestures making up the interaction. Trenda's artistic work explores screen technologies, the mobile phone in particular, and how our relationships are affected by them. The performance presents the artist enclosed in a red, synthetic suit covered with forty small LCD screens that are coupled with proximity sensors, moving and standing among an audience. Depending on the proximity of the artist to the interactors the screen will display different content. If the artist is further away the screen will relay common sentences and words: "It's OK", "Don't worry about it", and "Go ahead". If the interactor touches one of the screens, it will unveil a picture of the artist's body covered by that area of the suit and screen. The artist on her end will aim to touch and caress the audience if allowed. The work demonstrates the kind of mediated intimacy many of us are becoming used to, as relationships with friends, family and lovers, are maintained and nurtured via screen and audio technologies.

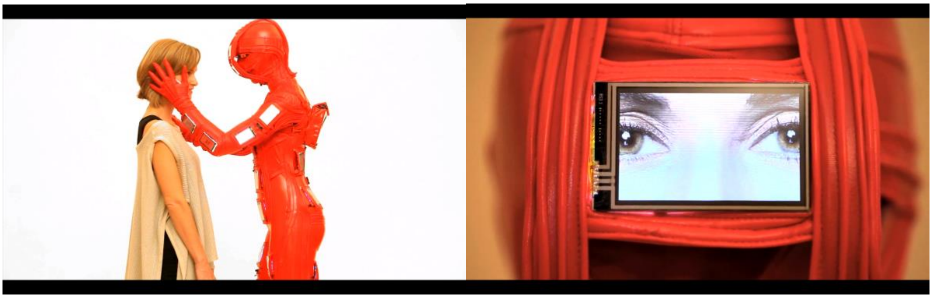

Figure 43 and 44. Screenshot from video documentation of *Proximity Cinema* (2013-15) by Tiffany Trenda. Courtesy of the artist.

It is important to note that the suit offers no tactile or haptic feedback. The haptic input from interactors is offered via a touch screen, which the artist cannot sense haptically, and tactile input from the artist is directly administered by her. There is no machine mediation of the tactile sensations beyond binary taps on the screens offering automated and scripted responses. This work actively demonstrates the many layers of a machine mediated relationship, and the limits of mediating affect via screen only. Secondly, machines that aim to facilitate the communication of affective messages, or interpret affective signs and relay affective responses, most certainly should consider the tactile and haptic qualities of the system.

There is an imbalance in the affective relationship between the artist and the interactor. When the interactor touches the suit, the artist is offered very little tactile feedback, diminishing any affective messages offered. The artist is also blinded by the suit, leaving out any visual feedback of the touch. When the interactor touches the screen, the flow of messages is replaced by a still image of the artist's body—disconnecting a very intimate connection between the person who touched and the person that is touched. The interactor is touch and image that is displaced from the moment of touch. It was created at another time and does not show the artist’s body of the present.

On the other hand, the artist will act out affective gestures as she “hugs, caresses, and touches” the interactor (Trenda n.d.) For some, this proximity is very intimate, bordering on private. However, she offers no such vulnerability back. The artist is like a castle, enclosed and impregnable, yet displaying the most intimate of her—her naked skin—but only as a still image. She disrupts the touch from the event, the now, letting the interactors touch the past, and only mediated via a screen. We are often engaging with machines and devices that are creating such imbalances, much due to the design of the machines. Trenda amplifies this imbalance in her performance design. She makes a rather obvious distinction between the two bodies involved in the interaction, in terms of what can be shared between them, forcing a power imbalance: an imbalance of the affective relationship that disrupts the contact between the parties. While affective touch mediated by a machine is possible, there needs to be a balance between touching and being touched, and systems that support rich and flexible transmission and recognition of haptic sensations.

Machine recognition of affective touch

The trajectory from mechanical and preprogrammed haptic feedback (e.g. massage chairs) to sophisticated machines that present open-ended interactive scenarios informed and adjusted according to tracking and mapping data from user and environmental inputs, is impressive. It also follows that one cannot interpret or even judge the potential of the latter, based on the performance of the former. The machine is no longer just a machine. There are several robots developed with the ability to recognize affective or emotional input.[79] However, all of them are highly specific and narrow in the types of touch gestures they recognize and respond to. A more flexible design, developed by a research team led by human-robot interaction designer Dr. Silvera-Tawil, consists of an artificial skin which detects human affective messages with great accuracy. In their experiment, six emotions and six social messages transmitted from humans, were classified and applied on a mannequin arm with touch-sensitive artificial skin. The result was comparable to human recognition of the same messages (Silvera-Tawil et al 2014). This suggests that we are moving towards the introduction of machine surfaces that not only recognize and translate human gestures, but also interprets, and engage with, richer affective content.

Affective coupling

Affect is most surely a mechanism for coupling, and if successfully supported (by bodies that can both convey and interpret affective content), it can ensure event

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[79] Notable projects include: Robot seal PARO, which has been used in elderly homes and among patients with dementia, can differentiate between strokes and hits, and responds accordingly. It was developed by Intelligent System Research Institute, Japan AIST (Paro Therapeutic Robot 2016), Huggable developed by Personal Robots Group at MIT recognizes nine different touch gestures (Huggable 2016), Probo developed at Vrije Universiteit in Brussel recognizes whether it is hugged, scratched, or hurt (Probo 2016), AIBO developed by Sony recognizes where it is touched/touch location (Sony Aibo 2016), and The Haptic Creature, a calming robot that breathes (Sefidgar et al. 2015; Altun & MacLean 2014).

encounters between man and machine. However, affective coupling is not a criterion for all kinds of haptic interaction or haptic interfaces. We have no need to couple with our health monitors or become one with our mobile phones. A key role of haptic media per now is merely to assist visual machine interactivity, offering notifications and alerts.

4.8 Haptic Figura and Interface

The material sign for communication and affective relationships

The haptic figura is proposed as an analytical tool for investigating material, semiotic and affective qualities of haptic interaction. Haptic materiality is dictating the degree of authenticity of haptic interactions, both in terms of emulating sensory experience and affording rich active haptic perception. The material solution supports the successful transmission of haptic signals, as signs and messages, and potentially, affective content. Haptic semiotics is analyzing the tactile-gestural communication, where the semiotic solution enforces the requirements for moving beyond informational exchange, to a domain of meaning generation and interpretation of haptic messages. Haptic interaction also affords affective communication, in line with and beyond the transmissive and interpretative. If we are to achieve this kind of communication, we need to present haptic interactive experiences that allow for the exchange and recognition of affect, for emotional contagion, interpretation, and interaction.

The haptic interface

We see emerging technologies open the door for richer haptic interactive experiences, although many of them are still in early developmental stages. This chapter has focused on haptic feedback when discussing material and semiotic qualities of interactions, which might suggest that we have sorted it all when it comes to reading and interpreting haptic input needs. However, in terms of gestural communication (beyond touch-gestures), the machine reading of gestural haptic input is not clear cut, and one is distinguishing between gesture recognition software that tracks hand gestures, or hand postures exclusively, as the machine recognition of hand gestures takes time. The rich tradition of haptic languages and sign systems have entered the world of interface design. With the design of haptic icons and tactons, which allow for the communication of more complex haptic messages, we still see that visual iconographic thinking still influences the scope of haptic input and feedback systems. It appears to be a pointless struggle to aim for the identification and classification of a complete haptic language for human-machine interaction that is shared and universal to all, as the cultural and communicative context of the haptic signal is so diverse. However, by enabling technologies that record and analyze how we may explore and grasp our world with the haptic sense, we are at least identifying haptic figures (key material and semiotic features) that make sense to us today, and which may be implemented in personal computers based on individual, social or even cultural preferences.

In the next chapter we extend our investigation and use of the haptic figura. We move from analyzing haptic interaction by measuring authentic sensations and message-carrying communication, to include the notion of productivity affording the general user and general tasks, as a criterion for more fully fleshed interfaces. We ask what kind of activities and tasks one can fulfill via well-designed haptic interactions, and what are the potential and limits of a haptic only interface?

5 INTERFACE

Haptic Media Scenes

Interfaces are always layered in that they are multimodal platforms addressing the auditory, haptic, and sometimes even olfactory senses, in addition to the visual. The extent to which each modality is addressed in the interface, on the other hand, varies. The sensory targeting in ocularcentric interfaces, such as the graphical user interface (GUI), and the most common implementations of the touch user interface, both of which favor the visual sense, is very different from the setup of various responsive environments, wearables, and gestural controllers, tracking human posture and movement. So we need an overview, and in the following I will critically assess the notion of interface in an attempt to identify key elements, such as relevant design strategies, and even suitable metaphors, for media that affords and situate the haptic senses. In the previous chapter we discussed how the concept of the haptic figura can be used to analyze tactile and proprioceptive communication between human and machine. It proposes that this communication should be considered from both a semiotic and material perspective, in addition to scrutinizing its potential for affective mediation. We used the tool to uncover basic interactive devices and methods that are important and relevant for haptic interactivity. However, to consider fully fleshed interfaces, we need to also scrutinize the media for its ability to accommodate desired tasks and actions.

This chapter is divided into six parts: Situating the Interface, The Body-Mind-World Interface, The Hand: Creation and Exploration, The Body: (Re)presence and Experience, The Sign: Recognition of Gesture and Bodily Intent, and The Haptic Interface. Part I aims to situate the interface by offering known directions, design strategies, and types of mediation, that are of particular relevance in interfaces for haptic communication and productivity. Part II frames haptic productivity in three different setups of haptic media: in haptic only systems, or in multimodal or cross modal interfaces. Finally, it introduces three interface scenarios, the Hand, The Body, The Sign, as fruitful directions. Part III presents haptic media interfaces for the hand as specifically apt to support creative production in 3D, performance, and spatial exploration. Part IV presents haptic media interfaces for the full body as key in mediating presence virtually or over distance. Part V discusses the promise of haptic recognition systems in identifying gestural commonalities and possible even bodily intent. Finally, part IV summarizes findings, presenting the reader with an overview of what haptic interfaces for productivity entail.

5.1 Situating the Interface

Before discussing interactive scenarios for the haptic senses, I need to clarify what I mean by interface. There are several important proposals to address in that context, and at the same time it is important to emphasize that it is far beyond the scope of this thesis to give the reader the complete history and taxonomy of interfaces.

The interface is a platform for dialogue between humans and their devices. In engineering terms, the user interface serves as the common ground connecting the user and a set of functionalities and content stored in a device. The interface should therefore address and adapt to a specific user in question to aid her in creating a meaningful relationship between actions taken and desired results, bridging the embodied user and computational processes. With the arrival of new haptic and sensor technologies, engineers, interface designers, neuroscientists, psychologists and philosophers alike ponder the opportunities inherent in platforms that explore the mediation between our different senses in human-machine interaction.

In the following I will address key design strategies and metaphors making up the user interaction commonly utilized in different productivity environments, with the aim to identify UI elements suitable for interfaces affording rich haptic communication and productivity.

Historical backdrop: augmenting cognition and extending reality

Augmenting cognitive function

One significant direction for interface design is to present systems that aim to augment our cognitive function and affords general productivity. Humans have long envisioned how we may, could or should relate to and interact with machines. As early as in 1945, Vannevar Bush introduced his concept of the Memex, a machine that would function as an external memory library (Bush 1945). The idea of extension and augmentation was continued in the '60s. First Licklider presented his vision of man-machine symbiosis, conceptualizing a machine that is assisting and deeply involved in almost all cognitive tasks, influencing human thinking, and being influenced in return (1960). Two years later, Douglas Engelbart presented his conceptual framework for an interface augmenting the human intellect (1962). And six years later he released his first interface, based on the framework, namely the oNLine System (NLS) and his mouse prototype (Engelbart and English 1968). This system marked the starting point for the development of the graphical user interface. In 1972, Alan Kay, developed the concept of the graphical user interface in his presentation of the Dynabook (Kay 2011), a demo including all the known elements of the GUI, namely the interactive features such as graphical icons, windows, menus, and pointer.

Although never built, the Dynabook inspired Kay's continued work towards the first introduction and commercialization of the personal computer in the early '80s. The graphical user interface as it is implemented in desktops and laptops later found a new home in mobile touch screen devices, ranging from mobile phones to tablets.

Extending reality

Another direction in interface design has been to create and facilitate immersive experiences for the mind and body, with the aim to extend reality. The main design criteria for has been that the virtual environments should be interactive and rendered in three-dimensions to mimic real life. In the mid-80s Jaron Lanier developed the visual programming language (VPL) for rendering visual three-dimensional environments. Together with Thomas Zimmermann, the inventor of the data glove, they founded VPL Research, the first company to sell virtual reality interfaces, debuting in 1987 with the VPL Dataglove, wired gloves for traversing the virtual space. The next two years their virtual reality system expanded, and by 1989, their interface consisted of a head mounted display,[80] the EyePhone, which introduced the interactor to a virtual environment and a full-body wearable, the Datasuit, which tracked and mapped the interactors position and movement in virtual space (Lowood 2019). The same year Jaron Lanier coined the term *virtual reality* to frame systems and projects relating to virtuality (Krueger 1991, xiii). Throughout the '90s we saw several takes on VR-solutions, a noteworthy design being the CAVEs (Cave Automatic Virtual Environments), first presented by the Electronic Visualization Lab in 1992 (Cruz-Neira et al. 1993). Here, the interactor is surrounded by screen projections on all sides which is cued to position and movement of the interactor, which is continuously tracked. The virtual space is navigated by sticks or data gloves, and the visual space is rendered in 3D by using stereoscopic goggles, presenting us with an early augmented reality experience.

For the promise of the early VR/AR solutions of immersing the user in new realities, there were significant challenges both in the interactive solution as well as the design of applications for the solutions. The navigational setup (consisting of head mounted displays and gloves) were wired and cumbersome to wear, offering little bodily mobility. Equally the very slow frame rate, producing lag as users tried to orient themselves within the virtual space. With CAVEs, the surround screens made the system completely site specific. Equally, programming the systems for new narratives and scenarios, was complex and time consuming. These factors made early VR-experiences something left to be desired, leaving out the notion of seamlessness and general use. However, they do represent a significant desire in human-computer interactivity. We want to be immersed in and partake in virtual scenarios and narratives.

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[80] The first HMD was invented by Ivan Sutherland in 1968.

While early VR and CAVEs argued for novel embodied experiences, I have criticized the role of bodily interaction in these solutions (see chapter 1), questioning the ability of predominantly visual representations of reality in offering immersive, embodied experiences. This critique is shared by several, including artist and engineer Myron Krueger, who pre-Lanier proposed the notion of Artificial Reality, when designing immersive responsive environments, In Artificial Reality the human body is in the center of the interface, specifically demonstrated through his VIDEOSPACE responsive environment (previously discussed in chapter 1). The real-time tracking and mapping of the position and movements of the body, in a three-dimensional space are the key ingredients for creating such an environment (Krueger 1993, Turner 2002). The emphasis on real-time rendering of human gestures, position, and movement, even at the cost of realistic and high definition visual representations of virtual environment, is reiterating in current virtual and augmented reality design (Greengard 2019, 101-102)

These two storylines, the machine that augments the intellect and the machine that extends reality, provide two directions for how we aim to be enriched by the machine. They have also inspired and resulted in two rather different design ideals and strategies for the user interface.

Design strategies: from general productivity to natural interaction

Most of the machines we surround ourselves with are specifically designed and shaped for certain tasks and actions. Your dishwasher, sewing machine, or loudspeakers are fitted with a user interface and form factors optimized for their intended function. However, the two directions presented above both aim for a more generalized use: the personal computer has always been intended to cover and facilitate a range of tasks and actions, and equally, VR/AR systems may be designed to present a range of narratives and scenarios.

We also distinguish between the operating system (OS) and user interface (UI). These two entities are often strictly separated. The operating system is the fundamental architecture and motor of the machine, into which the full set of instructions for running both software and hardware, as well as memory, is built. Humans rarely interact directly with these fundamental machine processes. Instead a representative layer, called the user interface, is presented to the interactor allowing her to communicate with the machine. In user interaction design there are specifically two different strategies worth mentioning: the presentation of functionality versus the mapping and tracking of natural actions in space.

Functionality display

An often-implemented strategy is letting the user interface present the functionality of the operating system to the interactor. This is most often done using icons (most often visual iconography) and menus. The user needs to explore the system to figure out how it works, unveil functions and methods to solve desired actions and tasks. This is the setup of the graphical user interface (GUI) of desktops, laptops, as well as tablets and phones. Traditional operating systems such as Linux, Windows or IOS have indirect and artificial methods for interacting with the machine, i.e. mouse or pointer. Whereas with mobile devices, running OS supporting touch screens, we interact with the graphical user interface directly, using our fingers and hands.

To guide the interactor in uncovering the potential of the machine, many of these interfaces are utilizing metaphors to cognitively ease the transition from the complexity and strangeness of the machine system towards the identification of desired functionality. The representation of metaphors is achieved through a consistent iconography. A well-known metaphor for the graphical user interface is the desktop-metaphor, where icons and windows, as well as the environment itself (the screen surface), represents functions previously known from office environments, such as the office desk, bulk of papers, printing, documents, thrash etc., which became common place with the introduction of the personal computer in 1984. There seems to be a change in metaphorical use on app-based devices, from the Desktop screen (relating to the office), to the Home screen (relating to the personal sphere). These devices are closer to the body, more private, and in a way become a part of you. What these interfaces have been very successful in, is representing a very general and broad range of functionality. The operating system supports such a variety of programs and applications, that these interfaces have been the go-to-media for general productivity the last three decades.

Physical actions and natural interactions

Another strategy for bridging the user with machine functionality is designing user interfaces that mimic natural interactivity with spaces and physical objects. This strategy is most certainly present in the design criteria of mapping and tracking human gesture, position, and movement in virtual reality environments. The approach to create interfaces modelled on natural human actions or natural, intuitive processes are called natural user interfaces (NUIs). Interaction should be intuitive and accommodate interaction methods we know from operating in the real world (gestures, movements and touch). The interface is designed to be non-obtrusive and invisible, with the aim to facilitate learning as you go. As proposed by Wigdor and Wixon (2011). We need to distinguish between the interface device (e.g. the Kinect), technologies that may achieve natural user interaction (e.g. motion and force sensors or gesture control software), and reality-based user interaction. As mentioned above, it is fully possible to design for natural user interaction on a graphical user interface, e.g. multitouch support on touch screen surfaces running a graphical user interface. It is also possible to achieve realistic user interactivity using small, wearable devices that render physical objects a layer of virtuality, e.g. using reverse electrovibration as demonstrated with REVEL (Bau and Poupyrev 2012). A particular subgroup of NUIs are tangible user interfaces (TUIs) which aim to let the real, physical world merge with the simulation, as input equals output, placing computing in a physical environment. Physical representations (physical icons or other tangibles) are coupled with digital information and mediate digital representations. The interface aims to emulate the tactile way humans engage in the world and grasp reality. The interactor only needs to know the function of the physical objects to engage with the interface, and never the workings of the operating system. This strategy has been popular in designing novel musical instruments, such as, Reactable,[81] but many prototypes have also been demonstrated in the multidisciplinary research field of human computer interaction and communication, such as Siftables[82] or the now discontinued Microsoft Pixelsense.[83] The challenge with tangible user interfaces are that they are suitable for a limited range of activities and tasks, due to the specific design of the physical elements of interaction. While there is a lot of experimenting happening under the umbrella of physical computing and The Internet of Things, we are still to find general-purpose interactive objects that can be programmed to map a range of functions. Still, one of the main arguments for tangible and more generally natural user interfaces is that you need no interface metaphor or visual iconography to let you identify what kind of machine you are interacting with, what different actions and tasks the system allows, and how you can perform them. Ideally, your body will lead the way, or at least ease the learning curve.

Navigation and manipulation: representation of function versus mapping of body and space

These two design strategies afford different means for navigating and manipulating interactive objects within the user interface. While the first one is concerned with displaying machine functionality in the form of visual representation of menus and icons on two-dimensional surfaces, the second strategy is concerned with presenting the user with possible tasks that can be achieved through physical actions by mapping human gestures, object behavior, and, in extension, three dimensional space.

So, on one end you have machines that are versatile and allow for multi-use, such as personal computers and smaller mobile devices. Both of these machines have a general build and operating systems that allow a range of different applications to

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[81] https://reactable.com/

[82] https://www.media.mit.edu/videos/labcast-20-siftables/

[83] https://docs.microsoft.com/nb-no/archive/blogs/pixelsense/

run on them. The user interface is designed to present the functionality of the machine, using metaphorical representations to guide users to their functions. And on the other end you have user interfaces that aim for tangibility and mimicking natural interaction with objects and the environment. These interfaces are often specialized to afford specific functions or tasks, as seen in various musical instruments, gaming environments for storylines, or special purpose collaboration surfaces (mostly prototypes).

Nature of mediation: hypermediacy or immediacy?

We return to the distinction between immediate and hypermediate interfaces, briefly discussed in chapter 1. The immediate interface is transparent or even invisible and bears a resemblance to the ideal fronted in natural user interfaces and virtual reality applications, of system invisibility and intuitive interaction. The hypermediate interface, on the other end, is a many-faceted, presenting several interfaces within the interface. These user interfaces are functionality displays, where navigational structure and menus are presented to the interactor as means to identify ways to perform desired tasks (Bolter and Grusin 2000, 20-52). The hypermediate interface promotes learning through the conscious search of machine functionality as a way to understand the system, while the immediate system fronts learning through intuitive, sub-conscious interaction, as we use the already acquired knowledge of navigating real space and manipulating objects. For this reason it seems acceptable to suggest that more hypermediate interfaces, such as the general purpose productivity milieu instigated with the design of the PC, affords computer literacy (we are, in a way, forced to deal with the framework of the system to use it), while more immediate interfaces, governed by intuitive interaction and presentation of tasks rather than system functionality, supports and front a more “fluent” interactivity with the machines. The desire to create fluent interactions are many developer’s dreams, as it promotes interactors that very quickly understand what they can do within the virtual environment, without knowing the system's potential and limits.[84]

Immersion, as in ability of a system to induce feelings of being present,[85] is not a direct consequence of immediate interface design, although there is certainly an underlying claim that the direct presentation of interactive experiences will advance this feeling. That said, there are a range of hypermediate interfaces that are highly immersive, despite the functionality display. Many multiplayer online role-playing games (MMORGs) display menus, chat channels, group overview, skill and inventory bar, and similar, on top of the virtual environment—without losing player immersion. Interestingly enough, most of these games offer simple toggle shortcuts for changing between first and third-person views, as well as hide/show all menu bars, affording a more immediate gaming environment. This suggests that immersion may more easily be achieved with immediate interface strategies.

Bodies as media

When we, in consideration of hypermediacy and immediacy, examine interfaces that directly map and track body actions, as well as render haptic feedback, the question of what kind of interface the body is, becomes relevant. In continuance of Bolter and Grusin, Eugene Thacker proposes the body as "both a medium (a means of communication) and [...] mediated (the object of communication)" (2004, 9), but specifies that it is the intrinsic material and technical qualities of the body that should be considered. The body is a particular kind of media caught in the fluxus between the immediate and the hypermediate: "As an instance of immediacy, the

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[84] The question of computer fluency versus literacy is also connected to the notion of tool ownership and control. Not knowing how a system works (machine potential and limitations, as well as repairability), put you at the mercy of the developer's hand.

[85] There are several definitions of immersion, but for the discussion ahead I will present immersion as an objective quantifiable quality, relating to the material solution, which leads to feelings of presence, a sense of being. Presence is an outcome of immersion. This definition is based on the experimental insights of Mel Slater and Sylvia Wilbur, working with virtual reality systems. They argue that the degree of immersion is dependent on "the extent to which the computer displays are capable of delivering an [...] illusion of reality to the senses of a human participant." (Slater & Wilbur 1997,604). And as such immersion becomes an objective criterion relating to quality of virtual reality or telepresence equipment.

body is situated by the phenomenological concept of 'embodiment' or lived experience. However, as an instance of hypermediacy, the body is simultaneously framed by the sets of knowledge on the body, including medicine and science. The incommensurability between these—between embodiment and technoscience—is perhaps the zone of body-as-media'' (10). Within this preliminary definition lies Thacker's proposal of *biomedia*, which emphasizes materiality of the biological body in intersection with technology (both bio and computer technology). Thacker is primarily concerned with biomedia as an approach to understand novel and deep technical configurations of the body, as a strategy and praxis for biotechnology. He seeks to differentiate it from strategies proposing technology as an external tool that merges with the body (the Heideggerian position),[86] as an extension that adds new functionality, or as a machinic component that replaces or automates the body (14). For this reason, Thacker's take on the body as an interface will be more relevant for invasive haptic interfaces, which are not covered in this dissertation. But even though we do not bring with us the full concept of biomedia, the insight that bodies fluctuate between immediacy and hypermediacy, is a quality and ability that ought to be recognized in the design structure for a haptic interface. We can intuitively emerge ourselves in interaction, but also shape ourselves to fit a particular setup.

The haptic interface for productivity would benefit from being a hybrid system, including strategies from both design trends. We would ideally utilize our body's immediate understanding of how the world works, utilize our haptic understanding of objects, motion, and space, but also communicate with a system that affords an element of generality and versatility, on which a range of applications can run.
But is there such a thing as an immediate general-purpose environment?

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[86] Reiterating Heidegger, immediacy may be seen as a technological solution presented to us "ready-to-hand", while hypermediate environments are tools presented for us "present-at-hand."

5.2 The Body-Mind-World Interface: Haptic figures and presentation of action space

What are the relevant design principles affording haptic interfaces for productivity? First of all, the criteria for rich haptic communication as framed by the haptic figura (material, semiotic, and affective qualities) should be taken into consideration, when designing user interactions. I would also argue that the interface metaphor for haptic interfaces, is the *operability of the body*. Our intrinsic and extrinsic[87] understanding of how our bodies perform when engaging with objects or environments—that being the hand, feet, or the body proper—is what guides the interaction.

Specifically, the interface ought to support rich haptic perception (based upon and extending natural real-world interaction), allowing interactors to actively explore an environment utilizing the full range of haptic sensitivity, both tactility and proprioception, to immediately and intuitively recognize what actions you can perform, and tasks you can do. Within this material solution lies the foundation for nuanced message-carrying communication, and the potential of affect as a reciprocal relationship between human and machine or mediated by a machine.

Presentation of action space: framing haptic productivity

Interface design centered on the presentation of possible actions and tasks, before the structured display of system functionality, is also in line with a phenomenological approach to media design, and well embedded in embodied cognition thinking, in which the body's preconscious understanding of its action space is factored in. Insights from phenomenology and enactivism discussed in chapter 2 and 3 suggest that our bodies engage in a reciprocal relationship with the world: we exist towards tasks, where possible postures and movements are constantly regulated pre-consciously by the body schema. Body schemata are pre-

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[87] Here I am distinguishing between intrinsic qualities of the body, general abilities shared by all humans and originating from the human genome, and extrinsic qualities, which are learned abilities and body techniques defined and made specific by tradition and culture.

conscious tactile and motor-control programs for solving spatial tasks and actions and denote the action potential of our bodies, as dynamic enactments of our bodies in space. Body schemata are revisable and extendable, as our bodies are exposed to novel activities and technologies. More importantly our perception not only has *direction*, with the use of tools we also *postulate goals*. In fact, a significant portion of our cognitive processes emerge as a result of our bodies interacting with the world. In this context, digital and sensor technologies, including haptic media, are unprecedented candidates for revising body schemata and extending cognition. These technologies allow us to move beyond the Heideggerian notion of extending bodily space through tool use or via abstract movements as proposed by Merleau-Ponty. We may even extend one sense into another, forming novel sensorimotor couplings. Within the realm of haptics, all of these strategies are possible, whether we are considering haptic only media, multimodal media or cross-modal synesthetic media.

Not all actions and tasks are best tackled by the haptic senses. We rarely smell with our hands or hear with our eyes. So, when discussing tasks and activities, which ones are well suited for haptic media interfaces? We have implemented haptics in mobile devices, wearables, and simulators offering notifications, confirmation, directional cues, and speed regulation (Lylykangas et al. 2013). We have also begun the design of simple affective messaging. That said, haptic devices today are primarily concerned with material capabilities and the ability to simulate various touch sensations. The semiotics are often reduced to binary signs (on/off, yes/no, day/night, more/less etc.) featured in various notification features. However, most of these are applications based on the general-purpose environment already established, suggesting the early beginning of a hybrid system connecting immediate and hypermediate strategies.

Haptics only?

Can we imagine a standalone haptic interface for productivity? And what is a haptic-only interface? If it entails a general productivity environment solely run by haptic input and haptic feedback, I am not so sure. There is definitely a range of tasks and activities which would be significant for a productivity milieu which is not very well implemented in haptics today and may never be.

We currently lack precise and efficient means for detailed handling of data. We have general sorting, grouping, selecting gestures in place, but when it comes to adding, controlling and fine-tuning parameters of digital files and systems, haptics is not accurate and nuanced enough. Some insights come from the music industry. There has been a lot of experimentation with haptic controllers for music production and performance. Controllers available to consumers, are primarily assistants to visual music software, such as Ableton PUSH[88] or Traktor Kontrol S4,[89] and suited for live performance and playback rather than composition. These controllers also offer very little haptic feedback. For detailed studio production work, the meticulous and delicate adjusting of parameters in recording, mixing, and mastering processes, these controllers offer very little assistance. While we do see multi button mice which allow for diverse and specific mapping of functions for different applications,[90] for more advanced haptic controllers utilizing spatial features and nuanced haptic input and feedback, the time it takes to map functions or personalize the device for a specific application makes them less attractive and useful.

Secondly, reading and writing are two significant processes for a general production environment that lack a suitable implementation with haptics. Both reading and writing are closely bound to the visual or auditory sense, and it seems almost futile to consider a purely haptic rendering of these two activities. In regard to writing, we do have a range of graphic and screen tablets that support text recognition of handwriting, and in that way support haptic input of the written word. However, it has gained little popularity due to being less efficient and precise than writing using keyboard input. And there are certainly devices for the seeing and

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[88] https://www.ableton.com/en/push/

[89] https://www.native-instruments.com/en/products/traktor/dj-controllers/traktor-kontrol-s4/

[90] In the case of RAZER Synapse, personalized template mappings of common tasks and actions (as shortcuts and system macros) for a range of applications (Blizzard Games, Adobe Creative Suite etc.) can be uploaded and downloaded to any RAZER mouse, giving the user up to 11 programmable buttons: https://www.razer.com/synapse-3

hearing impaired that supports tactile writing and reading, such as Braille and LORM machine translators, but in terms of precision and efficiency offers little to the non-impaired human.

While I imagine haptics will advance in both data handling and linguistics, and might some day culminate in a haptic only implementation, our experience with interfaces and real-world environments is always multisensory. So, rather than searching for the purely haptic interface, we may consider haptic sensitivity in isolation to identify its strengths. A key advantage of the haptic senses is the perception of three dimensions, reading objects and space. Presently, we see haptics becoming a key player in the growing field of spatial computing,[91] with projects such as the Hololens.[92] Spatial software allows for machine mapping of physical spaces and objects. These spatial reference points are represented in a virtual world layer. Combined with haptics (input controllers and feedback systems), position sensors and even eye tracking, these mixed reality worlds and their inhabitants can be felt and manipulated. And it is, perhaps, in the coupling of haptic with visual or auditory interactivity in multimodal setups, that the best application of haptics can be found.

Multimodality

The mouse is perhaps the best-known haptic device, with buttons and wheels to direct tactile input. But it is also one that is heavily dependent on its coupling with screen media and the visual sense. As interaction between the mouse itself and the pointer is indirect, the user will need to see the virtual object and environment in order to navigate it, by guiding the cursor. The mouse has been surpassed as a haptic device in the implementation of haptic controllers for VR-worlds. But even in these interactive scenarios, content and narrative are fed visually via a virtual or

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[91] The term *spatial computing* was coined by Simon Greenwold in his MA thesis in 2003, defined as "human interaction with a machine in which the machine retains and manipulates referents to real objects and spaces" (11).

[92] HoloLens is a mixed reality headset particularly targeted at training scenarios, coordinating eye movements and hand gestures to render navigate different applications, such as control panel, working with 3D models, and interactive virtual guiding or training layers, aiding the interactor in a physical space. Combined with a haptic hand controller, the spatial computing paradigm is enforced, allowing the interactor to feel the objects rendered. https://www.microsoft.com/en-us/hololens/hardware

augmented reality solution and haptic sensations are primarily accompanying the experience, rarely setting it. Still, the design is based on immediate, direct interaction, and the user if offered relevant haptic feedback, in addition to haptic input when navigating the space. Such multimodal, mixed reality systems seem presently to be most promising when considering richer haptic communication, albeit not necessarily for general productivity.

Cross-modality as technological synesthesia

Finally, we have a range highly specialized devices that let you experience synesthetic sensations, such as hearing colors[93] or tasting visual images.[94] And we might easily imagine a range of future applications of haptics that utilize this premise. As discussed in chapter 3, there is a range of media artworks that demonstrate the potential of extending haptic sensitivity into the visual and auditory realm, and further into novel areas of human sensation. Beyond gestural controllers offering cross-modal feedback, the premise of detailed coupling of audiovisual-haptic content is also proving significant for creating immersive VR experiences, both to extend the capabilities of hardware and to induce novel sensations in the interactor.

Scenarios of haptic media: The Hand, the Body, and the Sign

While there are many areas in which haptics may be applicable, we find that there are some areas in which haptics are more useful, such as assistant binary guidance systems (notifications, confirmations, and cues), object manipulation, texture recognition, and as a key sensory ingredient in creating immersive experiences in virtual environments. The applicability of the haptic medium depends on whether it

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[93] Neil Harbisson, a cyborg activist being colorblind, has permanently attached an antenna to his head that allows him to perceive color (including infrared and ultraviolets) as auditory vibrations. https://www.ted.com/talks/neil_harbisson_i_listen_to_color

[94] The BrainPort Vision sensor captures visual input via a head-mounted camera, which is translated to electro tactile information, and delivered to an array placed on the surface of the tongue. https://www.wicab.com/brainport-vision-pro

utilizes haptics only, multimodal, or cross-modal, synesthetic mediations of haptic sensitivity. Likewise, one media type, such as wearables, as opposed to responsive environments, affords different activities, sensations and experiences—particularly in the realm of haptic feedback.[95] To cover some of this diversity, I will interrogate three directions, or scenarios, of haptic media under the labels: The Hand and The Body, and The Sign.

In addition to assessing haptic interactivity and communication in terms of the material foundation, semiotics and affect as framed by the haptic figura, each interface direction is considered by its potential for productivity. Here I interrogate the presentation of action space, affordable tasks and activities, and discuss the interface for its versatility and function as an immediate general-purpose environment. As implied in the word *scenario*, I am not only considering the current state of a technology, rather imagining ahead, to consider the implications of a complete implementation of the technology.

5.3 The Hand: Creation and exploration

> *I put on the gloves, they layer perfectly with my skin.*
> *Skin and gloves become one as I sit down and clear the table,*
> *grouping current work files and dismiss them from view, before*
> *I initiate my maker space. I reach out and touch the ball-like*
> *object in front of me. I feel the shape, softness, and texture of it,*
> *and gently start to mold it into a figure, adding textures as I go.*
> *I want to make the imaginary creature from my daughter's dream,*
> *the Peliphant, and have it printed before she is back home.*

This vignette expresses some of the potentiality of haptic hand interfaces. The hand is versatile, we use it for so much: to search and recognize, to grasp and hold, to

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[95] Following the scope set in chapter 4, the discussion will only include non-invasive haptics, disregarding haptic implants and transplants.

shape and make things, to show affection and aggression, to indicate and point. How we use our hands has also evolved with the development of technology. Leroi-Gourhan presents a somewhat linear evolutionary thread suggesting the hand has gone from being a tool to become a driving force. First the gesture and tool was the same, as we used the hand for *manipulative actions*, moving to *directly motive action of the hand* in which the hand tool is separated from the guiding gestures, to *indirect mobility* where hand gestures run a motor, to *hand intervention* where hand are only used to start a motor process, to what he recognizes as modern day practice, in which the "the hand is used to set off a programmed process in automatic machines that not only exteriorize tools, gestures, and mobility, but whose effect also spills over into memory and mechanical behavior" (1993, 242). With haptic media interfaces for the hand, these evolutionary steps may co-exist, allowing the hand to be the tool, the guiding force, and the initiator. In the following, I discuss two directions in hand interface design, one aimed at creative processes, and another at exploration.

Thinking and creating with hands

Haptic gloves (often generalized as data gloves) are wearable peripherals for computer interaction that utilize the position, tactile and proprioceptive gestures and forces the human hand, and may mediate both nuanced haptic input and feedback. Data gloves are not new to the market. Several conceptualizations and prototypes have been developed over the last decades, the first ones being wired, input-only devices starting with the Sayre Glove developed at the Electronic Visualization Lab in Chicago in 1976 (Sturman and Zeltzer 1994, 32). With recent advances in off-the-shelf microcontrollers and sensor technologies that we see wireless editions that could find their way into the everyday computer environment, equipped with both haptic input and feedback systems.

Haptic gloves propose to record the way we use our hands to engage with the world and facilitate relevant feedback. We touch and put pressure on objects, our dexterous hand allows for a range of positions and gestures, such as pointing, pinching, grasping, clutching, and stretching. And all of the above-mentioned actions have found their technological sensor equivalent which can be utilized in glove design. Gyroscopes and accelerometers are used for position and movement tracking, bend sensors record finger stretching and clutching gestures, and pressure sensors record the force of touch—and those are just a few of the input sensors on the market. Most gloves today have reduced haptic feedback systems, primarily provided by vibration. However, there are several initiatives aimed to extend the range of haptic feedback offered, i.e. the virtual touch sensor based on pneumatic actuation developed as part of the Hands Omni project[96] or utilization of silicon nanomembranes equipped with electrotactile stimulators designed for fingertips (Ying et al. 2012), or various hand-held haptic feedback controllers, such TORC (Gonzales Franco and Ofek 2019) and Reactive Grip[97] previously presented in chapter 4. Currently, haptic gloves are primarily presented as controllers, rendering haptic input, as cues for navigation and activation. Or as feedback devices rendering haptic data to enrich spatial and object recognition and manipulation in virtual and real environments.

A glove project of particular interest, due to its versatility and potential for diverse applications, is Mi.mu.[98] These gloves are equipped with a range of motion sensors, including flex sensors, which allow for a detailed mapping of hand gestures. The accompanying *Glover* software lets you track and map orientation (pitch, roll, and yaw), direction (forwards, backwards, left, right, up, and down), and store nine compound postures, such i.e. closed fist, pointing and open palm, as control cues for third party software (primarily as MIDI or OSC messages). The gloves run on batteries and transfer sense data over wi-fi, allowing the interactor significant mobility. In addition, the glove features vibration sensors and led-lights feedback. Project-initiator and singer-songwriter Imogen Heap is the person who currently has demonstrated the technology most significantly. In 2012 Heap, inspired by an

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[96] Hands Omni project site: http://oedk.rice.edu/Sys/PublicProfile/25532450/1063096

[97] https://tacticalhaptics.com/

[98] The Mi.mu glove project site: https://mimugloves.com/

earlier MIT glove project, gathered a team of researchers and programmers to develop a musical performance tool for her shows, but ended up with a device that duals as a remote control and a musical instrument. Heap notes that this change in perception coincided with the development of the glove. In additional interviews,[99] she describes how she intended to develop gloves for performing her songs on stage as a playback device, but she ended up with an instrument on its own. Composing for and with the glove, the glove has become inherent in the design process of a musical piece. In an interview with Create Digital Music she states: “The gloves are like a second skin. They are part of me. An extension of me. I become hyperreal.” (Kirn 2014). Heap’s account of her experiences reiterates many of the points pressed by theorists discussed in previous chapters. Note how the transition of gloves being a performing tool to becoming a compositional tool might be considered an exercise in *abstract movements*. Or that the wearer experiences the glove as part of her, like a second skin, corresponding to how *tools integrate* in our phenomenal and lived body. Both processes that revise the body schema, according to Merleau-Ponty. We also note how Kirsh’s notion of the *enactive landscapes* (2013) features in, as the range of glove interactivity sets the field of production and equally invites new ways of composing.

While different applications are currently developed for the Mi.mu gloves, it is as a gestural music controller and tool for live performance that the gloves have found their primary market value. Mi.mu and similar projects[100] anchor the desire for hand-controlled devices that utilize natural hand movements and gestures—for creative production, such as composition, modelling, and live performance. Currently, most controller software for rendering haptic input and output are prototypical, or limited to simple customization, and bridge with few areas of

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[99] Interview with Dezeen Magazine (Fairs 2014), interview on Dara O’Brian’s Science Club (O’Brian 2012), and Wired Talk (Wired UK 2012).

[100] Two projects are worth mentioning here. The Beatjazz prototype developed by artist Onyx Ashanti, which is a handheld and mouth operated device for live performance, supporting musical improvisation, gestural sound design and looping (Ashanti n.d.). Secondly, the newly funded Kickstarter project, GripBeats, which is a armband reading haptic gestures from a 9-axis motor sensor and over thirty pressure points to trigger sounds, samples, and melodies, as well as filters and effect from a custom software, or simply as a MIDI-controller for existing musical software (“GripBeats” n.d.).

application. In regard to the *Glover* software, the trackable gestures and postures could theoretically be mapped to any action of choice. Where Imogen Heap needed a performance device that let her move freely on stage, another person might require completely different feature mapping to promote creative actions. The reason flexible and easy-to-use software supporting versatile mapping of haptic gestures is still a thing of the future has to do with more than adhering to commercial value and strategies for securing funding for development. There is also a limit in how complex the coding and mapping scheme can be before users will be put off by the time it takes to become relatively proficient in using the device. A second challenge lies in the limited haptic feedback, reducing most haptic gloves to controllers, and not the rich explorers and manipulators of objects and landscapes they could be.

Touching the virtual and afar: Exploration of new worlds

We have haptic hand interfaces that encode rich tactile and proprioceptive input as haptic gestures for creativity and control. What is missing from most of these devices is rich and nuanced haptic feedback. There are few, if any, implementations that combine strong material solutions for haptic input as well as haptic feedback. In the case of UltraLeap, the two companies behind LeapMotion and UltraHaptics merged, to create a hand interface affording both haptic input and tactile feedback. The Leap Motion optical sensor tracks hand movements and gestures in real time, and functions as a controller reading haptic input. Combined with UltraHaptics modules (such as STRATOS), UltraLeap supports feedback as focused ultrasound emanating from display surfaces (Carter et al. 2013), allowing for mid-air tactile sensations for objects, surfaces, and shapes, and compound tactile signs such as Click, Dial, Lightning, Open:Close, Ripple and Scan ("Haptics | Ultraleap" n.d.) A limiting factor of UltraHaptics is that the interactor is fixed in a standing or sitting position in front of the optical sensor, and above the tactile feedback module, which reduces the action space accordingly. The stimuli from ultrasound emission is also restricted in terms of textural representation, and the setup offers no proprioceptive feedback.

The challenge of creating rich textural sensation has been tested in the Touché project (Sato et al. 2012), in which the interactor, by wearing a small armband, experiences various emulated tactile sensations when touching both physical, everyday object and virtual objects presentation via screens. And the ability to introduce rich tactile, if not total haptic feedback in virtual scenarios as well as over distance have certainly many upsides. While we may not feel the surface of Mars or experience the texture of a water molecule, there are certainly projects out there that aim to tackle distal and virtual sensing.

One such project is the Tactile Telerobot, a haptic telerobotic hand for exploration and manipulation. This project is the fruitful collaboration between the Shadow Robot Company,[101] and SynTouch,[102] and HaptX.[103]

The robotic hand skeleton for remote exploration is based on the Shadow Dexterous Hands design by the Shadow Robot Company.

The robotic hands are equipped with a biomimetic tactile sensor, labelled BioTac, developed by SynTouch. This sensor will let the hands, specifically the touch sensing robotic fingertips, detect tactile information and feel the environment. The tactile sensor, the size of a fingertip, is quite elaborate, consisting of 19 electrodes and covered with silicone skin. Saline is injected between electrodes and skin, allowing measurements of changing resistance, when the sensors are pressed against something. To define tactile sensations, SynTouch has developed a rich database of touch profiles based on analyzing various materials. The sensor readings are represented in 15 dimensions of touch, deriving from five main categories of sensation: Compliance (deformability), friction, texture, adhesion, and temperature. ("SynTouch Technology" n.d.). This allows the robotic hands to sample and represent a rich tactile collection of sensations.

The sensory impressions recorded are delivered in real-time to the interactor controlling the robotic hand, via a haptic glove. The glove system, HaptX, can track

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[101] https://www.shadowrobot.com/telerobots/

[102] http://www.syntouchinc.com/en/

[103] https://haptx.com/

36 degrees of freedom which accords for detailed recording haptic input at almost every axis. Additionally, it offers rich haptic feedback, with the aim to replicate real-world objects. The glove design consists of a flexible microfluidic skin consisting of pneumatic actuators and air microfluidic air channels, which allows for skin displacement and tactile pressure sensations, offering rich experience of texture and shape (Varga n.d.). As it comes with a light exo-skeleton the glove can emulate proprioceptive force sensations in addition to tactile ones, giving the interactor additional nuanced experiences of weight and size. Besides showing remote colleagues' affection by giving them a massage, proposing that the system "fuses your hands with robot hands" (*Tactile Telerobot Showreel | Control Robots with Your Hands* 2019). The telepresence or virtual environment is presented to the interactor via a screen, and the combined corresponding visual and haptic feedback are the key criteria listed by Dolezal (2012), for extending sense of agency into remote lands.[104]

With the Tactile Telerobot you are given a chance to explore distal and virtual spaces and use the refined abilities of the hand to search, identify, and manipulate objects, utilizing perceptive curiosity and enactive strategies. Several potential applications for the tactile telerobot are suggested by the developers, and each of them could drastically change who we solve problems that pose too much of a risk to humans or are set in worlds outside our normal perceptive reach and grasp. One application suggested for the robot are dangerous and critical operations such as nuclear decommissioning and bomb disposal, but also testing and manufacturing within different biomedical scenarios (handling biowaste, working with contagious material, vaccine development etc.). Another direction proposes the exploration of new frontiers, space, currently unavailable to humans. Likewise, the robot can introduce novel sensations of presence and interactivity, with immersive robot and VR/AR experiences. A third type of application is related to training, either within

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[104] See chapter 2 for a discussion on re-embodiment in telepresence and virtual environments.

simulations or on-site via telepresence mediation.[105] This aspect will be explored in more detail in the discussion on full-body haptic interfaces.

Haptic gloves, either presented individually or in conjunction within a larger interface system, may be considered a strong candidate for a haptic interface for productivity. Utilizing the dexterity and gestural vocabulary already known by the hand we may interact with virtual as well as physical objects and space, use strategies for recognizing, arranging, placing, moving, search and sifting. However, most of these interactions centered around emulations of physical haptic sensations of objects and spaces, allowing us to utilize the already known operability of the hand. Rich semiotic interaction using haptics, is not only a question of the material solution, we need to recognize the signs as meaningful messages. Currently there are few implementations that demonstrate rich semiotic communication. As unveiled in the discussion of the haptic gloves for LORM-users in chapter 4, this device is successful because the users already know the tactile language.

5.4 The Body: (Re)presence and experience

Imagine the following:

> *Class, is everyone suited up and ready?" my teacher asks.*
> *I am not sure if I am ready. It is my first time. "Ok, everyone step into*
> *the Experience Deck, we will link up with the other groups shortly."*
> *Slightly nervous, I step in and watch our classroom transition into*
> *a large green hall room. One after another new groups of kids*
> *appear in the room. "Welcome, everyone, we have been looking*
> *forward to this shared biology class. Today will investigate*
> *the native wildlife of all our regions and share insights, but before*
> *we go to the first place, let's take five minutes to get to know each*
> *other a little. Let's shake some hands!" I shyly look around and see*

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[105] HaptX is already collaborating with Fundamental Surgery, who produces VR scenarios of various surgical operations. With the HaptX glove system the surgical simulation delivers relevant haptic feedback, resulting in a more realistic training scenario, both for on-site and telesurgical operations. https://www.fundamentalsurgery.com/

> *the same expression in the other kids as well. I realize we are all new to this. More relaxed, I step forward and hold out my hand.*

Mediation of bodily presence and virtual space

The idea of responsive environments as a method to induce feelings of presence is not new. Traditionally, these environments set the stage and physical border for a novel interactive experience. By tracking body movement, position and gestures, and matching it with most usually vivid visual and/or auditory feedback, interactors report sensations of immersion. Coupling haptic activity with visual and auditory response is a well-researched and developed strategy in media art for creating interactive experiences. Besides the Krueger's experiments with VIDEOPLACE, David Rokeby's *Very Nervous System* (2009) running from 1982-91*,* and Jeffery Shaw's *Legible City* exhibited between 1988-91 (Shaw n.d.), are two early and strong examples emphasizing the centrality of bodily movement and position in interactivity, both as tools for navigating the interface, but even more as a means to create the sensation of presence and immersion.

While we may imagine a purely haptic responsive environment, where the haptic input is rendered as haptic output, it is as space for multimodal and cross-modal interactive experiences these environments are successful. In these setups haptic input functions either as a navigational tool in a (audio)visual narrative, or as trigger for audio and visual mediation of space. I am distinguishing between haptic media for the full body which are multimodal and cross-modal. Both track and render haptic input as cues to trigger events and actions, but where cross-modal setups are translating these cues into other sensory experiences, the multimodal setups include haptic feedback to guide and assist primarily audiovisual narratives. While cross-modal interactivity will be explored more closely in the last section, The Sign, this section seeks to unveil how full-body haptic media can be coupled in a multimodal setup to produce novel experiences and feelings of presence.

As haptic input, the real-time machine reading and rendering of bodily movements and gestures can be tracked from wearables instead of cameras and external motion sensors, interactors may liberate themselves from the stage, the physical responsive environment per se. With this liberty comes another opportunity, namely that of offering rich haptic feedback. To my knowledge there are no well implemented ultrasound (or similar) devices that can deliver mid-air haptics for the full-body, so for nuanced haptic feedback for the full-body, we need to turn to wearables.

Suit up and dive in!

A rich haptic feedback system for the body can ideally deliver fluent and detailed sensations of force, vibration and motion, which can be presented as haptic cues, signal and signs, throughout the body surface. We have also come to a point in time where full-body haptic feedback is technologically feasible to be of real use, especially when combined with virtual and augmented reality narratives.

In the following I will present a current full-body interactive haptic wearable developed for the commercial market, to discuss potential and perhaps inherent and shortcomings of such setups. The Teslasuit[106] claims to enhance physical performance in selected situations and environments and showcases a segment of haptic technology that is currently popular in the developer community—tactile stimulus as emulation of reality. The Teslasuit delivers haptic feedback and temperature control for emulating delicate touch sensations to feelings of physical strain and exhaustion for the user. The haptic feedback mechanism is based on electrostimulation and is distributed over 80 suit points. Furthermore, it contains two biometric sensors for capturing and recording heart rate (EEG) and skin moisture, and is also rigged for motion capture, allowing body movements and postures to be recorded for later. This feature also allows for comparisons of performance over time, or as a basis for later suit programs. On that note, a dedicated software uploads various training scenarios or performance situations to the suit, with the aim to train reflexes and muscle memory (allowing certain gestures

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[106] https://teslasuit.io

and movement combinations to be recorded to memory). The suit may be used separately coupled with augmented or virtual reality technology to present various scenarios where the interactor can practice for specific environments or situations—and is targeted towards athletes, patients in rehabilitation, and training in specific industrial, medical, or manufacturing environments.

The Teslasuit utilizes two types of electrostimulation techniques to offer a combined sensation of touch and force, labelled transcutaneous electro stimulation (TENS). TENS consist of transcutaneous electrical nerve stimulation (TNS) meaning that the suit passes direct electrical stimulation of the nerve endings in the skin, and electro muscle stimulation (EMS)—forcing the muscles to contract, simulating a sense of force (e.g. the feeling of weight) (Mikhalchuk 2017). The haptic feedback is purely tactile as it only stimulates the skin surface, giving the interactor a simulated sense of kinesthetics (motion and force). Electrostimulation, as opposed to other tactile stimulation strategies,[107] does not require any moving parts as it contains no motors, in creating the sense of skin touch and force. And secondly, it requires moisture to be conductive. Direct electrical stimulation is rarely the preferred method for tactile experiences, as it can be unreliable, however, there are no public records of the Teslasuit having suffered from this. Overall, the Teslasuit definitely offers rich tactile feedback, but only pseudo-proprioceptive feedback (buzz-vibrations), as no actuators are involved in the processing engaging real force sensations, such as pressure, inertia or compliance. If we are to imagine a rich haptic interface for the body, the lack of proprioceptive feedback will limit the action space for the interactor, hindering potential actions and tasks to be perceived.

In terms of the material setup of the suit, and the intended use of it, it is fair to state that the communicative sign exchange in this interaction is first and foremost presented visually via the virtual and augmented reality story-lines, and not via haptics. I would also guess that most, if any, of the affective content, is coded

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[107] This method of creating touch sensations separates it from common tactile media devices (such as your smartphone) more commonly utilizing vibrotactile stimulation where mechanical vibration caused by small motors within the device is the source of the touch sensation. Or electrovibration where the electrical force is mediated indirectly, and touch sensations are produced only when skin moves over the haptic media surface. See chapter 4 for more details on tactile surfaces.

visually, in which haptic feedback may offer congruent sensory support, but that doesn't need to be the case. We can easily imagine the suit program to include gestural patterns that are experienced as affective, i.e. gentle strokes and pats.

Scenarios as lived

Teslasuit developers claim that their suit will offer us scenarios which will be experienced as lived ("Teslasuit" n.d.), but is the material and semiotic setup of this wearable sufficient to hold that claim true? I am wondering how realistic a simulated scenario or environment needs to be to induce feelings of presence? Or is almost perfect, or even roughly perfect, good enough to be a useful experience for the interactor. And is *lived* a measure of immersion in the experience? The suit experience will always also be a phenomenal experience, that is recorded to memory, no matter if the intended experience by the developer is matching the actual one perceived by the interactor. The experience may approximate sensing a real environment, it might even be sufficiently real enough for the user to fill in missing gaps of a full and rich physical experience to be useful and valuable. In virtual reality design immersion is measured in fidelity—the presentation of realistic (high definition), primarily visual, representations—and immediacy—the seamless and fluent presentation of the narrated experience. Both fidelity and immediacy are key to creating the experience of being *there* or *here*, but as of today, we have few congruent systems that have equal emphasis on both. Interactors report that seamlessness and fluency are most important to feel immersed in virtual environments (Greengard 2019, 93).

In chapter 2 we discussed the difference between the sensory body and the intentional body. The sensory body is always *here*, whether sitting in front of a PC or embedded in a haptic suit, *passively* experiencing the world. The intentional body, on the other end, can be transferred, and become our means to experience presence in telepresence and virtual scenarios. What is needed to induce feelings of phenomenological presence and embodiment *elsewhere,* is an environment that can mediate our *acting* selves, our intentions for action. This requires not only a fluent mediation of the media scene, as well as a rich material solution supporting visual feedback and haptic (tactile, but more importantly proprioceptive) perception. In addition, for the scenario to be experienced as truly lived, an element of risk needs to be present, which suggests that Teslasuit is still some way off before delivering experiences matching real life.

From real life experience to training in VR/AR

The main selling point of the Teslasuit is the potential of experiencing scenarios to train muscle memory and produce new bodily habits, particularly in scenarios coupled with VR/AR. There are no public test cases that illustrate the effect on users, however, the developers point to research done on haptic training in the field of carpentry which show a significant improvement in motor skills for both experts and novices when training in haptic-audio-visual environments (Mikhalchuk 2018a, Jose et al. 2016). An early research experiment with haptic-visual training showed that haptic guidance is most significant in training timing of motor skills, whereas the visual aid is more relevant when training position and shape (Feygin et al. 2002). The findings also show that each training situation requires that the specific lessons match a corresponding haptic gesture and visual representation, for the training to be effective. This indicates it may be challenging to develop a general-purpose haptic wearable fitting a range of scenarios and environments. As noted in a surgical training experiment combining VR simulation with haptic feedback, the design and mechanical quality of the haptic feedback system can highly influence the ability of the system to support the transfer of motor skills, despite being coupled with virtual reality simulation (Våpenstad et al. 2016). For these reasons, it is uncertain whether the increase in motor skills as shown in some experiments is transferable to the environment and scenarios provided by the Teslasuit, as both the haptic technology, VR/AR solution, and narratives, are novel, and aiming for success in many different areas. This becomes particularly relevant when considering the latest collaboration

Teslasuit has with virtual reality directors Next Frontier,[108] whose recent project *E.V.A* aims to train astronauts in overcoming the physical and psychological challenges connected to long-term living in space. Various virtual reality scenarios, ranging from soothing visits to well-known Earth habitats (e.g. a forest) and engaging in sport activities, to training in zero gravity simulations, are all different programs in the process of being coupled with haptic sensations provided by the Teslasuit. Will poor simulations counteract the benefit of the training? In the case of zero gravity training, will an inaccurate simulation result in astronauts evolving faulty muscle memory? As more and more tech companies start developing haptic media devices aiming to enhance performance in different industries, these questions will be increasingly important to answer, forcing further quantitative research into the field of performance measuring.

The body as a communication surface

The aim to emulate sensory experience, more than being a message-carrying channel, appears to be central in the Teslasuit design. For this reason, it may be closer to simulating a real-life experience as truly lived, than to represent language, as there is no need to be consciously aware and attentive for the sensory stimulation provided to be effective and useful. And there are challenges connected to semiotic representation for haptics directed at other parts of the body besides the hands, in terms of perceptive attention. A lesson might come from the tactile language *Vibratese* proposed by Frank A. Geldard in the late ‘50s. Vibratese consisted of 45 different tactile patterns distributed over the body, which could represent letters and numerals in the English alphabet (1957). And although Geldard’s experiments suggested it was easy to learn, the language is now longer in use (Pasquero 2006). Why not? A research review on tactile communication for the full body offers insight (Gallace et al. 2007). We become easily blind to tactile stimulus if many are presented simultaneously across the body surface. As such, Vibratese as a method

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[108] https://next-frontier.com/

for haptic communication is inherently challenging due to “the fundamental failure of early research to consider the central/cognitive as well as the peripheral limitations that may constrain tactile information processing across the body surface” (6). In addition, the tactile blindness phenomenon may occur in multisensory setup, if tactile signals are not presented congruently with other stimuli. This means that if a visual cue suggests that you should stop and a tactile cue indicates you turn left, your perceptive attention is split, and tactile stimuli may be lost. This tactile blindness becomes more explicit on full-body interfaces, than on the fingertips and hands. This is partly due to some body surfaces, such as backs, thighs, and legs, having either fewer or less specific tactile sensors, but also because these areas are rarely used for haptic communication. While the same research suggests we may train our sensitivity and ability of recognition and specificity, on other body surfaces (25), it still presents a current limitation in designing full-body wearable which support rich semiotic mediation.

5.5 The Sign: Recognition of gesture and bodily intent

> *I want to be alone when I read it. I rush home, enter, and snap my fingers three times before opening my palm. Lights turn on in the hall, living room, and office space, before my worktable is pulled out. I sit down, tap on the table, and open my email. There it is. The reply. I take a few breaths before opening it. And...I got it! The dream job. I tap and stroke my right arm. It is time for music!*

The last scenario is devoted to haptic media, gestural and motion controller systems specifically, that recognize and render haptic input as control signals for cross modal feedback. These are responsive environments and wearables that read haptic input such as position, touch and mid-air gestures, as well as movement, as control parameters for interactivity and user interaction. However, they offer no machine mediated haptic feedback. Many of the hand interfaces discussed previously double as gestural controllers (e.g. Mi.mu gloves), both due to the limited feedback offered by the devices, but also because gestures are recorded and mapped as control cues to perform desired actions and tasks. I also wish to differentiate these controllers from machine vision software implemented in environments that track and map posture, gait, movement, facial features, etc. These are facial and gestural recognition systems most often hidden from us, operating in the background, that offer no feedback, neither haptic nor audio-visual.

Building a haptic language: Recognition and classification of human gestures

There is a significant amount of research and development directed at creating mapping and tracking software and learning algorithms to accommodate real time recognition of human gestures. Many of these programs search and populate large databases, libraries of tactile and gestural patterns, analyzed and classified.

The most common strategy to capture gestures have been through camera based solutions, well known candidates being the optical sensor in the Leap Motion controller, or the Kinect motion and depth sensor, but we also have novel setups experimenting with wi-fi interference, such as WiSee (Pu et al. 2013). But we have not exhausted our options yet. The Soli project, initiated by Google ATAP,[109] has developed a small radar system for recognizing movement and touch gestures, as key features of non-verbal language. The interface is based on a small gesture sensor where radar is utilized to track micro (sub-millimeter) movements of your hand as well as body movements with high positional accuracy. Radar as opposed to camera is also more energy efficient, is also not dependent on line of sight, and can see through other materials. Another advantage is that radar can recognize and track subtle and fine gestures like finger rub, which are otherwise difficult to detect by

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[109] The site of Google ATAP and Soli project : https://atap.google.com/soli/

gesture recognition software utilizing cameras, such as the Leap Motion sensor discussed above.

Utilizing machine learning to recognize a large set of possible movements, the aim is to build a novel library of human gesture vocabulary (Lien et al. 2016, 142:6-8). Currently the radar will be aware of your presence, whether or not you are there, if there are more than one interactor in the vicinity, and if you sit. It tracks body cues that onset interactions, such as reaching, leaning, and turning. A few hand gestures have also been added to the library, such as pinching (thumb-index finger, and thumb-pinky finger), dialing (finger rub), sliding, (finger slide), swiping (fast and slow hand wave), pushing, pulling, circling (with index finger), and palm hold (Wang et al. 2016, 855-6). As noted by Soli developers, it has taken a long time just to arrive at a version of swipe or slide gestures, as people intuitively will act out those gestures in many different ways. This gesture set marks the starting point for applications, but the aim of the project is higher: As stated by one of the lead software engineers of the project, Patrick Amihood, that by analyzing the data signals captured by the sensor they are building a device that is "interpreting human intent" (Google ATAP 2015). We will return to the notion of intent.

The first big commercial implementation of the Soli radar chip came with the mobile phone Google Pixel 4. And although the phone is postulated to offer new experiences of presence, reach and gestures ("Google Pixel 4" n.d.), the current implementation in Pixel is limited. The few gestures, such as fast and slow swipe, and features supported, can easily be replaced by other sensors, such as camera, accelerometer, and gyroscope. So, the idea about using radar as a method for reading haptic input as control parameters, exceeds the actuality, for now. The challenge lies in the defining gestures that appear general and natural to us all, without introducing a too steep learning curve. As such, the project asks if there exists a shared natural tactile language or haptic action repertoire that can be unveiled (archetypical thinking) by this technology, or if they merely track current trends and cultural habits, and as such are more or less social constructions. But even if we are considering a linguistic construction, is it plausible to think that we can create an all-natural haptic language, as there are a plethora of nuances within every gestural twitch and turn? What is certain, is that the project aims to build a haptic vocabulary based on how we engage with the world, moving beyond the icon-thinking where the icon holds visual similarity to the object or event it represents, to identifying a haptic vocabulary shared between many of us (and experienced as useful to us), even liberating us from the touch screen.

From language to intent: Intention control and the role of bodily anticipation

In chapter 3, the Xth Sense technology was introduced to show nuanced proprioceptive activity at the core of a biomusical performance system, where muscle sound is amplified and transposed into music. This technology could also be utilized as a haptic gesture recognition system, which given the right bridge software could function as a universal controller. A challenge in muscle sound as an interface paradigm for productivity environments may lie in the ability to present precise and accurate control signals, sometimes our muscles are sluggish. This is a problem investigated by CTRL-labs in the development of a neural interface for the arm, CTRL-kit,[110] in which electrical activity from the motor nervous system of the brain is mapped, to be used as a control input for a range of devices. The system listens into motor neurons as they signal action potential on its way to the hands. This signal activity is recorded and then sent to a deep machine learning network to decode the intention of the action, before returning the analysis as a control signal. This process is called *intention capture* and allows you, supposedly, to map most interactions currently possible with hands. You do not even have to move your hands, just thinking about them moving is enough to set off an action. This fits well with the phenomenological notion of the intentional body. However, the premise of no-movement is taken far in the founder’s claim that not only is intention control

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[110] CRTL-kit is developed by CTRL-labs, as of fall 2019 a part of Facebook Reality Labs. https://www.ctrl-labs.com/

close to universal, it may even free you from the mobility restrictions set by the body, as it "allows you to do [...] something kind of exotic, like dream about having eight arms and to propel yourself like an octopus. To not be victimized by your muscles" (Reardon 2018). First thing first, there is no support for this claim in the technology as it is currently demonstrated. And although Reardon proposes that the reading of motor neuron activity is a strictly *neural* activity suggesting that the motile action potential of a human body is primarily set in the brain, I am not so sure. His descriptions and demonstration of the technology suggest to me that intention control is the closest thing we have to getting a reading of the body schema. And if that is the case, the Octopus scenario is a long way away. As previous findings suggest (the extent of severe schema revisions discussed in chapter 2), our body schema is rather truthful to the species-specific genetic makeup, which leads me to believe that it will be an elaborate task to control eight arms with any precision or predictability.

5.6 The Haptic Interface

The three scenarios discussed above, centered around the Hand, the Body, and the Sign, all present different strengths and shortcoming of current haptic media implementations. The principles of the natural user interface are deeply embedded in all of these initiatives, aiming to let natural, everyday interaction with real world objects, informed by our inherent and learned action potential, guide user interactivity. However, looking beyond assistive applications of haptic feedback as notification and confirmation systems which are built upon current general-purpose systems such smartphones, most haptics are present in novel, specialized scenarios coupled with (audio)visual content. The haptic interfaces for the hand show great promise in creative applications and spatial computing, to work with composition and performance, but also with modelling, both individually and in collaborations. However, it is as a tactile and gestural controller mediating control signals, cues and signs, triggering actions and events, the hand is currently most utilized. The full-body haptic interface is a scene for new virtual and telepresence experiences, as an assistant to virtual or augmented reality narratives.

Haptic interfaces are presently, without doubt, most developed to render haptic input as control signals and signs, and as affective messages. And, of the three scenarios discussed, haptic feedback is, with few exceptions, presented in wearables, either for the hands or the full body. Responsive haptic wearables, that either support rich haptic feedback or trigger fluent audiovisual feedback, are reported taking on the role of a second or new skin, functioning as a border medium between the inner and the outer world, self and Other. Imogen Heap talks about her gloves as a skin layer, and Teslasuit developer suggests that "smart clothing is our cybernetic 'second skin', which in the future can become the 'sixth sense' both when immersed in a virtual world and in space" (Mikhalchuk 2018b). We have previously discussed (in chapter 2) how the skin acts as a connector between the internal and the external, between subject and object, me and the other. And when considering haptic wearables, these media skins connect us with virtual and remote locations and sensations. However, the skin border is not absolute, so many things transit through: physical elements such as moisture, temperature, and pulse, but also our embodiment, as haptic (tactile and proprioceptive) and affective sensations. For haptic media, wearables, in particular, it is probably most relevant to see the skin as a *communication surface* (that traces and registers the external world), both affective touch, as well as the semiotic reading of expression and body language. Sensory emulation as a communication strategy is certainly the most developed in full-body haptic interface, aiming to present the interactor with virtual sensations mimicking reality. And while there are many haptic media that are well-developed materially able to read nuanced haptic input, and present rich haptic sensations emulating real life experience, we lack implementations that can mediate rich semiotic content, specifically for the full-body, which is currently technologically and physically infeasible. The mediation of semiotic communication is still rather one-sided as few systems have implemented haptic feedback beyond binary notification and confirmation cues or as emulation of physical sensations. It is in the development of gestural controllers that we have the strongest indications that a haptic language for the hands is in progress, with radar and neural reading of motor activity as novel strategies for capturing bodily actions as cues and signs for tasks and actions, and messages. However, insights from the Soli project in trying to unveil (or construct) a universal haptic language suggests that human intuition in terms of haptic interaction, may not be as general as we like to think. This is certainly an obstacle in creating a fully fleshed general-purpose haptic media for communication, at least one that can be intuitively grasped. The immediate general-purpose environment is yet to come.

CONCLUSION

Setting the Stage

This thesis aims to present the significance of involving haptic perception in personal computing environments for productivity extending the screen-based milieu of today. I do so by demonstrating the unique role of haptic sensitivity in cognitive processes and the underutilized potential of involving rich haptic communication in interface design. Specifically, I have investigated how the haptic senses (touch and proprioception) impact our cognitive faculty when mediated through digital and sensor technologies, and secondly, how these insights are employed in interface design to facilitate rich haptic communication. The first research question was framed and discussed from two theoretical disciplines, namely new media phenomenology and enactive-extended embodied cognition. The second research question was investigated through the concept of the haptic figura and analyzed in three larger interface scenarios. Overall, the theoretical insights have been tested step by step through a set of case studies, based on works of digital art.

The plot and the findings

We have seen that the haptic senses are involved in all sensorimotor activities, which proposes that active sensory impressions, i.e. looking at something or directing your hearing, are specific sensorimotor actions all influenced by haptic sensitivity. The influence is twofold, both tactility as distributed through the entire skin surface, and proprioception as a key contributor to motor-control programs.

I departed from the phenomenological claim that our action potential is set by the body schema, plastic motor control programs that frame bodily reach, which are influenced by habit, techniques, tools, and technologies, in processes of confirmation and revision. Furthermore, the schemata are driven by a motor intentionality, a bodily agency, that identifies possible actions to reach goals—we exist towards tasks. All activity shapes our body schema and bodily space. Perception is not only an active process, it is enactive, we establish the world as we act in it. However, our perception not only has *direction*, with the use of tools we also *postulate goals*. Tools extend what we perceive as possible tasks in a given space and situation, the reach of our bodies defined as the peripersonal space, allowing us to form new sensorimotor couplings. I have argued that the extent of embodiment is set by the sense of ownership, experiencing an action as your own, combined with a sense of agency, the experienced possibility of generating actions. With digital and sensor technologies we have been given unprecedented opportunities for targeting and displaying touch and proprioceptive elements of our perceptive experience, and extend the peripersonal space—something which has been thoroughly explored in digital art.

Founded in the enactive-extended embodied cognition framework, I have presented evidence that cognition may be distributed beyond the body proper, through the application of tools and technologies to extend peripersonal space, but also that sensory extensions into other modalities made feasible with technology, are likely to affect and influence cognitive processes. By involving more of our sensory apparatus in interactive scenarios, beyond eyes and fingertips, we can expand our perceptive and enactive landscape—our awareness about the world, our action potential, and our thinking about the world. The final border of embodiment and cognitive reach is still very much disputed, but in discussing machine mediated haptic communication, I have argued it is most beneficial to set this border in conjunction with the reach of motor intentionality, namely at the extent of sense of agency.

While sense of ownership and agency are hardly separated in real-life interactions, the distinction may become apparent in machine mediated interactivity, specifically in setup that delimits haptic input and feedback, and this is the main reason screens, while great surfaces for organizing thought and visualizing complexity, are poorer mediators of presence on their own.

With these insights at hand, I turned to the second research question, to figure out how machine mediated haptic communication may be incorporated and useful in interfaces for productivity. This also called for taxonomy or a tool to help understand what rich haptic communication entails. I have argued that haptic interactivity in HCI has historically tended to be designed and analyzed from a perspective on communication as transmissions, sending and receiving haptic signals. This narrow view is limiting in terms of envisioning and designing haptic interfaces that utilize the potential inherent in haptic sensitivity.

A key contribution of this thesis is therefore the concept of the haptic figura, which I have introduced as an analytical tool to frame the communicative qualities of haptic media. Specifically, the concept gauges rich machine-mediated haptic interactivity and communication in systems with a material solution supporting active haptic perception, and the mediation of semiotic and affective messages that are understood and felt. This is not a measurement of poor or good haptics, rather it emphasizes that the capability of the haptic interface should be understood and utilized in terms of what kind of communication it supports. As such the concept may function as a design tool for developers, but also for media critics evaluating haptic media.

The haptic figura frames the communication potential of haptic interfaces, and as such offers a good basis for measuring what tasks and actions a system may afford. I have shown that there are specific limitations and opportunities inherent in haptic media interfaces with regards to productivity, and several insights are worth mentioning. First and foremost, I have distinguished between haptics in personal computing environments based on GUIs, such as PC and mobile devices, and specialized haptic systems.

The first category are general purpose systems with an operating system base, and a shared user interface, the GUI, onto which diverse applications are built. In these systems haptics primarily have an assistive function, offering cues for notifications, confirmations, and possibly direction. It is difficult to imagine a fully fleshed haptic system operating within the constraints of the GUI. Similarly, the material solution of a system that can support rich haptic interactivity is specific according to the tasks and actions the system affords. To imagine a haptic interface that is rigged for all eventual haptic engagements, seems unrealistic, and definitely not very user friendly.

The second category refers to specialized solutions where haptics are featured in stand-alone systems or integrated in audiovisual mixed-reality systems. Certain haptic tasks, pertaining to physical thinking processes, spatial creativity, and gestural control, are best supported by hand interfaces, while experiences of presence in virtual and augmented reality systems benefit from full-body interfaces. When considering haptic media interfaces for general productivity, particularly stand-alone systems, there are limitations that may be hard to overcome, as we lack precise and efficient methods for detailed handling of data, and linguistic processes such as reading and writing.

From a communication perspective I have distinguished haptic media that aim to reproduce realistic sensations, to those who facilitate message-carrying and meaningful exchange. Within specialized haptic systems, sensory emulation as a communication strategy is most developed in full-body haptic interfaces, aiming to present the interactor with virtual sensations mimicking reality, and affective sensations. Implementations that can mediate rich semiotic content are most developed for hand interfaces, gestural controllers specifically. Rich semiotics for the full body is currently technologically and physically infeasible.

Results and contributions

In this thesis I aim to situate the haptic by bringing together insights from several disciplines. Specifically, I argue the significant role of the haptic senses in sensorimotor coupling and establish embodiment as extendible in accordance to sense of ownership and agency. With this backdrop I offer concrete arguments for targeting haptic senses in interface design. I also present interactive scenarios and interfaces utilizing haptic senses and their usability, both potential and limitations for productivity.

Specifically, I provide a concept that challenges a reductionist position where the notion of haptic communication is becoming a mere grammar of signals, classifying/analyzing the receptors and emitters of signals in the hand and body and how the signal reports to the skin and muscle system. Instead I present the haptic figura as a metaphor and analytical tool for analyzing haptic media. Departing from the concept of the figura as an idea-form, the haptic figura proposes that both material and semiotic qualities of machine mediated communication should be scrutinized, as well as the affective relationship regulated in the interaction.

Finally, I point to the importance and relevance of using works of electronic and digital art as case study objects. In the heart of my research is the inquiry of identifying the unique position of digital and sensor technologies in targeting the haptic senses. Digital art and artistic expression provide us with a rare opportunity for investigating novel and creative development and experimentation with technology, which is not bound by demand for commercial application. This provides particular insights into haptic interactivity and communication.

Research design: opportunities and shortcomings

Any cross-disciplinary research design is challenged by the fact that several fields need to be addressed and sourced to adequately summarize the state of research and identify key insights. For obvious reasons there are nuances and historical observations and understandings that are overlooked in such a design. On the other hand, a cross-disciplinary research strategy may allow for known arguments and established conclusions to be challenged or even further strengthened, both in the process of framing and answering the research question(s).

In this thesis I have sourced theoretical insights from new media phenomenology, embodied cognition and human-computer interaction research, sought empirical evidence from neuroscience, and framed my analysis through works of digital art. All of these fields have specific premises, arguments, and insights valuable to the understanding of haptic sensitivity and machine mediated interactivity, and it is through this common analysis valuable findings have surfaced. Nonetheless, it is beyond the scope of any doctoral thesis to fully embrace several research fields, so I have made several selections in terms of which theorists to focus on, what frameworks within a field to get acquainted with, and what works and experiments to present. The field of embodied cognition is vast and by no means in agreement, instead I have aimed to show the breadth of the field and identified and argued for my position within the extended-enactive view. Similarly, the neuroscientific evidence and research on haptics, are experiment-based or prototypical, in which the results are relevant case-by-case.

Future research

While this research has touched upon the difference between specialized and generalized haptic systems, we still lack good descriptions for how haptics may enter more fluently into existing general-purpose frameworks in PCs and mobile devices, beyond notification functions. We also need to better understand the role of haptic sensitivity in shaping muscle memory and body schema, and what this entails for our cognitive processes. Scientific research is not settled, in theory nor empirically on the extent of embodiment, and what kind of cognitive processes that may permeate skin and skull, ranging from sub/nonconscious functions to higher level conscious thinking.

I propose the haptic figura as a starting point for evaluating machine mediated haptic communication, as an outline for a taxonomy that considers haptic communication beyond the material solution and signal exchange, and recognizes the affective and semiotic dimension of haptic interactivity. We are just seeing the start of haptic semiotics as a research field, based on research on haptic icons and messages, and the attempts to create shared libraries for tactile and haptic cues and signals. The affective dimension of machine mediation of haptic communication is still in its early stages, mainly situated in the robotics industry, teaching machines to recognize affective cues, and here I can imagine many useful cross-disciplinary projects connecting new media phenomenologists and enactivists, alongside developers and artists.

Before you go...

Already explored in science fiction, we can easily imagine haptic technologies allowing us to touch the untouchable, where we are offered illusions of sensing as complete as those in the Matrix. Sensory data read from a remote environment or created virtually, are translated and mapped into a format fitting the interactor's body sensors, delivered as haptic representations. This may be sensory information that is beyond the scope of a human body to register: What does absolute zero feel like?

In such a scenario we are confronted with a complete programming of the sense of touch. As vision is in danger of becoming automated through ocularcentric technologies, such a scenario would render touch algorithmic, and no longer able to act as a reality-checking device. The human observer and perceiver has been removed from the objects in the world.

And where lies the edge of embodied extensions—alterations, augmentations, additions and replacements? We are still unclear on the limits of prosthetics, and the nature of the mapping function between our own action repertoire and tool-supported action repertoire. What is certain is that how we decide to understand the mapping function—whether as code, as a translation, as interpretations, or as interactions, will be part of how tools are presented to us, and in turn, absorbed by us.

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Graphic design: Communication Division, UiB / Print: Skipnes Kommunikasjon AS

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ISBN: 9788230850190 (print)
9788230869956 (PDF)