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Towards a Phenomenology and Ecological Psychology-Inspired Approach to Designing for Interactive Systems

Jelle Stienstra

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door

Jelle Tjeerd Stienstra

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voor Kees,

The greatest good you can do for another is not just to share your riches, but to reveal to him his own. **– Benjamin Disraeli**

Preface

I feel that in my life I was first taught to think by generalizing, ordering, discretizing, modeling, measuring, calculating, objectifying, structuring, and so forth. Those skills have contributed to my growth in becoming an industrial designer and 'proper researcher'. They have helped me to function in a world consisting of abstractions, hierarchies, generalizations, and symbolism, as seen in accounting principles, legislation, stock indexes, educational systems, and mechanisms that imply bureaucracy and control. These principles are thoroughly embedded in the world I live in, exemplified in the everyday products I use, such as traffic lights, telephones, complex remote controls with dozens of buttons, and so on.

However, once I was introduced to David Abram's *Spell of the Sensuous* (1996) and the Designing Quality in Interaction group's provoking pamphlet (Djajadiningrat, Overbeeke & Wensveen, 2000), I began to realize that there are other ways of approaching my profession—ways that are much more appropriate to my being-in-the-world and to how I make sense with it; ways that are compliant with the continuous and holistic nature of my skills in their engagement in a more-than-abstracted world.

For a few years now, I have occasionally been wearing glasses and a few things have become clear to me. My prescription is not that strong. However, the glasses contain one positive and one negative lens. At first, this new world I stumbled upon engaged me in curious ways. The negative and positive sides caused the world to reveal itself to me in a skewed manner. I started to kick my feet into the ground while walking, the squares I used to see became trapezoids, everything on the right side of my orientation was taller, and so forth. In short, my balance with my world was at stake.

A few days after first being confronted with this distorted world I started to regain my grip on it. I noticed that the more I moved and touched with my hands, the more I came to terms with it; the world turned back to the way it had been. Experiencing this attunement to the world first hand made me realize that I come to terms with the world around me through a bodily engagement. Meaning is not something that is out there, in the things or people themselves, or in me, but something that resides and emerges *in* interaction.

Next to being physically confronted with my own bodily capabilities to cope with the ever-changing world, I am constantly confronted with products and systems that mainly demand my thinking skills, and somewhat neglect me as an expressive and emotional being, when I attempt to engage with them. It is apparent to me that there is an often neglected mismatch between human capabilities and the capabilities of interventions made by mankind (i.e., the deterministic technologies and policies that govern the ways in which people interact). With this mismatch between human and technological capabilities I no longer wish to comply. I am intrinsically driven to challenge what seems often taken for granted, to defy the conventional deterministic grounds we utilize when shaping the world. I am driven to make more space for the inherent and unique qualities of people in a complex social world that seem to have long been forgotten (Abram, 1996; Thackara, 2005).

While applying this ambition of changing the routines of life to the field I have chosen (i.e., design), it is my strong conviction that we need different ways of looking at the world when designing products and services that are meant to be used by people. In effect, *design* should be a tool to create products and systems that provide meaning to life. I seek to provide an alternative approach to designing that is anchored in a human-centric philosophy. I feel it is my responsibility as a designer to map the qualities of computing to the bodily capabilities of our being.

I seek to provide an alternative approach to designing that is anchored in a *human-centric* philosophy.

For my quest, I have sought guidance in theories of ecological psychology (Gibson, 1979) and phenomenology (Merleau-Ponty, 1945). These theories are characterized by their appreciation for the unique bodily capabilities of people that underline their subjective experience in a complex, dynamic world. Phenomenology[1] explores the nature of human experience in relation to the concrete phenomena of daily life. In this sense, phenomenology provides an alternative way of looking at the world that contradicts how most mainstream sciences address the act of designing.

[1] Even though several phenomenological stances have the potential to provide valuable designerly insights, I primarily look to the Phenomenology of Perception developed by Maurice Merleau-Ponty (1962), as it centralizes people as subjective beings and, more specifically, reclaims the overlooked body in the experience of the world.

Phenomenology rejects the deterministic and objective approaches that overlook the ordinary, everyday experience of the world around us. Instead, phenomenology embraces the direct experience in open and dynamic environments, emphasizing that life and the world are deeply intertwined. Not unlike ecological psychology, phenomenology places emphasis on the emergence of meaning *in* interaction with a focus on the relationship between the body and the world. In effect, meaning is not something that is defined in a product or a person, moreover it develops through bodily engagements with the world.

It is out of respect for the unique subjectivity of individuals that I refuse to escape in generalizations and standardizations and—as Kees Overbeeke would say—mediocrity. While the use of objective discrimination is a fruitful mechanism in many disciplines, it is, as I will argue, reductive and disrespectful when designing for people who are *unique* and skillful.

As will become clear throughout this work, I favor a phenomenology-inspired designerly approach to designing and shaping things in the world, which conflicts with mainstream engineering approaches at times. This is, however, not to say that I deny or even seek to discourage the benefits of mainstream approaches. I furthermore acknowledge that my work is grounded in and accompanied by a vast body of knowledge available in related fields such as human-computer-interaction and robotics. Alongside these other efforts, I explore and propose an alternative design vision that is anchored in a theory that makes the human as a holistic, skillful being its central focus. In this I acknowledge a human that is capable of more than mainly thinking; a human that can do, feel, think, as well as synergize with others. I aim to consider the continuous, emergent, holistic, and highly dynamic qualities of our being as opposed to the discrete, predefined, hierarchical, and fixed qualities that are rightfully assumed by many interaction designers and researchers.

I suppose that for a dissertation entitled *Designing for Respectful Embodied Interactions*, attention should be paid to the meaning of the concept 'respect'. Nowadays, respect is in its common understanding a loaded term and it refers to a series of societal and abstract connotations that I do not mean to dwell on through this work. This work has little to do with interactive products and systems that honor, admire, show polite (dis-)agreement or merely accept things as they are not to cause offense. Rather, the term *respect* does not stand on itself. That is, 'respectful embodied interactions' is used to highlight and endorse a phenomenological primacy for design, i.e., it points to addressing human bodily capabilities in an appropriate manner when designing products and systems to be used by people.

Respectful embodied interactions as a step forward in articulating the aesthetics of the impossible.

The underlying reason for incorporating 'respectful embodied' in the title of this work is as much descriptive as aspirational. I seek to comprise and further a design research program and tradition that aspires similar ambitions in capturing alternative views that re-evaluate the role of the body, and that shares similar theoretical anchors. Practically, I aim to further open up the design space for products and systems that sensibly[2] take the unique bodily capabilities of people, technological capabilities and particularities of complex contexts into account. As such, I work towards a notion of respectful embodied interactions as a step forward in articulating the aesthetics of the impossible as positioned by Overbeeke (2007). I thrive on this hope and ambition to support transforming the world in line with the holistic and complex nature of people; to create a world that has a better fit for me. Indeed, it is (t)his *dream* that I pursue.

[2] Throughout this work, the term *sensible* is not taken in its lay meaning, referring to the reasonable, reliable, or cautious quality or behavior of things. Rather, the term aims at the sensitive and appropriately attentive character of products and systems, i.e., products and systems that are capable of capturing as well as suitably and astute responding to the complexity of given situations.

General Objective of the Dissertation

As introduced in the preface, this work is grounded in phenomenology and ecological psychology, which offers a perspective on (interaction) design that is anchored in a human-centric philosophy. Maurice Merleau-Ponty's phenomenology of perception, supported by insights from James Gibson's ecological psychology, points to the role of the body in the emergence of meaning. Both theories claim that meaning emerges *in* interaction, and that the body and world are implicated in this in a reciprocal manner. These theories, and consequently this research, contradict many aspects of the mainstream sciences; they approach the world and the construction of meaning through perception as subjective, holistic, and dynamic as opposed to objective, hierarchical, and deterministic. In doing so, the phenomenological perspective points to the need for both interaction aesthetics and system-level revolutionary ways of design thinking in its own right.

It is my objective to explore the consequences of a phenomenology and ecological psychology-informed approach to designing interactive and intelligent products and systems. I do this with two foci. First, I investigate *how* the approach to design could impact the way people engage with the world. Second, I illustrate *how* a phenomenology-driven interaction design theory can be applied to product and systems design.

The primary means to investigate the consequences of a phenomenology-inspired approach to design is through design itself. As I am a designer, not a philosopher, I take a research-through-design approach (Archer, 1995; Frayling, 1993) in which I develop both theoretical and practical insights in the act of designing. In my case, through several *vision-driven* (i.e., a vision directed by the theories) design exemplars, I develop both theoretical and practical knowledge on interaction design. My work with the design exemplars focuses on developing these reflections and knowledge to sharpen the vision and theory, rather than on the practical and functional implementations of the systems and products *per se*. Nonetheless, as stated before, I do aim to show how the approach could (meaningfully) affect the lives of people.

Particular to my approach is that I go through several iterations with respect to the design exemplars and the research as a whole. As such I iterate and build upon my insights and challenges with the purpose to generate a substantial and coherent body of knowledge. The practical design insights and the interaction design theory derived from the philosophy are tightly interwoven and developed throughout the process of the work—both 'sides' developed reciprocally over the course of this dissertation and expressed through the design exemplars.

Fundamentally, phenomenology proposes a (different) way of looking at the world and how *people* make sense in it. Other theoretical perspectives, that are rightfully used when matching with research endeavors, take this same world and people as subjects of investigation. Considering this, it would not be surprising that phenomenology- or ecological psychology-informed insights share characteristics with results that are derived from other theoretical foundations and approaches. Nonetheless, it is my aspiration to single out some insights that might be more specific for the theories I utilize. To explore the design consequences of a phenomenology-informed stance I take the act of designing as a main method, i.e. I take an approach to design inspired by phenomenology and ecological psychology, and explore in which way the outcome of this approach is in conflict with more mainstream design approaches. In effect, most insights have been revealed by designing in and with the *status quo* of design tools and theories. By being sensitive to discrepancies between my approach and mainstream approaches surrounding me, I aim to reveal particularities that are be more difficult to spot if I would let myself in with other theories and approaches.

Taking the theory as a point of departure, and applying and embodying it, in almost a radical manner, has revealed practical insights for design. It has been against a background of knowledge that can be considered as the *status quo* that is highly influenced by mainstream science and engineering disciplines. For this reason, it might seem at times that I oppose well-established forms of science and engineering. On the contrary, my aim is not to disregard those approaches, but to come to terms with them in dialogue. In the latter part of this dissertation, I reflect upon my work's appeal to related work.

As phenomenology informs me, I attempt to map the *continuous* of our being to the *discrete* of computing. This points to the need for design and interaction methodologies that respectfully connect our embodied opportunities with complex functionality. It is this gap of extremes, i.e., the fundamentally different nature of people and designed artefacts, that I try to close.

I am fully aware that there is a middle ground in between the blacks and the whites that I sketch. As such, I have tried to nuance several bold statements that contrast my insights from those of others. Nonetheless, to prevent pragmatic concessions to mask essential phenomenology and ecological psychology-informed insights, I depart from the extremes. Consequently, this work does contain statements that come across as provocative.

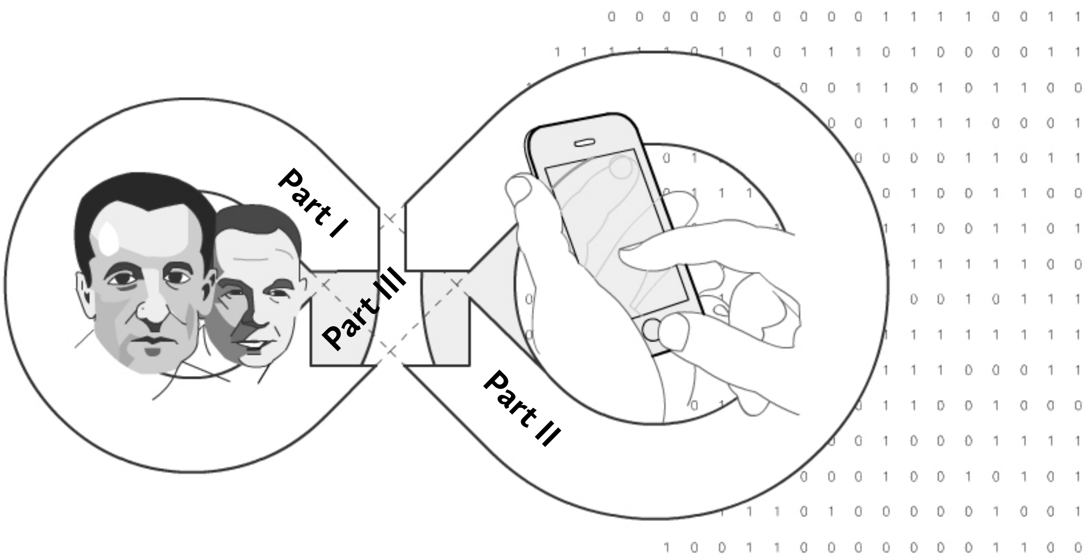


Fig 1. Part I: Departure for Interaction Design and Part II: Designed Exemplars are connected via Part III: Annotations and Reflections in which the approach to design research, the insights regarding the interaction paradigm, and supportive tools and methods are discussed.

Structure

For this dissertation, I created a structure that aims at supporting and reflecting my process and insights while remaining readable. This work is presented in nine chapters distributed over three main parts. *Part I: Departure for Interaction Design* lays the theoretical foundation and outlines its basic implications for the interaction design of interactive and intelligent products and systems. This part concludes with an initial theory-informed perspective for designing for respectful embodied interactions. *Part II: Designed Exemplars* treats the vision-driven design explorations and explains why they were developed, the design specifics, how people interact with them, and how they relate to the theory-informed design perspective on respectful embodied interactions. *Part III: Annotations and Reflections* clarifies how the insights derived from the design exemplars translate into design theory and *vice versa*. In other words, the first part of this dissertation describes the theory-informed perspective. The second part shows that this perspective could lead to typical designs by means of presenting the theory-informed design exemplars. The third part illustrates how designers can arrive at similar outcomes by elaborating on the lessons learned from the approach taken, and how these lessons learned relate to existing and related theories.

The first chapter of *Part I: Departure for Interaction Design* introduces phenomenology, ecological psychology and their related theoretical strands that have been the departure point for my work. After briefly introducing the main philosophers and their ideas, I review similar lines of thought that have been absorbed in the discipline of interaction design. I furthermore describe why and how the theories have influenced my work as an interaction designer (researcher).

In doing so, I establish the background through which to understand my theory-driven approach to interaction design. The purpose of the subsequent chapter, Respectful Design, is to set the stage for this theory-informed perspective that is used to develop and refine the interaction design theory, and practical ways of making it come to life in my designed exemplars. Here, I describe four human capabilities, i.e., *perceptual-motor, emotional, cognitive,* and *social skills*, from the perspective of phenomenology of perception and ecological psychology, and argue for my emphasis on bodily skills as the core and departure point of my investigation. By showing how design can disrespectfully persuade people in and through their daily activities, I clarify my objective to design for people and their skills in their *here-and-now* engagement with the world. *Part I: Departure for Interaction Design* concludes by briefly introducing my approach to the research—the research through design approach—and how it is used in the development of the designed exemplars.

Part II: Designed Exemplars presents the designs used to explore and illustrate the phenomenology-inspired design vision. These projects were created between 2009 and 2014 as part of my industrial design curriculum and my dissertation. The designs are discussed in terms of four topics: (a) their design context and challenges, (b) their interaction design and implementation, (c) their consequences for usage, and (d) their relation to my perspective on *respectful embodied interactions*.

The first exemplar concerns the Augmented Speed-Skate Experience, a device that empowers athletes in refining their technique. Movements that are normally difficult to feel are mapped to an auditory interface that consequently enables athletes to obtain a more thorough *grip* on their technique.

The second exemplar is called the Sensible Alternative and is an operating system for smartphones that allows people to bypass the menu structure and other hierarchies. Adding a pressure-sensitive spot to the back of the smartphone enables people to access relevant applications that are then pushed through the screen.

The third exemplar involves several designs for (*empathic*) interaction in an independent living context in which a robot serves as a supporting agent for elderly people in a smart home environment. The exemplar consists of movement behavior designs and an interface that utilizes the dynamic qualities and action-possibilities of the robot, people, and their *contextuality*.

These three designed exemplars form the basis of my work and have been explored in user studies. A fourth exemplar called the Sensible Door explores opportunities that were identified and left open by the previous exemplars. The purpose of this exemplar is to explore the design consequences of bringing the main insights of the other exemplars together, and to explore them in a context in which several products and entities serve as one integral *socio-technical ecosystem*. This exemplar has not been validated in a final user study. Nonetheless, an iterative design process involving user confrontations was used to further the design and to reveal insights.

In the final part of the work, *Part III: Annotations and Reflections*, I reflect on and discuss the academic contributions of my research as described in the dissertation and embodied in the designed respectful embodied interaction exemplars. I do so by comparing and elaborating upon the designed exemplars in relation to both the theoretical foundation and my act of designing. In Part III, I thus set out to address the gaps between theory (the phenomenology and ecological psychology-inspired interaction design theory) and practice (the designed exemplars) in order to provide design-relevant theoretical and practical insights that complement the respectful embodied interactions.

Part III is divided into three chapters. The first chapter, *Doing Design Research*, elaborates my approach to the research as staged in Part I. That is, I expound the approach taken to distill the consequences of a phenomenology and ecological psychology-inspired approach to design and how it relates to similar approaches that aim to flesh out implications from the interplay of theory and design. In particular, this chapter explores methodological questions and approaches to design research that follow the phenomenological stance. I point to the theoretical consequence of valuing holisticity, the body, and the uniqueness of people in the design research process, and highlight qualities of design (research) thinking and doing that are better suited to the proposed respectful embodied interactions approach to design. This is done so by reflecting on the role of the prototype, evaluation and the design researcher's attitude. This first chapter of Part III reframes the focus of this dissertation and elaborates how the insights were developed.

The second chapter, *Respectful Embodied Interactions*, focuses on the consequences on interaction of taking a phenomenology and ecological psychology-inspired approach, as to how the designed products reveal themselves *in* interaction. That is, in this second chapter I articulate how people engage with the designed exemplars (i.e., how they make sense with it), and how this relates to other frameworks for design that share ambitions (e.g., natural interaction, persuasive computing, and ubiquitous computing). As such I elaborate the overarching tendency of my work and its characteristics, labeled *interactive materiality*, and the role and ways of addressing human capabilities in a respectful embodied manner. The insights are elaborated from direct interaction between human and artefact towards interactions that play out between people and multiple connected-artefacts that display some form of agency (i.e., product ecologies). In short, the second chapter elaborates what *respectful embodied interactions* are really about, what it means to people and how it relates to other work.

The third chapter, *Supportive Design Approach and Tools*, dives deeper into the tools and methods that were used, attuned, and shown to be valuable in designing the exemplars. In other words, this chapter describes practical, supportive tools and approaches that are useful to designing for respectful embodied interactions. While the first chapter of part III, *Doing Design Research*, focuses on the implications of phenomenology and ecological psychology for design research, in contrast, this closing chapter primarily focuses on its implication for designing; for the creation and development of products and systems.

Additional Reading Support

To assist you, as reader, in grasping the insights presented throughout, I have incorporated two additional annotations that aim to enable you to 'feel' what I find difficult to express through descriptions, and expose the design insights. In other words, my intent is to allow for empathy and to provide take-aways.

Throughout the work, a few anecdotes are presented. These are not to be confused with quotes from other scholars or people who engaged with the prototypes. The anecdotes are written by me and therefore do not contain any reference to a source. At times, these anecdotes will seem too good to be true. The purpose of them, however, is to let you 'experience' what you cannot capture in a strictly cognitive manner (and I have difficulties expressing in a formalized way). The phenomenological anecdote (van Manen, 2007; 2014) is an expression that follows a poetic yet structured way of writing and aims to utilize *pathic knowledge*, i.e., people's ability to grasp complexity without being able to capture it in words.

I have incorporated 'annotated insight' in which I highlight paramount insights. As such, they can come across as rather trivial. They are not necessarily original contributions of this work, rather they pinpoint design relevant ideas that are embodied in the theory, the design exemplars or the design process. Besides pinpointing (a) original knowledge contributions and (b) research insights by other scholars that are supportive to this work, I (c) emphasize a few practical approaches and insights for designers who aim at developing similar products and systems. As such, the insight boxes do not necessarily contain exclusive, novel insights or knowledge contributions, rather, they point out ideas that are paramount to designing for respectful embodied interactions.

Part I: Departure for Designing

Part II: Designed Exemplars

Part III: Annotations & Reflections

Part I: Departure for Designing

This part introduces the philosophical anchor I take as departure point for my investigation. The first chapter discusses phenomenology and related relevant theories, and describes how these theories have already been adopted by the field of interaction design. The second chapter introduces my own stance toward designing, i.e., it stages *respectful embodied interaction*. The third chapter introduces my approach to this interaction design research.

The body is the ultimate instrument of all our external knowledge, whether intellectual or practical ... experience (is) always in terms of the world to which we are attending from our body. **– Michael Polanyi** (1983 p. 15)

Theoretical Anchor[3]

[3] The Theoretical Anchor chapter does contain parts of other work such as (a) Stienstra, J.T., Marti, P. & Hummels, C.C.M. (Forthcoming). Sensible Interfacing: Action-Possibility Driven Interaction Design. *Submitted to International Journal of Design*. and (b) Stienstra, J.T., Hengeveld, B.J. & Koskinen, I. (Forthcoming). Designing for Social Skills: a Phenomenological Perspective on Interaction Design. *Under review at International Journal of Design.*

Most theoretical approaches found in interaction design are based on highly structured conceptual frameworks that allow for generalizable models. These models are convertible to design in a relatively easy manner. However, I consider most of their scopes to be too narrow, and they ignore issues that are critical to the practicality of interaction design (Rogers, 2004; Stolterman, 2008).

Within this work, I seek inspiration in the theories of phenomenology of perception and ecological psychology, as they enable me to discover and utilize fundamental insights that are anchored in the notion that the (emergence of) meaning in design and technology is to be found in a subjective, dynamic, and embodied engagement with the world. While ecological psychology has previously served as the inspiration for human–product interaction on the matter of a body–world relationship, phenomenology serves design by extending this view through the role of intersubjectivity in sense-making and *contextuality* of the *here-and-now* in particular. Phenomenology centralizes the subjective, embodied, and contextual engagement of people with products in a complex, rich, and dynamic world (Dourish, 2004). Similarly, other post-cognitivist approaches, such as distributed cognition, actor-network theory, and activity theory, serve as theoretical anchors or compasses, as they help designers to understand technology and activity as central to human experience (Kaptelinin & Nardi, 2006). A similar perspective to considering the role of the body and activity is taken in enactment theory (Varela, Thompson & Rosch, 1991), which capitalizes on phenomenology and ecological psychology (Noë, 2004). Fundamentally, I consider the utilized theories as a way forward in redressing the balance between knowing and experiencing. That is, their attention to experience, to the forgotten body, to the *here-and-now*, promises to emphasize and give space to how people *are* (act, feel and synergize) in the world rather than to how they *think* and lose connection with it.

Following Rorty (1991), I acknowledge that there is no single correct vocabulary of knowledge or overarching theory. As such, it does not make much sense to compare theoretical anchors, as different approaches suit different purposes. Phenomenology of perception complemented with ecological psychology serves as my theoretical anchor because it is rich enough to capture the essential elements of the actual use of technology. At the same time, it is descriptive and generalizable enough to be practical and useful when designing.

This design research is grounded in theory. To be more precise, I depart from the basic notions found within phenomenology of perception and ecological psychology, and seek the implications of applying the derived principles to design. Before I turn to these theories from a designerly perspective, it is necessary to provide a brief, more general introduction of the theories in terms of their roots, main characters, and commonalities.

Phenomenology and Ecological Psychology

Edmund Husserl

The phenomenological tradition explores the nature of human experience related to the concrete phenomena of daily life, the 'things themselves'. It was Edmund Husserl (1859–1938) who rejected the deterministic and objective approach of the sciences that consistently overlooked the ordinary, everyday experience of the world around us. Instead, he turned to direct experience in open and dynamic environments that are subject to mood and metamorphoses, emphasizing that life and the world are deeply intertwined. To him, the world as directly experienced is hardly determinable; it is of an ambiguous and transforming nature. Husserl discerned that the life-world is peripherally present in any thought and activity, and suggested that underneath a diverse cultural life-world there lies a unitary life-world supporting all discontinuous and diverse worldviews. For Husserl, the earth is all-encompassing; it is the basis of all relative life-worlds. Accordingly, the direct felt and lived experience only has value in reference to this primordial and open realm called earth.

Martin Heidegger

Martin Heidegger (1889–1976) rejected the dualism of Husserl's theory by rigorously undermining the transcendental character of the life-world with the notion of being-in-the-world. He placed being before thinking as opposed to thinking before being, the Cartesian cogito ergo sum (Abram, 1996). This move truly opened up the phenomenological field by framing the meaning of life as constituted by the unity of the subjective past and future in the present, as presented in his *Being and Time* (Heidegger, 1962). Unlike Husserl, who saw the world as a surrounding to act upon, Heidegger approached the world as a medium through which we can act. In effect, through active participation, meaning emerges.

Maurice Merleau-Ponty

Maurice Merleau-Ponty (1908–1961) went so far as to state that we need a body in order to experience the world (Merleau-Ponty, 1962 pp. 125-131). According to the French phenomenologist, perception is inherently (inter-)active; it is a reciprocal interplay between perceiver and perceived, between body and context, person and world. Merleau-Ponty placed the body at the center of the emergence of meaning, and proposed that our experience of the world (hearing, touching and tasting) through interaction is only possible because we are part of the same sensible field (having sound, texture, and taste). The inherently active perceptive skills of our bodies enable meaning to emerge in the interaction between artefact and person in context. Perception itself is inherently interactive, conceived of as a reciprocal interplay between perceiver and perceived.

Synaesthetic perception is the rule, and we are unaware of it only because scientific knowledge shifts the center of gravity of experience, so that we have unlearned how to see, hear, and generally speaking, feel, in order to deduce, from our bodily organization and the world as the physicists conceives it, what we are to see, hear, and feel. **– Maurice Merleau-Ponty (1962 p. 229)**

Even though the phenomenon of synaesthesia[4] has often been studied as a rare extraordinary experience, Merleau-Ponty (1962 p. 229) made it evident that our primordial, preconceptual experience is inherently synaesthetic. In effect, the body readily transposes qualities from one sensory domain to another, according to a logic we easily understand but cannot easily explain (Abram, 1996). Merleau-Ponty argued for a trans-modal experience—the concerted activity of all of the senses as they function together. Experience through senses is characterized by divergent yet complementary modalities that have evolved in complex interdependence with one another. Each sense is a unique modality of the body's existence, yet in the activity of perception, these divergent modalities necessarily communicate and overlap.

[4] In design, *synaesthesia*, the blending of the senses, has served as a useful mechanism to develop artefacts in which the inherent relation between scent, sound and vision is utilized (Smets & Overbeeke, 1989; Smets, Overbeeke & Gaver, 1994).

In his last, unfinished work, Merleau-Ponty (1968) put forward his notion of the Flesh—the reciprocal presence of the sensible and sensitive. He elaborated on the confluence of our various sense modalities as they make sense of the world through their continuous coupling and collaboration. This view frames the interplay of the body's different senses as that which enables the confluence between the body and the earth through reciprocal participation. Merleau Ponty's point is not that movement and perception are very closely linked causally, but that they are two sides of the same coin; the body and the world itself essentially co-mingle (Carman, 2008 p. 109).

Merleau-Ponty spoke of *skillful coping*—our body's way of finding a maximum grip on the world, guided by our intentionality, i.e., our directedness. We constantly, though unconsciously and involuntarily, adjust our orientation and action-ability to maintain our grip on the environment (; 2014). In other words, we are attuned to find an optimal bodily engagement that affords us the maximum grip (*meilleure prise*) (Merleau-Ponty, 1962).

Samuel Todes

The Anglo-American phenomenologist Samuel Todes (1927–1994) built upon the work of Merleau-Ponty by elaborating on the actual structure of the body, or the concrete material structures and capacities of the body, in its sense-making engagement with the world. In his work, he pointed out that our body, standing balanced in its gravitational field with its forward rather than backward orientation, is constitutive of the circumstances we are in (Todes, 2001). While Merleau-Ponty emphasized the active nature of perception (i.e., movement and the reciprocal nature of the lived body, which enable a better grip on the world), Todes pointed to the specifics of our orientation: the structure of our body and how it affects experience. What Merleau-Ponty called embodied or skillful coping, Todes called *poise* (Todes, 2001 p.65). For Todes, it is this primary form of directed intentional action—our action-ability between body and world—that unites the body, environment, objects, and other persons. To be *poised* is to be self-possessed by being in touch with one's circumstances.

Alfred Schütz

Alfred Schütz (1899–1959) centered his work around the theme of intersubjectivity. Taking the phenomenological stance that people experience the world in their unique way led him to argue that each of us fundamentally lives in his or her own subjective world. If this is the case, how can we achieve a common experience of the world through a subjective understanding? Schütz, in his first major work *The Phenomenology of the Social World* (Schütz, 1967), argued that intersubjectivity is mutually constituted by its actors in the mundane and practicality of life. Rather than universal law, intersubjectivity arises from collective action. Despite his deterministic and linguistic/reflective/typifying approach to meaning and his rational and planned approach to action (Schütz & Luckman, 1973 pp. 233) that conflicted with Merleau-Ponty's prereflective, primordial take on meaning, Schütz acknowledged that the meaningfulness of social action is required to emerge within the context of the actors' own experiences in the world through the course of (inter-)action.

My interpretation of Schütz's contribution—which follows a Merleau-Pontian and Gibsonian approach in examining Schütz's ideas from a bodily perspective—is that to act socially, one needs to understand the intentions of other people. Understanding others, arriving at shared meaning or intersubjectivity, requires one to understand the possibilities for action in others through understanding their own (possibilities for action). The bodily turn, informed by Merleau-Ponty and Gibson, also points to grasping and other forms of non-cognitive understanding and acting upon in order to enable tacit forms of shared meaning to emerge.

Franz Brentano

Closely related to the philosophy called phenomenology are the psychological counterparts Gestalt psychology and ecological psychology. Both phenomenology and Gestalt psychology were mainly developed in Europe as a direct result of Franz Brentano's (1838–1917) 'descriptive psychology'. Gestalt psychology was initially developed by the German psychologists Max Wertheimer (1880–1943), Kurt Koffka (1886–1941), and Kurt Lewin (1890–1947), claiming that perceptions are products of complex interactions. Like Martin Heidegger and Alfred Schütz, Kurt Koffka was a student of Edmund Husserl. Husserl, Lewin, and Koffka were all mentored by Carl Stumpf (1848–1936) who was a member of the Brentano School. Merleau-Ponty was thoroughly influenced by Gestalt psychology through Aron Gurwitsch and used the work of Gestalt psychologist Kurt Goldstein to arrive at his phenomenology of perception (Merleau-Ponty, 1962)[5].

[5] Those relations gave rise to an acknowledgment of a body-world fit fleshed out in Koffka's (1935) notion of demand character, Lewin's invitation character, Merleau-Ponty's (1962) grip, Todes's (2001) *poise*, and Gibson's (1966) *affordance*.

James Jerome GIbson

Eventually, Koffka moved the Gestalt psychologists to the United States in the 1920s, having a great influence on the ecological psychology of James Gibson (1904–1979). Gibson emphasized that the world is perceived as essentially meaningful, as we are attuned to the world through our capabilities to perceive and act. His theory of direct perception is a theory of knowing the environment (Michaels & Carello, 1981). The essential notions of the theory are Gibson's (1966; 1982; 1986) concepts of *affordance* and *effectivities*, which suggest that we perceive the world in terms of what we can do in and with it. In effect, we perceive useful information in terms of action-possibilities. As such, Gibson's work provides practical mechanisms for designing, which I will return to later.

Furthermore, with his resonance model (Gibson, 1966), Gibson suggested that perception involves the tuning of our body (as our perceptual system) to information as opposed to mentally capturing and storing information. We do so in holistic ways (i.e., through detection not calculation), attuning our perception to useful information through what Shaw and McIntyre (1974) characterize as *attensity*, i.e., the strength of attraction information holds for a perceiver. Just as a musician develops his or her hearing capabilities, an obstetrician develops his or her sense of touch. Ecological psychology thus stresses the unity of human and artefact and the attuning qualities of our effectivities, through which our bodies become sensitive to their environment. In the ecological sense, perceptions and actions themselves concern knowing, rather than having knowledge (Michaels & Carello, 1981).

Francisco Varela

Francisco Varela (1946-2001), biologist and philosopher, introduced phenomenology into neuroscience by adopting the notion that we already participate in the world before we reflect on it. His emphasis on investigating how the experiencing body makes sense of the world aimed to further experimental epistemology (1987), at 'a redressing of the balance between knowledge and being' (Varela, 1976 p.67). Consequently, the neurosciences have revealed evidences for the worldly and bodily context in which we are always embedded and embodied (Varela, Thompson & Rosch, 1991; Varela, 1996; Thompson & Varela, 2001; Barbaras, 2002; Thompson, 2007; Froese, 2011). For instance, the discovery of the mirror-neuron by neuropsychologists at the University of Parma reveals that primates as well as people inherently respond to others in a bodily manner. It is speculated that this capability enables us to understand the intentions of others (Rizzolatti, Fadiga, Gallese & Fogassi, 1996) and that it is a neural basis for human emotion such as empathy (Iacoboni, Molnar-Szakacs, Gallese, Buccino, Mazziotta, & Rizzolatti, 2005).

Alva Noë

Alva Noë (2004; 2012) profoundly bases his enactment theory on phenomenology and ecological psychology. While the existential phenomenology of perception developed by Maurice Merleau-Ponty focuses on the role of the engaged body in shaping meaning, Noë allocates a considerable role to our knowing capabilities as part of our perception and ability to shape meaning. He argues that what we perceive is highly influenced by what we think. He thus extends the role of the body as posed by Merleau-Ponty and Gibson to incorporate memory and intellect. He does, however, take a traditional epistemological and metaphysical approach, i.e., he subscribes to geometrical rather than phenomenological criteria, and thus "fails to appreciate Merleau Ponty's effort to describe our ordinary intuitive understanding of ourselves and our place in the world" (Carman, 2008 pp. 225-230).

Phenomenology and Ecological Psychology in (Interaction) Design

Over the past decade, phenomenology has become a source of inspiration in the field of interaction design. This is evidenced by the various attempts to include the school of thought in the way of looking at design and technology, to apply its premises in design, and to incorporate its values in the design process. Phenomenology's attention to the subjective experience of people is thought to provide valuable insights for designing products that highlight the qualities of being and our bodies. Winograd and Flores (1986) brought Heidegger's concepts of 'present-at-hand' and 'ready-to-hand' to human–computer interaction; Hubert Dreyfus (1972; 2007) applied the philosophy to artificial intelligence; and Paul Dourish introduced the work of phenomenologists Maurice Merleau-Ponty and Alfred Schütz to the design research community with his influential book *Where the Action Is: The Foundations of Embodied Interaction* (Dourish, 2001).

These scholarly endeavors have led to the wide application of the aforementioned phenomenological and ecological notions such as (inter-)subjectivity, embodiment, being-in-the-world, and others. In the field of interaction design, it was Dag Svanæs (1999) and Paul Dourish (2001) who advocated for the subjective and embodied nature of our being emphasized by this philosophy. According to Hummels and Lévy (2013), these phenomenology-inspired contributions to interaction design have broad implications on the act of designing; the interaction with designed systems, products and services; supporting methods, processes, frameworks, techniques, and tools; and design research methodologies. So far, most design research that departed from a phenomenological stance has primarily focused on the act of designing (Fällman, 2003; Loke & Robertson, 2011) and the interaction with systems (Deckers, Lévy, Wensveen, Ahn & Overbeeke, 2012; Svanæs, 2013; Marti, 2012). Ecological psychology and phenomenology-inspired perspectives on the act of designing and ways of doing design research shares insights with pragmatist principles for design grounded in the work of John Dewey and Donald Schön (Ross & Wensveen, 2010; Hummels & Lévy, 2013; Dalsgaard, 2014). This overlap is due to their shared perspective on subjective experience and mutual denial of dualism and objectivity.

Ecological psychology, as described by James Gibson, was introduced into design research by Gerda Smets and colleagues (Smets, Stratmann, Overbeeke & van Nierop, 1988; Smets & Overbeeke, 1994), although it was Donald Norman (1988) who made the concept of affordances popular through his book *The Psychology of Everyday Things* (later entitled *The Design of Everyday Things*). Using the example of a door handle to explain the concept of affordances; we perceive a door handle as graspable (*affordance*) because we have hands that can grasp (*effectivities*). For an infant, this door handle is not perceived as such, as the handle is too big for the hand (it is not body-scaled) and most likely out of reach; the effectivities of the infant are not compatible with the door handle's properties. Applying these principles to design, ecological psychology argues that functionality reveals itself through interaction and builds upon the match between our human capabilities and those of the artefact.

Norman's (1988; 1999; Fisher, 1999) and Gaver's (1991) interpretations of *affordance* discussed by McGrenere and Ho (2000) somewhat differ from Gibson's (1986), in that, these authors separate affordances from perception (Fisher, 2004; Kaptelinin & Nardi, 2012). In itself, Norman's interpretation is valuable for design, as it provides interaction designers with an accessible notion with which to work. However, Norman's somewhat cognitivist interpretation tends to overlook the bodily relation Gibson emphasized, leading to symbolic and representational screen-based solutions in which the user is reduced to a 'clicker'. On the other hand, Norman's view does enable the notion of 'cultural affordance', i.e., affordances that have been shaped through (collaborative) use, such as walking on the right side of the road or going when a green light appears. However, from a strict Gibsonian point of view, it is difficult to accommodate this notion of 'cultural affordance', as Gibson described *affordance* as a body–capability–artefact relation while somewhat ignoring a socio–cultural context. Djajadiningrat, Overbeeke, and Wensveen (2004) see *affordances* applied in a 'clinical way', that is, they recognize that the notion of *affordance* is primarily used to describe the body–artefact fit, thereby neglecting the irresistibility of the affordance, i.e., an irresistible desire that makes one act, and that can be designed for. [6]

[6] To make space for the *irresistibility* of an *affordance*, I believe design could utilize *attensity*, the strength of the body-world fit, as posed by Shaw & McIntyre (1974).

Related Theoretical Anchors in (Interaction) Design

Pertinent to using phenomenology is that it profoundly shifts how we think about the world (Merleau-Ponty, 1962; Abram, 1996). In design, phenomenology shifts the way in which we think about design (Dourish, 2001; Klemmer, Hartmann & Takayama, 2006), create (Mitcham, 2006) and validate it. It is this aspiration to counter a Cartesian body-mind split and to make space for the subjective and embodied qualities of our being in the world that unites a variety of theoretical strands. This kind of reframing has been advocated in a variety of related disciplines, such as psychology (Saariluoma & Oulasvirta, 2010), anthropology and etnography (Suchman, 1987), cognitive and neuro sciences (Varela, 1987; Damasio, 1995), artificial intelligence (Dreyfus, 2007), computer sciences (Winograd & Flores, 1986), education (Robinson, 2001) and robotics (Brooks, 1986; Pfeifer & Bongard, 2007). These often provocative critiques on prevailing theories are highly influential to their own fields and raised awareness in the design community to pay attention to the subjective bodily experience (Rauterberg, 2014) and to relinquish a strict body-mind split (Harrison, Tatar & Sengers, 2007; Rauterberg & Feijs, 2015). The kind of work that follows these attempts to break with or provide an alternative perspective to mainstream, scientific and engineering approaches is often associated with what is called the 3rd wave of HCI (Bannon, 1991; Bødker, 2006), critical design (Bertelsen & Pold, 2004) or the humanistic approach (Harrison, Tatar & Sengers, 2007; Bardzell & Bardzell, 2016). In what follows, I stipulate a few directions that are somewhat compatible and useful to my endeavors to develop an interaction design theory and approach, i.e., designing for respectful embodied interactions.

In line with Merleau-Ponty's active nature of perception, Lucy Suchman (1987), a social scientist, argues that people do not execute internally created 'plans for action', but act in concrete circumstances. She argues that a technology-oriented starting point for human–computer interaction does not properly address the full richness of the socio-cultural, emotional, and situated components of a context. Moreover, she argues that human action is constantly constructed and reconstructed through dynamic interactions with the world. For her, meaning emerges in situated action; the world does not exist before us, before we come to inhabit it. In effect, our sensory capacities and behaviors bring forth both ourselves and the world in our interaction with it. Consequently, the essential element for making sense of the world is the sensori-motor coupling between a person and his or her environment (Suchman, 1987; van Dijk, 2013). The notion that sensori-motor coupling is pivotal in sense-making supports both James Gibson's perspective on the emergence of meaning and that of his wife, Eleanor Gibson, who pays special attention to learning in a social context (Gibson & Pick, 2000).

I interpret Suchman's view to propose that, contrary to Ambient Intelligence (i.e., technology that directs functions and consequently people in dealing with the world) or Augmented Reality (i.e., technology that mediates functionalities as suggestions towards people in dealing with the world), technology has the opportunity to dynamically negotiate with people *in* interaction.

This view resonates with the work of Dourish (2004; 2006) who considers *contextuality* as an interactional problem rather than as a representational problem derived from a phenomenological orientation. This means that (a) instead of considering context to be information, it is considered to be a relational property held by the actors in the world; (b) contextual features are not defined in advance, but instead define themselves dynamically *in* interaction; (c) context is not stable, as it attunes itself to the particularities of the environment; and (d) context and content are not separate, and *contextuality* arises from within activity.

Participatory sense-making De Jaegher and Di Paolo (2007) build upon enactment theory (Varela, Thompson & Rosch, 1991; Noë, 2004) to develop the notion of *participatory sense-making*. In other words, they recognize that the emergence of meaning (or grasp of *affordances*) occurs through learning with (acting) others. Participatory sense-making aims to reveal the deep entanglement between brain, body, and interactive dynamics during a social engagement. Schütz also recognized this point (Schütz & Luckman, 1973), although he addressed shared meaning on a higher, more cognitive, and less embodied level. Participatory sense-making is not something that occurs in individuals, nor in interaction itself (Di Paolo & De Jaegher, 2016), rather the hybrid, dialectic nature of participatory sense-making undermines a body-mind split that tends to perpetuate.

Activity theory Besides the aforementioned similarities between phenomenology, ecological psychology, pragmatism, and enactment approach, the theories I take as my point of departure also share perspectives with cultural-historical activity theory (Kaptelinin & Nardi, 2006). Moreover, activity theory, in line with phenomenology and ecological psychology, builds upon the notion that activity is pivotal in the constitution of meaning. At the same time, activity theory addresses more than just individual skills, knowledge, and judgment, and is not restricted to the 'generic' human being, since it understands human conduct as anchored in collective/shared practice. In interaction design, this philosophical stance is articulated in the work of Bertelsen, Bødker, and Klokmose (Bødker, 1991; Bertelsen & Bødker, 2002; Bødker & Klokmose, 2011; 2012[a]; 2012[b]), and Kaptelinin and Nardi (Kaptelinin & Nardi, 2006), among others.

Actor-network theory The actor-network theory (Callon 1986; Latour 1993) and distributed cognition (Clark, 1997; Clark & Chalmers, 1998) are related post-cognitivist theories in interaction design (i.e., theories brought to interaction design to remedy the shortcomings of cognitivist theories) that consider technology and interaction to be central to human experience. While activity theory and phenomenology commit to the individual and subjectivity, distributed cognition and actor-network theory focus on analyzing larger-scale agentic entities that include individuals as components. Even though I acknowledge the systemic and reciprocal character of being-in-the-(social)-world from a Merleau-Pontian perspective (following the intertwining) and thus the active role of the world beyond the individual, I primarily position myself to explore and design for the subject, the person.

The design of interactions implies not only the design of technological objects that allow for specific interactions, but also the design of the human subjects who interact with these objects. **– Peter-Paul Verbeek** (2015 p.27)

Post-phenomenology As Dourish (2001 pp. 109) highlights, Winograd and Flores (1986) apply Heidegger's distinction between present-at-hand (*vorhanden*) and ready-to-hand (*zuhanden*) in how we act through the world to the human–computer interaction community. People are able to engage with their artefacts in present-at-hand situations in which they are sort of cognitively aware of using the artefact, and in ready-to-hand situations in which they experience the artefact as an extension of their body in a cognitively unaware manner. Post-phenomenologist Ihde (1990; 1998; Verbeek, 2015) interprets Heidegger in an exploration of how technological artefacts disclose the world in a non-neutral manner. He posits four modes to describe human–technology relations that constitute and influence being-in-the-world: *embodiment relations* (i.e., how technology is embodied in use), *hermeneutic relations* (i.e., how technology is contemplated upon), *alterity relations* (i.e., how technology becomes the quasi other), and *background relations* (i.e., how things that are not directly the focus of attention impact use) (Ihde, 1990 pp. 72-163). These four modes closely relate to Heidegger's *ready-to-handed* and *present-at-handedness*, and could be used to analyze product and service designs (Secomandi, 2013). Chalmers (2004) recognizes that the—often by designers aimed for—embodiment relation and ready-to-hand situation meet the hermeneutic relation and present-at-hand situation inescapably. Dreyfus (1991) suggests three modes of present-at-hand activity that are met in the course of engagement: breakdown, analysis, and contemplation (Chalmers, 2004). These modes are intrinsic to and seem paramount in the process of learning a *skill*.

To describe the influence of artefacts on people's actions, Akrich and Latour (1992) introduce the concept of 'scripts', combining mere functionality with context of use. Verbeek (2006) analyzes the same influence in terms of technological mediation from two perspectives: mediation of perception and mediation of action. Artefacts, on the one hand, can transform how we perceive the world; on the other hand, they can translate how we are able to act in the world. In this context, a script can be understood as a specific aspect of technological mediation, wherein "things mediate actions as material things, not as immaterial signs" (Verbeek, 2006).

Tromp, Hekkert, and Verbeek (2011) present a framework of how technology can transform behavior. Their framework is based on two dimensions, i.e., *salience* (hidden to apparent) and *force* (inhibition to invitation), which lead to four ways in which technology can transform people's behavior. Within this framework, technology can *invite* behavior through seduction or persuasion, or *inhibit* behavior through decisiveness or coercion.

Coming to interaction design from a phenomenological perspective, I embrace the notions of tacit (Polanyi, 1983) and *pathic knowledge* (van Manen, 2007), which express the crucial insight that knowledge is not necessarily a cognitive attribute. What is useful here is that these concepts acknowledge that meaning (that emerges *in* interaction) does not need to be verbalized before it actually becomes meaningful. In this sense, skillful coping rests on the primacy of action. From a phenomenological and ecological psychology perspective (Gibson & Pick, 2000), skills develop in a phenomenological order, according to which skills develop hand-in-hand with bodily *effectivities*. In effect, as limbs and other bodily functions become actionable, functionalities and opportunities emerge. Thus, the developing body and action are reciprocally constituent in the development of skill and meaning.

Eleanor Gibson (Gibson & Pick, 2000) outlines four hallmarks that are descriptive of human behavior (i.e., agency, prospectivity, seeking order, and flexibility). In her framework, the key concept of *affordance* (Gibson, 1966; 1986) ties bodily capabilities and the world together. For her, *agency* has to do with the 'self' as rooted in perception, and the ability to learn how to control one's own activity and external events. The second hallmark, *prospectivity,* concerns the forward-looking character of behavior. Considering affordance, prospectivity means to perceive a potential opportunity for action enabled by the body. The third hallmark, *seeking and using order,* refers to the ordinary quest for regularity, order, and pattern. We search for useful body-dependent invariance over change. In other words, we are sensitive to invariance, movement, or distinctness within the diversity that comes to settle within ourselves. The hallmark *flexibility* recognizes that perception and action adjust to new situations and to changing bodily conditions (e.g., the growth of one's body, improving and depreciating skill etc).

To me, the development of one's skills toward *ready-to-handedness* has much to do with skill and engagement. This links up with and Csíkszentmihályi's (1996) concept of flow and what Rauterberg (1994) identifies as the relation between incongruity and information, which can be described as being completely involved in an activity. It is as if time flies. In order to achieve this sense of flow, a balance must be struck between the skill level and the challenge. If a challenge is too simple for one's skills, one will be bored; if a challenge is too difficult for one's skills, flow is unlikely to occur. Both Heidegger's phenomenology of being-in-the-world and Csíkszentmihályi's positive psychological notion of flow are framed from a subjective perspective, yet I feel that the possible intersubjective nature of a social context is underexposed. That is, little attention is paid to how people, *in* interaction with each other, sustain the flow by reciprocally managing their own skill and by that the 'challenge' towards the other.

Use of Theory

I particularly connect to the work of phenomenologists Merleau-Ponty and Todes who centralize the body and active perception in how people engage with the world. To me, as a designer, this as a fruitful departure as their work helps me understand how design becomes meaningful to the people that use the artefacts, *in* interaction, through a bodily engagement. Similar to Merleau-Ponty, Gibson suggests that meaning emerges *in* interaction based on the relation between the acting body and the animate world. Whereas Gibson speaks of people attuning their skills in order to optimize attensity, Merleau-Ponty speaks of the acquisition of a habit for achieving maximum grip (Merleau-Ponty, 1962), i.e., we develop our body to both think and act according to how the world makes sense to us. These insights are useful when designing for the interaction between person and artefact. The later work of Merleau-Ponty is particularly useful, as he argues beyond the single reciprocity between person and artefact to emphasize the intertwining of the body with the environment as a whole 'interdependent web' (Merleau-Ponty, 1968). That is, his work points to an embodied perspective to incorporate context.

My approach to and utilization of phenomenology and ecological psychology builds upon the work of the aforementioned authors. As stated before, I do not claim to be a philosopher, nor do I intend to be one. First and foremost, I am a designer and so address theory through that lens. Therefore, I derive insights and essential elements on the basis of my designerly background; through the act of designing. It is in the (iterative) act of making, experiencing, and reflecting from the theoretical perspective that I arrive at knowledge that is phenomenology-informed, phenomenology-informing, and design practical.

In the following section called 'initial takeaways for design', I describe four theory-informed aspects of engagement of people with the world that were identified in the early stages of this work. The basic phenomenology-inspired insights that people are *unique*, that meaning emerges *in* interaction, that this occurs and develops in an active bodily engagement, and that *contextuality* shapes the dynamics and dialogue of engagement, are developed progressively throughout the dissertation. While briefly revisiting the theory, I here introduce the four aspects that helped me to understand what is involved in experience and set the stage for the design exemplars.

Initial Takeaways for Design

To reiterate, Gibson, Merleau-Ponty, and Todes highlight the central role of the body and its active perception in engaging with the world (Gibson, 1986; Merleau-Ponty, 1962; Todes, 2001). They conceive of the body as constituent to the emergence of meaning *in* interaction. I believe in taking a humanist approach, seeing interaction design as being about how people experience, and consequently about how we can design for them as holistic beings. In other words, I feel that we have to return to the body as a whole and to how it makes sense in the world—to how we experience in the *here* and the *now*.

The approach I take to designing products and systems thus focuses on the interaction between people and their world, not on the products *per se* (Stienstra, 2016). Interactivity, to me, mainly concerns the *here-and-now*, the direct engagement, the very moment in which we (inter)act and engage. It is the subjective stance, and first person view that cannot be escaped (Rauterberg, 2014; Smeenk, Tomico & Turnhout, 2016), that I consider a valuable point for departure. Even though people may interact with others somewhere else or leave a message to be read at some later moment in time, the moment of experience and the engagement of a skill ultimately take place in the *here-and-now*: at the tip of the tongue, with the touch of the fingers, or within the boundaries of the gaze, imagination, or reflection.

Phenomenology and ecological psychology highlight that our body and action-ability is our primary means to engage with the world and that our direct experience of and with the world is in the *here* and *now*.

In what follows, I look at the 'now' in which this all happens to posit a few basic theoretical considerations. These considerations or initial insights are derived from ecological psychology and phenomenology of perception and should serve to practically help interaction designers to examine the mapping between the capabilities of the interacting human and technology, to clarify the relationship between the body and functionality, and thus in the end, to develop embodied interfaces that are, I believe, better attuned to how people engage with the more-than-abstracted world (i.e., these initial insights serve to design for *respectful embodied interactions*).

Based on the boundaries of direct experience, I pose a set of limitations and opportunities for our body in direct experience with the world. I approach this from four perspectives: the nature of the interaction itself, the roles of the bodies involved in interactivity [7], the *contextuality* that transforms the interactivity, and the development of the interaction. I illustrate these perspectives by elaborating on the activity of cycling.

[7] In the context of these four perspectives, I speak of interactivity and interaction to indicate a subtle difference in the scope of its impact. That is, interaction, is often intentionally directed, whereas, interactivity, to me, highlights that our bodily engagements influence the world beyond our direct interaction.

Nature of Interaction

The interaction of the cyclist with the bike, road, pedestrians, roadblocks, plans, and so forth is of a continuous, active-perceptual, and holistic nature (Merleau-Ponty, 1962). Houses move by, corners have to be taken, other cyclists have to be avoided, force has to be sustained on the pedals, and little steering adjustments must be made to cope with the irregularities of the road.

From an ecological psychology perspective, perception requires action (Noë, 2004). On the bike, the cyclist continuously interacts with the world through his or her bike. The world coming closer, moving underneath is perceived and acted upon in a reciprocal manner through miniscule steering and pedal-movement adjustments, as well as through conscious steering and braking in times of danger.

Merleau-Ponty (1968) extends this theory about the continuous nature of perception by highlighting its holistic nature. He calls upon synaesthesia to point out the intertwined nature of our different sense and acting mechanisms. In other words, we do not perceive and act upon the street and its holes and the other people separately, by independently steering and braking. Rather, to Merleau-Ponty, this process happens in a holistic manner, with an attunement of the body to what is feasible.

Some cyclists consciously steer and anticipate the need to brake; others 'dance' around the corners. These two extremes can be described by Heidegger's *zuhanden* and *vorhanden* (Dourish, 2001; Winograd & Flores, 1986). Cyclists can embody the bike insofar as the bike functions as an extension of the body; the cyclist does not interact with the bike, but rather interacts with the streets or destination through the bike, i.e., the cyclist engages in a *zuhanden* manner not focused on the act of cycling. A novice cyclist or one who notices a flat tire, on the other hand, fixes his or her attention on the bike and not on the road, i.e., the cyclist engages in a *vorhanden* manner focused on the act of cycling.

For phenomenology-informed design it is apparent to acknowledge that (a) people engage with the world in an active continuous-sustained manner, (b) that our active perception is holistic and does seek for grip, and (c) that we are able to engage through artefacts, not just with them.

Role of Bodies

Throughout one's lifetime, one may consider using several different types of bikes. When one is young, bikes with and without side wheels are desired to cope with the growth of the body and the development of skills. Later on in life, one might desire a city or sporty bike for mountains or speed cycling. At some point in life, an electric bike may not be seen as a luxury. Not all bikes afford cycling for the body.

Both ecological psychology and the phenomenology of perception stretch the pivotal role of the body and interaction with the world as constituent for meaning to emerge. They view meaning as residing in between the body and the world (the body and the bike), not in either of them, and emerging *in* interaction. What makes them compatible is what Gibson (Michaels & Carello, 1981) refers to as affordance and Merleau-Ponty and Todes (2001) as maximum grip and *poise*, respectively: the fit between the action-possibilities of one and the other. My hand fits around the handlebars, and my feet on the pedals. At least if my legs are long enough.

Even though it is an undesirable outcome, cyclists crash or get crashed into. Sometimes it is just a matter of not paying attention (e.g., too much traffic to take into account or simply because one's thoughts drifted). At other times, accidents occur because of one's lack or overestimation of his or her skills (e.g., one is too slow or powerless to brake in time to avoid an accident). In such cases, the capacities of people are challenged in a way that they cannot cope with the activity.

It is thus worth considering that (d) bodily meaning emerges in interaction constituted in-between the body and the world, as (e) a fit between the actionable possibilities of the body and the world, and (f) that both our bodies and skills grow and depreciate through experience.

Role of Contextuality

Cycling at night or in the morning are two totally different things. In the evening, the light is different, the cyclist is more tired or maybe stressed, the roads are less crowded, the stop signs are less relevant. In effect, different situations demand different attitudes according to the dynamics of context. Merleau-Ponty (1968) speaks of the intentional arc through which our body does its best to find equilibrium with the world. Cyclists attune to the world as they seek maximum grip between the foot and the pedals, or pace and exhaustion. The way the cyclist acts and perceives, therefore, is not predetermined, but fluent and dynamic depending on the nature of the environment.

I believe that, for design it is apparent to pay attention to that (g) people behave intentional, i.e., we have a focused engagement, that this is (h) highly context dependent and that (i) this contextuality is hardly determined but extremely dynamic of nature.

Role of Learning

People do not innately know how to ride a bike. It takes time and effort, probably even blood, sweat, and tears, to learn how to ride a bike. According to these theories, the now is not just about this moment; it is a unification of the past and an anticipation of the future (Merleau-Ponty, 1962; Michaels & Carello, 1981; Noë, 2004). In the case of the cyclist, the past is all that he or she has learned so far, through falling and standing up, from trying and from help, from all the hours of encountering similar situations. The body learns *in* interaction and attunes its action and perception capabilities to the emergent needs. In other words, the more one cycles the better one is able to anticipate the depth and speed of the activity, e.g., which gear to take with head wind, when to switch gears, when to accelerate, or how to let a pedestrian pass in the most elegant way. In Merleau-Ponty's terms, the cyclist's body gears itself to the maximum grip under an intentional arc, thus combining the action-possibilities of the body with the most relevant aspects of the ever-changing *contextuality*.

A cyclist might become so used to his or her bike that it starts to feel like part of the body, a second nature that makes cycling almost automatic. While in the first days of learning one might consider the challenge of learning exciting, after a while when skills are well developed, this cycling for the sake of cycling may become boring. Fortunately, the bike offers various ways of riding to keep it engaging (e.g., one can race or utilize the activity to 'clear the mind'[8]).

Phenomenology acknowledges that (j) meaning emerges against a background of past experiences, that enables us to anticipate the future, that (k) we gear ourselves to what is most needed, and (l) even incorporate 'other things' through which we engage.

[8] To me, a fruitful method for organizing thoughts is to engage in physical activity.

For interaction design, the primacy of action and consequent emergence of meaning *in* interaction are complicated notions to grasp and implement, as they are born from perspectives on the world that profoundly contrast with most of the perspectives we, people, (and especially design engineers) have accumulated over the years. The easy way out, somehow, is to simply accept that the primacy of action is a given. Taking the notion that meaning emerges *in* interaction in its simplest form, it is possible to argue that every design is a good design to the extent that people interact with the products that are positioned in the world, and meaning emerges somehow independent of the complicated buttons, symbols, procedures, and other representations. The design is able to speak to us (though sometimes via manuals). However, I believe that the value of applying an approach inspired by phenomenology of perception and ecological psychology to interaction design does not lie in merely accepting the theories' premises, but in looking more carefully at their constituents. In many designs, the interaction between human and product does not match. Simply put, most interaction design paradigms are disrespectful toward our being-in-the world and overlook the capabilities of our bodies.

Whereas it is common to utilize phenomenology of perception and ecological psychology as descriptive tools, I believe that they also hold a directive value for design.

First of all, design is about people. It is about our lives, our hopes and dreams, our loneliness and joy, our sense of beauty and justice, about the social and the good. It is about being in the world. **– Kees Overbeeke (18/07/1952 – 08/10/2011)**

Respectful Design[9]

[9] This chapter explores respectful design from a phenomenology-informed design perspective. As such, it aims to develop an alternative approach to designing for interaction with intelligent products and systems.

[10] Here, I do acknowledge that the human capabilities attune to those of the artefact and *vice versa*. In other words, the dynamic interplay that emerges has to be considered as well.

In my opinion, designing interactive artefacts and systems is about designing for people and their behavior. It is about designing technology to be interwoven in the social fabric of everyday lives (Frens & Overbeeke, 2009); it is about how people experience, continuously and holistically. This goes beyond mapping artefactual functionalities to human capabilities: I feel it is about designing *artefactual capabilities* for *human capabilities*.[10] In such a complex design context, computational technologies, which function in a discrete paradigm, need to fit our human, continuous paradigm. I take a humanist approach, seeing interaction design as being about how people experience, and consequently about how I should design for them as holistic beings. I take the stance to design for *perceptual-motor, emotional, cognitive*, and *social skills* in a balanced manner in order to respectfully address the full human skillset.

Here, I follow Kees Overbeeke's programmatic inaugural lecture (Overbeeke, 2007) that established four skills as design-practical characteristics to guide design. I expand this by elaborating on the fourth human skill, i.e., the *social skill*, which in my view is still underrepresented in the discipline. However, I see it as a pivotal skill in designing for truly meaningful (and respectful) interactions. Where *perceptual-motor skills* primarily concern doing, *emotional skills* feeling, and *cognitive skills* knowing (Overbeeke, Djajadiningrat, Wensveen & Hummels, 1999), I believe that *social skills* involve the capabilities to synergize (Stienstra, Hengeveld & Koskinen, Forthcoming). The term 'synergize' is used to emphasize that our *social skills* utilize the three aforementioned other skills belonging to oneself and others. This synergy enables us to perceive and act upon each other's behavior appropriately. In the context of *social skills*, 'perceiving' is related to the affirmation, appreciation, and acknowledgment of others' skills. I approach appropriateness as contextually negotiated through interaction. Through interaction, the intentions of one another are perceived and acted upon in a way that enables the other to fulfill his or her intentions. With a focus on respectfully addressing the full human skillset, I give a counterweight to the designed interactive systems that tend to mainly exploit *cognitive skills*.

This perspective on addressing humans as holistic is shared by others for various reasons. For instance, sociologist Richard Sennett (2008) and cultural ecologist David Abram (1996; 2010) point to the undervalued bodily aspects of our being in the world. They make these claims to respectively underline the foundations of craftsmanship (Sennett, 2008) and rootedness of our body in the emergence of meaning (Abram, 1996). In interaction design, Verplank, Norman, and Buxton are more explicit in identifying the skills people possess that are relevant for the discipline. According to Bill Verplank (Moggridge, 2007 pp. 126-127), designers should ask themselves three questions: How does it do, feel, and know?. Donald Norman (2013 pp. 49-55) describes three levels of 'processing'; the visceral most basic level, the behavioral level concerning learned skills, and the reflective level concerning conscious cognition. He argues that emotion and cognition cannot be separated and that design should cover all of these levels in order to be successful (Norman, 2004; Ortony, Norman & Revelle, 2005). It is further suggested that by addressing physical, mental, emotional, ánd social aspects in game design, resilience can be built to boost longevity (McGonigal, 2011).

Bill Buxton (1994) poses three levels or mirrors of human capabilities according to which we should consider technology. He speaks of physical, cognitive, and social mirrors that respectively relate to the bodily motor sensory skills, the way we think, learn, and solve problems, and how we relate to the social environment. He in particular urges designers to 'correct the current distortions' in how bodily skills are addressed, and to consider the bi-directionality of the senses and the multifaceted nature of our skills (i.e., our multi-sensory, multi-channeling, and multi-tasking capabilities) when designing for interaction (Buxton, 1994). Arguing that human *cognitive skills* should be addressed, Buxton emphasizes the way people learn to deal with complex information. He thus proposes that designers consider systems that utilize learning by exploring and doing (in a bodily manner) in order to more accurately reflect and support how we think, solve problems, and make decisions. To incorporate the multifaceted nature of our skills, he champions Interactive Perceptualization over Interactive Visualization. Interactive Perceptualization implies that all the senses are to be involved when engaging with products and systems that aim to better enable us to explore and understand relationships, test hypotheses, and deal with the complexity of our lives. The third, social, mirror that is put forward concerns the ambition to bring people together. Not unlike Overbeeke (2007), Buxton (1994) recognizes this opportunity, yet fails to deliver a workable strategy to address this matter.

Interaction design has had many definitions since the term first surfaced in the 1980s, coined by Bill Moggridge and Bill Verplank. I approach it as 'designing the dynamic relation between a person and artefacts.' I adhere to this description especially because, since interaction design has moved into the digital realm (human–computer interaction), it has been predominantly focused on 'mapping system functions to a user's *cognitive skills*'; we need to learn in order to act. This is a paradigm that is characterized by discrete hierarchical structures, symbolic representations, and procedural interaction styles.

It is only recently that other paradigms have emerged that reconsider the relevance of our *perceptual-motor* and *emotional skills* within the realm of human–computer interaction (Rauterberg, 1995; Klemmer, Hartmann & Takayama, 2006). Approaches such as experience design (Aarts & Marzano, 2003), affective computing (Picard, 1997), tangible interaction (Ishii & Ullmer, 1997; Shaer & Hornecker, 2009; Basinker & Gross, 2010), embodied interaction (Dourish, 2001), and a few more have been proposed to counterbalance the emphasis on human cognition. The work of Dourish (2001; 2004) is most closely related to what I put forward, as it shares a similar theoretical foundation. The other approaches, despite their desire to counterbalance the emphasis on human cognition, depart from theoretical foundations that are inconsistent with the premises of direct perception and the emergence of meaning *in* interaction. In themselves, they are useful avenues of inquiry, but they hold limited value for developing my particular strand. For example, the idea of Radical Atoms, following Tangible Bits (Ishii, Lakatos, Bonanni & Labrune, 2012) as derived from tangible interaction, conflicts with a phenomenology-inspired design vision on practical, theoretical, and ethical grounds (van Dijk, Moussette, Kuenen & Hummels, 2013). I do not claim that my stance is more valuable, yet I choose to limit myself in terms of the theoretical anchors I employ and attempt to reconcile. Ishii's work departs primarily from a computational perspective, whereas I hold value in the rich human-centered yet contextual starting point.

Nonetheless, I do aim to bring both human and technology together, while acknowledging that there is a simple yet crucial difference between how humans and computational artefacts operate; we (humans) experience and act in the world in a continuous way, whereas computation is based on discrete formalizations and procedures. This difference has several consequences. Firstly, we tend to humanize artefacts (Reeves & Nass, 1996), especially when they start to demonstrate human-like behavior. We do this by projecting our, i.e., human, qualities onto the artefact; we refer to our bodies when there is mechanical activity, attribute emotions to blinking and colored lights, and such. However, our qualities are continuous, which creates a mismatch with those of the artefact, the qualities of which are often based on presets or digital dogmas. Secondly, our skills allow us to balance and prioritize all that happens within a particular context; based on a number of often-unconscious factors, we combine the action-possibilities, emotional situation, and paradigms and rules of play into a holistic context on which we act, rather than maintaining them as individual streams of information. This type of synthesis, i.e., the skill to deal with a holistic and fluctuating *contextuality*, is very difficult for, and generally absent in, current interactive artefacts (Ahn, Barakova, Feijs, Funk, Hu & Rauterberg, 2015).

Computing power has advanced to the point where computational systems are increasingly embedded in our everyday environment as eloquently put forward by Weiser (1991), and computational systems can increasingly approximate a personal and contextual awareness through complex learning algorithms and process large amounts of data. The phenomenology of perception and ecological psychology-informed perspectives pose an ambition that makes structured, hierarchical, procedural approaches to become obsolete for interaction design. This aspiration is somehow similar to how, for example, Brooks (1986; 1991) and Varela (1987) sought to pave ways for an alternative approach to developing robotics and to conduct neuroscience. In interaction design this aim to make space for a subjective stance is advocated by humanistic approaches. Interaction designers (in the broadest sense of the term) can focus on the very uniqueness of people and their context, instead of generalizing them in (or from) user models. It is widely acknowledged that people have adjusted themselves to artefacts (Thackara, 2005; Verbeek, 2005; Aarts & de Ruyter, 2009); now it seems time for products to adjust themselves more to people and their capabilities. In this, phenomenology and ecological psychology offer interaction design a perspective that centralizes human capabilities rather than technological possibilities.

For me, design is about how we are in the world, it is about how we, people with abilities and skills to act, feel, think, and synergize, face life. Products ought to support and empower us, yet our being-in-the-social-world is sometimes at odds with the interaction paradigms. I claim that our skills are not addressed in a balanced manner or approached appropriately. To address this disconnect, I approach interaction design as 'designing the dynamic relation between a person and artefacts' in which our *being-in-the-social-world* is approached in holistic and respectful ways.

Human Capabilities

Before turning to examples of the inappropriate and unbalanced use of our skills in interaction with products and systems, I first elaborate on the particularities of the four skills outlined by Overbeeke (2007). From an experiential perspective, these skills overlap, are highly integrated, and are inextricably bound up with one another as we experience holistically. Nonetheless, subdividing the skills for theoretical purposes opens up insights for designing products and systems that resonate with our human capabilities in a balanced and respectful manner.

In design research, the first three (*perceptual-motor, emotional,* and *cognitive*) skills have loosely been defined by Djajadiningrat, Wensveen, Frens, and Overbeeke (2004 pp. 297) who describe them as follows:

To us, good interactive products respect all of man's skills: his cognitive, perceptual-motor and emotional skills. Current interaction design emphasizes our cognitive abilities, our abilities to read, interpret and remember... With perceptual-motor skills, we mean what the user can perceive with his senses and what he can do with his body. With emotional skills, we mean our ability to experience, express emotions and recognise emotions.

Wensveen later refers to cognitive, perceptual-motor, and affective skills, substituting affective skills for emotional ones. His work highlights the interplay between the domains of knowing, doing, and feeling (Wensveen, 2005). Ross (2008) refers to bodily, cognitive, and *emotional skills* in which bodily skills represent the perceptual-motor. He suggests the possibility of influencing social behavior by incorporating value systems in the interaction paradigm of artefacts. In his view, the other (bodily) skills are useful means to accomplish this. Van Dijk (2013) explores how the sensori-motor skills play a role in the social context of creative collaboration. To support shared insight, he develops expressive (physical) traces that become social artefacts, forming the link between social interaction and sensori-motor coupling.

From my perspective, all skills concern meaning of some sort, and thus I deliberately choose to follow the order and terminology of *perceptual-motor, emotional,* and *cognitive skills*. The most convenient way to distinguish between these skills is to consider their purposes (i.e., doing, feeling, knowing, and synergizing). However, I choose to further delineate the skills in terms of the kind or form of 'information' they concern, as this could help designers to evaluate design. The other purpose of delineation is to help foster a mind-set that leads to improved designs, i.e., designs that respectfully address the *human capabilities* as they utilize appropriate 'information'-channels.

I consider that humans directly utilize *perceptual-motor, emotional,* and *cognitive skills* when they engage with products, in a direct interplay between product and human. *Social skills* are skills of a different nature; they span the others and bridge between people[11].

Social skills utilize our other skills of oneself and others. That is not to say that they come first or last; they develop reciprocally. *Social skills* come to work in the interplay between the *perceptual-motor, emotional,* and *cognitive skills* of oneself and the others.

In the following parts, the skills are elaborated upon from a developmental and 'about-content'[12] perspective, embedded in phenomenology of perception and ecological psychology. *Social skills*, as design practical notion, is an addition to and extension of the three skills defined earlier, and is elaborated in this chapter.

[11] Our *social skills* could be mediated through the design or addressed as an integrative part of the design itself, as I will argue further on.

[12] I use this term 'about-content' to avoid the usage of terminology such as 'information', 'data', 'meta-data' and 'values' that inherently refer to cognitive representations. With 'about-content' I wish to embrace the directly felt *emotional* and *perceptual-motor* kind of information as well.

To get a visual grip on things is not to apprehend their surface appearance, but to sense their bodily affinity with us, to commune with them, to inhabit them.
– **Taylor Carmen** (2008 p. 186)

Perceptual-motor skills

In general, people use *perceptual-motor skills* to do things. As the terms *perceptual* and *motor* imply, these capabilities are about sensing and acting within the world. They concern the direct human skills of sensing (e.g., hearing, seeing, smelling) and moving about (e.g., moving, (reciprocal) touching, making sound, and so forth). From a phenomenology of perception and ecological psychological point of view, perception is active[13] (Merleau-Ponty, 1962; Michaels & Carello, 1981). The body has to (perceive-) act on something in order for it to make sense. Thus, *perceptual-motor skills* are only effective *in* interaction with the world and in an environment filled with (interactive-) artefacts and people.

[13] One could argue that *perceptual-motor skill* should be renamed perceptive skills (i.e., leaving out the 'motor' because action is inherent to perception) or more accurately sensori-motor skills. However, I chose to stay consistent with the original naming in which the perceptual and motor emphasizes the integrative nature of both. This explication or redundancy is useful since the phenomenological viewpoint is not common sense.

To me, *perceptual-motor skills* deal primarily with *affordances* (Gibson, 1986) as 'about-content'. They are thus about grasping and affirming 'about-content' as opposed to appreciating or acknowledging. Design for *perceptual-motor skills* thus pivots around the body–world fit, and necessarily involves an understanding of the bodily capabilities and the capabilities of the artefact or system (Paterson, 2007; Moussette, 2012).

Through the use of *perceptual-motor skills*, which are in a way the most direct skills through which humans interact with the world, other embodied skillsets can be addressed: the emotional and cognitive. In other words, *perceptual-motor skills* offer access to the world and enable the other skills to develop.

The gesture is spontaneous and immediate. It is not an arbitrary sign that we mentally attach to a particular emotion or feeling; rather, the gesture is the bodying-forth of that emotion into the world, it is that feeling of delight or of anguish in its tangible, visible aspect. **– David Abram** (1996 p. 74)

Emotional skills

People primarily use their *emotional skills* to feel. These skills allow humans to feel as they interact and gain an appreciation for the expressiveness embodied in the subjective qualities of the artefacts and nature surrounding them. Thus, *emotional skills* allow people, sometimes irresistibly, to act through their emotions and to express their impressions and *vice versa*.

A variety of scholars have ascribed different roles and function to emotions and feeling in order to make the concepts useful for design. In affective computing, users' emotions were typically identified as discrete units of information that are isolated from context and everyday life. Boehner, De Paula, Dourish & Sengers (2005) countered this trend by posing an interactional approach to emotions that pays attention to culturally grounded, dynamically experienced, and to some degree emotions that are constructed *in* action and interaction. In interaction design research, this perspective to incorporate socio-cultural aspects of emotion has been extended by Höök and colleagues (Sundström, 2005; Höök, 2009; Ståhl, 2014). In their work, that concerns what they call 'the affective loop', they aim to address emotions from everyday, physical and bodily experiences, as well as by turning to the work of Damasio (1995).

Whereas Ortony and Norman (Ortony, Clore & Collins, 1988; Norman, 2004; Ortony, Norman & Revelle, 2005) advocate a cognitive base of our emotions (i.e., they frame emotions as part of cognitive capabilities), it is Rauterberg (2010) who argues that intuition and emotions play a pivotal role in-between the unconscious and conscious. This is similar to how Damasio (1995; 2000) sees emotions and feelings. Emotions results from the processes in which what is unconscious becomes conscious; emotions and feelings are not opposed to reasoning, rather they are essential to its process. This resonates with how I position *emotional skills,* in a way that skills play a pivotal part in the emergence of meaning rather than being a separate subsystem. And the physical body plays a significant role in this.

When utilizing *emotional skills,* people imbue their context, including the artefacts in that context, with emotional values in interaction. For example, artefacts that can hurt induce a feeling of fear, a fluffy pullover makes one feel at ease. Subjective emotional meaning also emerges in interaction. The emotional expands the perceptual-motor's concern with embodied Gibsonian affordances, moving toward 'about-content' that is to be appreciated, felt. The 'about-content' for *emotional skills* is related to qualities and frictions. These qualities are not of the world; these are subjective qualities embedded in the relation between the lived-body and the world.

The seminal works of psychologists Paul Ekman (2003) and James Russell (1980) on discrete emotion classification, as well as Desmet's PrEmo (2002) present valuable ways to assess product qualities. In subsequent work, Desmet and colleagues (Desmet & Hekkert, 2007; Desmet, 2012; Fokkinga & Desmet, 2012; Desmet & Pohlmeyer, 2013) give this a practical turn, i.e., they aim to formulate how to design for emotions. However, these approaches do not fit well with the subjective stance of the phenomenological perspective nor with the dynamics embodied in interactive products and systems that are the focus of this dissertation.

Jordan (2000) distinguishes four sources of pleasure in product design: physio-pleasure, which is directly derived from touch, smell, and taste; psycho-pleasure, which follows cognitive reactions; socio-pleasure, which derives enjoyment from others; and ideo-pleasure, which does so in relation to human values. These categories show some similarity to the *perceptual-motor, cognitive,* and *social skills,* and, as Wensveen (2005) highlights, display a highly integrative character.

Phenomenology and ecological psychology, as developed by Merleau-Ponty, Todes, and Gibson, pay little attention to *emotional skills*, mood, and their dynamics. Although the concept of *affordance*, as coined by Gibson (1986), has found its way into human–computer interaction and physical interaction design, it has often been criticized for its clinical application, i.e., there either is or is not an *affordance* (Overbeeke & Wensveen, 2003). In line with the ideas of Djajadiningrat, Overbeeke, Frens, and Wensveen (2004) and Dreyfus and Kelly (2007; Withagen, de Poel, Aráuro & Pepping, 2012), I believe that there is more to it: an *affordance* can be inviting, *irresistibly* inviting.

Attensity Taking a phenomenological stance on *affordance*, Dreyfus and Kelly (2007) argue that affordances are not mere possibilities for action, but 'solicitations to act'. In my work, I aim to open up irresistibility through the recognition of 'attensity', i.e., the measure of affordance in how much a body–artefact relation affords. Since the bodies of people develop *in* interaction, the development of skills and conditions for learning has to be considered. Relating the idea of irresistible affordance to Csíkszentmihályi's theory of flow (1990; 1996), irresistibility is empowered when skills and challenges meet or slightly challenge each other (Janlert & Stolterman, 2010). Designing for 'attensity' thus argues that artefacts or systems should be able to appreciate the *emotional skills* of interactants in order to provide not only appropriate but even irresistible behaviors.

As Lenay (2010) highlights, *emotional skills* have much to do with movement, i.e., 'we can be moved', and expression (Wensveen, Overbeeke & Djajadiningrat, 2000; Wensveen, 2005; Bruns Alonso, 2010; Bruns Alonso, Hummels, Keyson & Hekkert, 2013). This connection to movement ties the *emotional skills* back to the *perceptual-motor skills* (Hummels, Overbeeke & Klooster, 2007; Ross & Wensveen, 2010; Lévy, Deckers & Cruz Restrepo, 2012).

One of the biggest successes of the personal computer world is the spreadsheet. One of the main reasons for this is that it 'fits' the way that people think about certain problems. Rather than generate masses of new numbers, it helped users refine data into information by enabling them to explore and understand new relationships.
– **Bill Buxton** (1994 p. 8)

Cognitive skills

Cognitive skills are used to constitute concepts and paradigms, make abstractions and generalizations about the world, remember, direct attention, reflect, and associate related experiences on a conscious/aware level; they allow people to know and think within the world. *Cognitive skills* are sensitive to structure, hierarchies, categorizations, orders, and procedures, and are commonly addressed as such. In this work and for design practical reasons, *cognitive skills* deal with information as 'about-content' mostly through acknowledging rather than through affirming and appreciating (Stienstra, Hengeveld & Koskinen, Forthcoming).

It is further crucial to acknowledge that *cognitive skills* enable people to fully embody the information that is processed *in* interaction, leading to *ready-to-handedness* (Pfeifer & Bongard, 2007). As such, I also acknowledge that *cognitive skills* enable people to fully embody the information that is processed *in* interaction, as derived from our perceptual-motor encounters, leading to a Heideggerian *ready-to-handedness*. Sometimes this occurs by diverting the handling of information to the other skills (e.g., typing becomes embodied on a *perceptual-motor* level in terms of muscle memory). From a phenomenological perspective, human thinking capabilities are greatly shaped by our perceptual-motor encounters (Abram, 1996; Gibson & Pick, 2000; Gallagher, 2005; Gallagher & Zahavi, 2008). In other words, as complex as dealing with information seems to be, as long as it is addressed consistently, i.e., invariably, people are able to learn to handle that information, to embody it (Pfeifer & Scheier, 1999).

In line with Buxton's (1994) view on addressing *cognitive skills*, I observe that our capabilities to deal with hierarchies, symbols, language and so forth, are often addressed inappropriately. We, as people, are easily overloaded with information. Consequently we struggle to make sense out of it. To re-iterate, I am not against addressing *cognitive skills,* rather, I think it is worth to address them from a more bodily and less symbolic perspective as well. As such, I wish to match interface capabilities in interaction design to our *cognitive skills* that we use to rationalize and make sense of complexity (Janlert & Stolterman, 2010; 2015).

Sociality is an essential structure of my experience inasmuch as it discloses a horizon of others whose point of view on the world cannot in principle be collapsed into my own, nor mine into theirs. – **Taylor Carman** (2008 p. 149)

Social skills[14]

In the previous sections, I introduced *perceptual-motor, emotional,* and *cognitive skills* as the capacities that allow people to interact with the world. However, it is undeniable that people are also social beings (e.g., they learn from other people, they discuss with others, they fight, they deceive, spoil, and love others); as such, they possess *social skills*. I conceptualize *social skills* from the perspective of ecological psychology and phenomenology, which acknowledge that meaning emerges *in* interaction. The body, in its ability (i.e., including *perceptual-motor, emotional* and *cognitive* capabilities) and the world are constituent in this. Therefore, when giving form to the world (designing), designers need to take a closer look at the body (and its relation to the world). For this reason, when considering *social skills*, I dominantly depart from the body and more particularly from our skills, as well as their context.

To me, *social skills*[15] concern the human capabilities to perceive and act in relation to other beings or things. What makes the 'acting upon' appropriate depends on a variety of factors. For example, growing up in similar contexts, i.e., with similar value systems, cultural factors, languages, and so on, will most likely contribute to the emergence of a shared worldview among different people and help them to 'act appropriately' upon a situation. These similar contexts can occur on different scales, for example on the scale of a continent or on the micro-scale of two people living together. For acting upon a situation, people have access to the environment, the artefacts, and the other subjective beings with whom they engage. Conventions, cultural habits, appropriate behaviors, and common sense shape the context that results from their being-in-the-world, with others in the world.

For people to interact through a common world or shared context, typically they require a language of communication. This 'language' can of course be the spoken word, but can also be of a more embodied nature. Language, by nature, is a social construct and has evolved to the extent that it starts to lose grip on its bodily and contextual roots (Abram, 1996). In this dissertation, I primarily address the 'languages' spoken by our *perceptual-motor* and *emotional skills* to re-discover its constituents. Language, in the form of the spoken word as developed from those constituents in social interaction, thus language that dominantly dwells on our *cognitive skills,* will not be neglected nonetheless. As one's *social skills* involve the perceiving and interpreting of a context followed by the appropriate acting upon that context, I deliberate on three forms of *social skills* that incorporate the other three skillsets (i.e., *perceptual-motor, emotional* and *cognitive*). First, I offer a design-practical theoretical perspective. This is followed by three human–human interaction examples that illustrate the three forms of perceiving and appropriate acting upon in context.

[14] The core of this section is taken from (a) Stienstra, J.T., Hengeveld, B.J. & Koskinen, I. (Forthcoming). Designing for Social Skills: a Phenomenological Perspective on Interaction Design. *Under review at International Journal of Design.* and (b) Marti, P. & Stienstra, J.T. (2013) [a]. Exploring Empathy in Interaction: Scenarios of Respectful Robotics. *GeroPsych, 26*(2), 101-112.

[15] In this framework of design for human capabilities, the term *social skills* is not taken in its lay meaning, referring to being a smooth operator at cocktail parties or a good manager at the workplace, etc. (or a bit less colloquially, perceiving others' needs, moods, emotions, thoughts, and acting accordingly without stepping on their toes even when in trouble). Here, rather, the term is derived from Gibson's ecological psychology and approached from phenomenological and pragmatic perspectives. *Social skills* here primarily refer to the ways in which other people open up action-possibilities to us in a process of ongoing action, on which we can act appropriately or inappropriately.

Design-Practical Theoretical Perspective

As valuable as ecological psychology has proven to be for designing for perception and action (as represented by a large body of work in the design research community, e.g. Djajadiningrat, Wensveen, Frens & Overbeeke, 2004; Maier & Fadel, 2009), I observe that the notion of 'acting upon appropriately' seems to be the mere product of effectivities and *affordances* on a *perceptual-motor* level. Moreover, Gibson himself does not seem to address 'appropriateness' or the social. Only Michaels and Carello (1981, after Shaw, Turvey, & Mace, 1982) mention appropriateness as follows: "insofar as an action contributes to, bringing about a change in the existential circumstances of the agent (e.g. reaching a desired goal) the action is appropriate".

Merleau-Ponty frames the interplay between the senses as the enabler of confluence between the body and the earth through reciprocal participation. The way in which people experience and make sense of the world opens up the field for designing experienceable artefacts of an expressive rich and continuous nature, ones that accommodate the uniqueness of one's (bodily capable) being, accommodate one's continuously active perception (sense-making), and enable meaning to develop against a participatory background, especially since understanding and grasping are rooted in the understanding of others.

Merleau-Ponty's work reveals the active participatory nature of perception, but he does so by examining mainly the interaction between humans and their passive context/surrounding. Therefore, in order to practically utilize the *perceptual-motor skills* in a social context, that is, one that copes with the emergence of meaning in between two (or more) active actors, we need to expand his perspective. For this, I turn to the work of phenomenologist Schütz.

All genuine understanding of the other person must start out from acts of explication performed by the observer on his own lived experience. – **Alfred Schütz** (1967 p.13)

According to Schütz (1967), the transference of subjective meaning can be achieved through acting or mental enactment, but evidently through projecting the action of the other onto oneself, provided that both actors have similar action-possibilities/bodies. To act socially, one needs to understand the intentions of other people. Understanding others, arriving at a shared meaning or intersubjectivity, requires people to understand the possibilities for action in others through understanding their own (possibilities for action).

Empathy

The aforementioned perspective is closely related to empathy, a common phenomenon in psychology. Empathy is a fundamental feature of human beings that enables them to reach out and connect with others, to know and to feel what another person is thinking or feeling, and to actually feel another's emotional state (Rueckert & Naybar, 2008; Marti & Iacono, 2015). Yet, empathy predominantly refers to the appreciation of the other's feelings and not so much the acting upon them.

Not unlike the perspective on emotion, empathy is seen as a controversial construct that evokes debate over its nature, definition, and measurement in any context (Marti & Stienstra, 2013[a]). It implies the apprehension of another's inner world and a joint understanding of emotions. Notwithstanding this lack of consensus, its beneficial effect on attitudes and social behavior has been widely recognized, leading to a growing number of applications of the concept in different fields. For example, in human–computer interaction, Bickmore (2003) attempted to emulate empathy in virtual agents. In design research, Koskinen, Battarbee, and Mattelmäki (2003) developed methods and techniques as inspiration for design in order to understand how people make sense of emotions. Similarly, Di Paulo, Froese and de Jaegher utilize empathy towards their notion of participatory sense-making (de Jaegher & Di Paulo, 2007; Froese & Di Paulo, 2010).

Taking a phenomenological approach to action and perception, I adhere to Marti's perspective that empathy is not the result of an internal judgment or merely a cognitive activity (Marti & Stienstra, 2013[a]). It is a social product that emerges dynamically as an outcome of the interaction through which the actions and perception of people synergize with one another. Synergizing in the context of human–robot interaction is, for example, when both robot and human are looking in the same direction (e.g., toward the source of a noise) (Breazeal, 2002), robot anticipation (Marti, Tittarelli, Sirizzotti & Stienstra, 2014) with opening a door, sharing joy or fear when watching a movie together.

Schütz (1967; Schütz & Luckman, 1973) provides an understanding of how people arrive at intersubjectivity. He also provides distinctions between the orientation and the application of/for social action or behavior. In accordance with Schütz, I speak of *social action* only when the meaning of the act is social. More than just that multiple actors are somehow and somewhere included in the meaning of the action, *social action* is characterized by the fact the actors appear at its thematic core or at least in the thematic field of the project. In other words, social action requires the actors to confront the intentions or objectives of the other (in either compatible or incompatible ways).

Battarbee and Koskinen elaborate on Forlizzi and Ford's (2000) pragmatist model of user experience in interaction from a symbolic interactionist standpoint regarding co-experience in interaction (Battarbee, 2004; Battarbee & Koskinen, 2005). They recognize that the 'lifting up', 'reciprocating', and 'rejecting and ignoring' experiences people have with products hold for mediating technology and co-experience as well (e.g., people lift up, reciprocate, and reject others via media; they act and impact others in these ways). I see these three ways of (co-)experiencing as means to act socially, and ways to increase or decrease challenge. Yet, what is socially appropriate is not addressed as such by them.

Flow theory

In some ways, the appropriation of behavior (i.e., the increase or decrease of challenge) resembles the flow theory of Mihály Czíkszentmihályi (1996). Despite the (somewhat false) connotations for gaming and its objectives to remain in flow, I do believe that this theory applies to the reciprocal growth and engagement in social interplay. As pointed out before, flow can be achieved by balancing one's applied skills and the level of challenge. In the case of a social encounter, the challenge is defined by the other applying his or her skills and *vice versa*. In other words, skill and challenge can be modified in reciprocal interplay, thereby maintaining the balance (sustaining flow). While the actors, for the most part, mediate this balance between applying skill and thus challenging the co-actor, at times balance is not found or achieved, e.g., the opponent is winning, the other is talking on a different level of abstraction, or simply the languages do not match up. Designed technology can play a mediating and active role in establishing and maintaining the reciprocal flow by allowing conversation to take place on an equalized level.

Engaging in a mutual flow with each other or with artefacts can be part of the synergizing effect I am looking for with regard to *social skills.* Design can affirm actor(s)' skills (or lack thereof) and adapt its own challenge and skills to enact an appropriate behavior. This behavior of the artefact can, in terms of challenge, express itself by aligning the (body, expressive, lingual) languages to enable communication (i.e., functioning as mediator), increasing/decreasing the level of complexity, depth, or richness to conform to the developing/diminishing skills of the actor, or on the other end of the spectrum, taking over the initiative (i.e., functioning as control, ambient intelligence) or leaving space for the actor to flourish (i.e., functioning as facilitator, augmented reality).

Affirming Perceptual-Motor Skills

One way to affect one's *social skills* is through the affirmation of another's contextual action-possibilities with respect to *perceptual-motor skills*; in other words, people can act socially when they observe someone else's need for perceptual-motor assistance. Take for example the situation that an artefact is within your reach but out of reach for someone else: you can support or respect the other's attempt to grab the artefact by acting appropriately on this situation and utilizing your own *perceptual-motor skills*. Sports and music offer many other examples of *perceptual-motor skill* complementation in social behavior (Stienstra, Hengeveld & Koskinen, Forthcoming). In such contexts, individual, subjective actors not only embody their own action-possibilities and intentions, but even those of their co-actors.

Many team sports rely on the social interplay emerging from the *perceptual-motor skills* of the partaking athletes. Consider the simple activity of passing in soccer. As simple as it may look on television, when you are actually on the pitch and trying it for yourself, you realize that passing involves more than just putting your foot to the ball; passing involves the ball, the soccer pitch, and the way the ball bounces and rolls over it, as well as the relation both have to the impact, speed, and angle of your soccer boot. But not only these factors play a role, as passes are typically directed at others. As such, the optimal pass is influenced by the pace, dominant foot, and walking pattern of your teammate in relation to the opposing goal, as well as the reach and pace of the opponents trying to disturb your intentions. The receiving player is not merely walking and waiting for the ball to arrive properly under foot; his or her actions involve avoiding opponents, and putting him/herself in scoring position or in better position to pass the ball on.

In this example, even though seemingly simple, the athletes interact socially through the affirmation of each other's *perceptual-motor skills* (as well as those of their opponents) and act upon this situation through their own *perceptual-motor skills*. In the context of *perceptual-motor skills*, *social skills* allow people to affirm action-possibilities (in Gibsonian terms: *affordances*) in others and act upon them on a *perceptual-motor* level. In the following section, I contextualize *social skills* in the light of *emotional skills.*

Our *social skills* allow us to affirm and appropriately act upon another person's action possibilities.

Appreciating Emotional Skills

When utilizing *emotional skills*, people attribute emotional values to the context of their interaction, which includes the artefacts that are interacted with. For example, artefacts that hurt induce a feeling of fear, whereas a fluffy sweater may make one feel more comfortable and at ease. These examples illustrate that subjective emotional meaning emerges *in* interaction. Similar to how *social skills* allow a person to affirm and act upon others on a perceptual-motor level, the appreciation of another's emotions is fundamental for initiating an appropriate acting upon emotionally. *Social skills* allow people to interpret external emotions, or even transfer those to themselves (empathy), thereby eliciting the urge to support the other. Take for example the following situation.

The traditional string quartet consists of a first violin, second violin, viola, and cello, or more precisely, someone playing the first violin part, someone playing the second violin part, someone playing the viola part, and someone playing the cello part. The reason why I phrase this so laboriously is to highlight the fact that playing string quartet music means more than merely stacking four parts on top of each other and starting and ending at the same time. String quartets are organisms in which each individual instrumentalist plays a double role: on the one hand, each is responsible for the execution of his or her individual musical part; on the other hand, all share responsibility for the group execution of the overall composition. This requires not only awareness of one's own musical output, but also an understanding of that of the other three musicians; this is what 'brings music to life'.

In such situations, the string quartet starts behaving as an emotional organism in itself (Davidson & Good, 2002), recognizing and affirming each other's musical actions and acting upon them based on a shared contextual appreciation (Schiavio, & de Jaegher, 2017). In effect, this example illustrates how *social skills* utilize *emotional skills* to arrive at an appreciation of one's behaving self and others' feelings, and to encourage one to act appropriately in context; this is constituted in a shared encounter.

Our *social skills* allow us to appreciate and appropriately act upon another person's emotions.

Acknowledging Cognitive Skills

Considering *social skills* in relation to *cognitive skills, social skills* allow people to recognize, acknowledge, and comprehend the lines of thought expressed by others through verbal language. This occurs even to the level of people finishing each other's sentences. I illustrate this through the following example.

In most cases, discussion is driven by language, which uses symbolic representations of complex paradigms, shaped and defined through conventions, yet grounded in a contextual life-world. This implies that different people think and speak differently; they have different understandings of the complex network of words used to convey messages. Consequently, part of a discussion requires the participants to recognize the perspectives of others in relation to one's own perspectives. Moreover, a comprehension of the other's use of language can propel a discussion when both people involved choose their words carefully, i.e., aimed toward a mutual understanding.

These examples do reflect a somewhat positive attitude toward *social skills*. At the same time, failure in social interaction such as misunderstanding or a complete breakdown of communication can be seen as the lack of *social skills* of the people involved. Yet, I do want to highlight that people can be rude, or at least direct in their social behavior. One can yell loudly at another person to warn of an apparent danger, or decide to let a person get out of his or her chair while being fully aware that help could be useful. Here, these somewhat negative actions function in light of what is considered the appropriate behavior given the circumstances respectively to prevent the other from getting hurt and to permit the other to try something for his or herself first. Obviously, this does not mean that I consider systems that interrupt with warnings of approaching danger or systems that passively wait for people's action to be social *per se*. I argue for a contextually embedded acting upon, as well as a respectful addressing of the appropriate skillset in terms of its capabilities of dealing with '*about-content*'.

Evident examples of interactive products and systems that utilize people's *social skills* in one way or another (i.e., to mediate or act socially) can be found in the domain of communication tools. Prominent examples are social platforms where people can share their thoughts and images; translators that bridge language gaps; and emoticons that somehow provide the means to appreciate someone else's feelings. When placing these solutions within the framework of addressing *social skills* through other skills, many of the commercially available products and systems emphasise *cognitive skills* (i.e., discrete texts and emoticons are symbols to be interpreted and do little to engage our embodied skills of doing and feeling, if at all).

Our *social skills* allow us to acknowledge and appropriately act upon another person's reasoning.

These examples sketch a distinction as to which kind of *social skills* (*perceptual-motor, emotional,* or *cognitive*) are affected. These *social skills* are highly interwoven in one's actual being-in-the-(holistic)-world, although elaborated separately here for design-practical reasons. Indeed, people's everyday activities cannot be dissected and organized into three separate categories. Rather, everyday situations appeal to all of a person's skills in a complex and interconnected way.

Looking at interaction design, however, I still see, as mentioned throughout the work, that designers are taking a predominantly less holistic approach to the experiences they are designing for. I attribute this to a thorough under appreciation of people's *social skills* or skillset as a whole. Before I elaborate on how the interaction design of products and systems can benefit from appealing to skills in a respectful manner and how to design for this, I first exemplify the four skills through four light designs and further express what I consider to be disrespectful in design.

Four Light Designs

To briefly illustrate how these four skills (i.e., *perceptual-motor, emotional, cognitive,* and *social skills*) can be addressed in design and to set the stage for the remainder of this dissertation, I describe four light designs[16]. Even though these four designs evidently serve the same purpose, i.e., providing light, they have their own distinct interaction design paradigms and qualities in use.

[16] The four described light designs do not singly address one skill, however, they dominantly rely on one in particular. I do not favor one design over the others. They serve different purposes.

Fonckel

Designed by Philip Ross, the Fonckel is a lamp that is not controlled via a discrete on/off switch but via embodied interaction; the light appears where the lamp is touched. This occurs in a direct and continuous manner, providing an engaging interaction with the light (not the lamp). The user does not interact with the lamp through symbols or via representations, but through direct and immediate interaction with the surface that makes the light appear (Ross, 2008; Ross & Wensveen, 2010). The Fonckel addresses the *perceptual-motor skills* of people, in particular utilizing the strength of one's action-possibilities. This lamp strongly connects one's physical action to the visual reaction, eliciting the convergence of perception and action in the interaction design (Stienstra, Bruns Alonso, Wensveen & Kuenen, 2012).

Comfort Lamp

Together with Axl Pizzinini, Federico Tecchi, Arne Wessels, and Lilian Admiraal I designed the Comfort Lamp. The Comfort Lamp is a lamp for children who are afraid in the dark. Through the use of a soft toy as controller, this lamp empowers children who are scared in the dark by lighting up their room for them to see that there is nothing to be afraid of. The child's natural cues of discomfort, such as holding tightly to the soft toy, generate a comforting light in the bedroom, thus providing an intimate sense of comfort and security. The more the soft toy is squeezed, the more the room lights up. This lamp addresses the *emotional skills* of the child, in that, it utilizes the embodied and emotional expression of desiring light (i.e., embracing the soft toy to seek comfort).

Philips Hue Most functional light switches and controls primarily addresses people's *cognitive skills.* By touching a button or switch, we can simply turn on the light in the space. Some lamps allow for brightness or colors to be changed, often enabled by a (rotary) controller at which the colors or brightness can be set, i.e., a dimmer. In order to use these often discrete and sometimes even unlabeled toggles, that we have grown quite accustomed to, we rely on our capabilities to remember and distribute our cognition to the environment by finding reference, and understanding its systematics. It is when we interact via representations in the form of, for example, buttons, that our *cognitive skills* are addressed. Our engagements with those representations, at first, often occur in a *present-at-hand* manner as we do not directly interact with the matter, i.e., the light, and have to grow accustomed to use them.

Perception Rug Designed by Eva Deckers, this Perception Rug has the capability of commencing a "conversation" with the people walking on it. The light that is embedded in the rug moves over the floor and can sense when it is perceived (Deckers, 2013; Deckers, Lévy, Wensveen, Ahn & Overbeeke, 2012). This opens up the possibility for social behavior. Once it knows that it has the user's attention, the light spot can potentially persuade or direct the user through its movements, e.g., light stripes on an airplane aisle can direct people to the nearest exit. I consider this work to address one's *social skills,* as it intends to capture the intentions of people and furthermore act upon those intentions in an appropriate manner. This is slightly different than the current way that lights moves down an isle in the airplane, in order to persuade people to follow its direction. In contrast, the light incorporated in the Perceptive Rug engages with people in a direct and reciprocal manner.

Disrespectful Design

Even though the interaction with products and systems occurs on a *perceptual-motor* level, i.e., in most of the cases people still have to physically touch a product or system in order to make something happen, most interactive products and systems predominantly address people's *cognitive skills*. Designers often presuppose and rely on the tools at hand that enable them to create sequences, labels, and hierarchies resulting in products and systems that inherently make people deal with representations and other disembodied control. As such, most interactive products and systems urge people to use their *cognitive skills* and make less use our *perceptual-motor, emotional,* and *social skills.* Nonetheless, it is somewhat less apparent what the consequences of this are.

Design Reduces

Take the example of buttons and switches. They have flooded our everyday lives and seem to function as they should. They can easily turn on or off appliances, set specific channels and modes, navigate through menus, or simply trigger a functionality. To me, there is more to human touch (Stienstra, Overbeeke & Wensveen, 2011[a]). Consider the rich repertoire of emotions people are able to hold and express. People can be gentle, mad, obtrusive, firm, considerate, comforting, and so forth. Yet, when they use a button or switch, this range is suddenly reduced to the mere access of a predefined function, and the appliance is not addressing these emotions. Buttons and switches are lenient; they (most of the time) do what you expect them to do once you have figured out their purpose and touched them.

Design is Ignorant to Expression

Moreover, it does not matter how the button is addressed; the function will happen in its singular way. For example, if I roughly slam a light switch, the light turns on, but the same happens if I do so in a gentle manner. The mapping of input and output seems coherent insofar as the button's function (i.e., going from off to on) is consistent with the possibilities of the light (i.e., going from off to on). I will not deny that there are circumstances in which a simple button is extremely useful. In my view, however, there is often a mismatch between the capabilities of the human body and the limited capabilities of the light-switch (i.e., people convey so much more with their hands when addressing a button than what it allows for). Although buttons may seem innocent, I believe they are reductive in nature. In short, 'buttons' underuse people's skills, are lenient, and are thus ignorant to the nuance of people's expression. Consequently, such reductive tools make people careless about their expression, as their behavior is not reflected in the way they engage with the button. If people experienced the effect of their actions, they could have the opportunity to make sense of those actions in relation to their background.

Of course, it is not just one button that will cause harm. At times, it is certainly a well-grounded decision to have a button that is singular in its function. But, on a broader scale, the world people engage with is filled with straight lines, reductions, simplifications, and disembodiments, as evidenced in most architecture, bureaucracy, and so forth. By contrast, if artefacts were designed to respect people's more-than-abstracted capabilities, people are invited to live up to their embodied potential.

Design Restrains

In addition to limiting people's full expression, reduction is often guiding. For instance, keyboards have four buttons used for giving directions. In this schema, up, down, left, and right become more than just representative of directions; they become the directions in which people 'think'. If people's rich, expressive capabilities were opened up, they could explore what lies in between the obvious options.

Design Addresses People's Capabilities in an Unbalanced Manner

Most artefacts come with a guide. Even if it is not needed to understand how the artefact works, it is needed when the artefact fails to work, or needs an update or upgrade (Frens & Overbeeke, 2009). Besides the guides demanding a lot of people's *cognitive skills,* most of the interfaces of the products they engage with address the same skills, i.e., those contrary to *perceptual-motor, emotional,* or *social skills.*

With a distinction of skills, a dangerous dichotomy is implied. A dichotomy that reinforces a body-mind split that phenomenology and ecological psychology attempt to undermine. To phenomenology it is evident that the body includes body and mind. The four skills are to considered useful for design as they highlight the neglected and under addressed skills of holistic human capabilities.

Earthly Engagement is Taken for Granted

In his final work, Merleau-Ponty (1968) expands the perspective that body and mind are not to be separated by making a claim that body and world are united as well. In other words, he points out how body and world intertwine and develop one another as one. Inherently, he reinstates the roots people have in a earthly engagement (Abram, 1996). When looking from a design perspective, the world is dematerializing as it becomes more and more digital (Bannon, 2005; Thackara, 2005; Verbeek, 2005; Kaptelinin & Nardi, 2006; Campenhout, Frens, Overbeeke, Standaert & Peremans, 2013). This causes people to lose a grip on the world. In turn, people slowly begin to lose the opportunities to express themselves in an embodied manner (Abram, 2010). If products and systems address the full human skillset, people might not need to 'clear their minds' or 'escape reality' due to a mental overload (Buxton, 1994). Rather, people could reestablish a relationship with Earth as they better understand their footing in it through 'earthly' engagements.

Inappropriate Technology

An example often used to illustrate how disrespectful technology can be is the 'vending machine'. Most vending machines require users to remember codes that represent the drink they are interested in. Then, users need to press that code, deposit the necessary money, confirm their order, and receive their drink along with any change. But where is the drink received? Often at the user's feet, which requires the user to bend over and thread his or her arms through a narrow hatch. If people remembered their nature as human beings (i.e., that people have a holistic skillset and that they are deeply rooted and entangled with a physical earth and other social beings), they could prevent themselves from accepting things from technologies that they in most cases would not accept from other human beings.

Skill Acquisition is Taken for Granted

Most products and systems do not take the skillful development of a user into account. In terms of the skill–challenge relation, designed-for interactions can be too difficult or too easy (Buxton, 1994; Janlert & Stolterman, 2010). I am not arguing to make everything simple. On the contrary, I would not want technologies to take over my engagements. I, among many others, still find pleasure in challenges and the act of learning, in acquiring a skill (Csíkszentmihályi, 1990; 1996). Rather, if human capabilities were considered the means for people to engage with the world, designers could address people in a way they could handle and perhaps challenge them to grow (their skills).

Highly complex products in the digital world enlist complex functions, hierarchies, system architectures, procedures, and so on that need to be used by humans. Design should comply with people's rich continuous perception instead of the boundaries when organizing thoughts. Defined objects, actions, rules, discrete representations, sequences, and hierarchies are the building blocks of most product interface interaction. This contrasts with how people perceive and interact with the world. I believe that human perception is holistic, defined as a trans-modal contextual experience; associative, defined as meaningful behavioral opportunities provided by the body in a Gibsonian way; and continuous, defined as a continuous flow of interaction more than discrete state changes. The richness and limitations of people's experience are rooted in all their human capabilities; their unique *perceptual-motor*, *emotional, cognitive* and *social skills*. With the increasing computational power, people do no longer have to depend on generalizing models, absolute numbers, averages, and predefined judgments. Computing no longer needs to depend on its own simplified, abstracted life-world as it slowly starts to understand the bigger picture of life and its sensitivities.

Approach to Design and Research

The central topic in my work is exploring the consequences of a phenomenology and ecological psychology-inspired approach to designing intelligent products and systems and to make steps towards what I call *respectful embodied interactions*. In the first place, I aim at constructing a theory of interaction that informs the field of interaction design about generic qualities and characteristics for (phenomenology-inspired) interaction design. My work thus seeks to provide design-relevant knowledge (i.e., practices, approaches, and tools as presented in Part III) by addressing gaps between theory (phenomenology and ecological psychology) and practice (phenomenology-inspired product and system design).

In order to do so, I embrace the philosophy of phenomenology to its fullest extent. In other words, to generate design-relevant knowledge from the theory, as a design researcher I find it crucial to fully embody (i.e., in both doing, feeling, and thinking) a phenomenological stance in order to bring out its essence. As hinted at before, utilizing phenomenology has several consequences for interaction design (i.e., the act of designing; the interaction with designing systems, products, and services; supporting methods, processes, frameworks, techniques and tools; and the way of doing design research). These consequences will be addressed throughout the remainder of this dissertation.

My approach, quite frankly, diffuses the act of designing and doing research. In effect, and for practical reasons, I have adopted the *reflective transformative design process* (Hummels & Frens, 2009, 2011; Gardien, Djajadiningrat, Hummels & Brombacher, 2014) and adapted it towards a reflective design research process. This reflective transformative approach to designing has been present throughout my education as (interaction) designer. The approach encourages quick iterations and transitions between five core design activities (i.e., making, thinking, envisioning, integrating, and exploring and validating in context) with an emphasis on reflection.

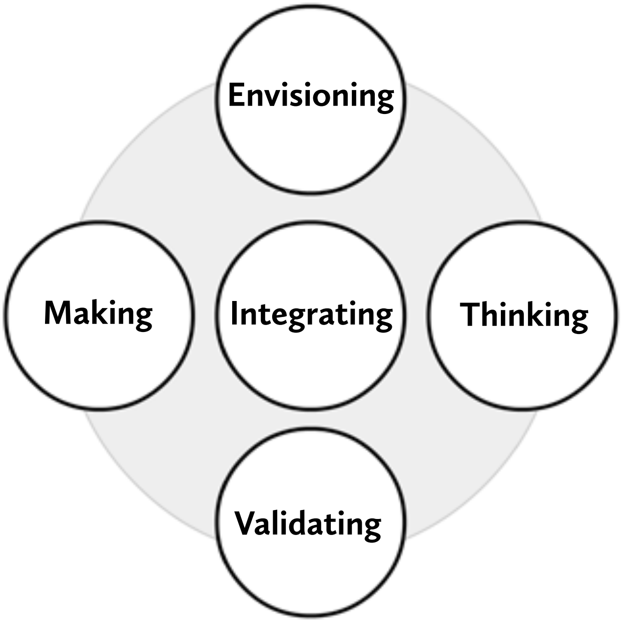


Fig 2. Reflective Transformative Design Process used to direct my research through design process. Core design and research activities are united by reflection *in* and *on* action (Hummels & Frens, 2009; 2011).

What appeals to me in relation to my design endeavors and my theory-informed approach to design research is that this design process supports a designerly way of doing. Through critical reflection, designer researchers can develop their own process that fits best with what is currently needed. It allows them to give direction to their work in a way that appeals to their own skills of doing and validating in context. In doing so, designers are able to quickly confirm their designerly hunches of what they envision a design to be.

In the context of this dissertation, I use the reflective transformative design process to give form to the design-practicality of the theory that I aim to embody in the exemplars. As such, the driving force behind the design research process is the *envisioning* activity, in which the theory-inspired vision, i.e., the respectful embodied interactions design perspective is shaped through making, thinking, integrating, and exploring and validating in context, will flesh out throughout the iterations.

It is my intention to develop a well-grounded, rigorous, and disciplined set of propositions and insights that can then be appropriated to meet the needs of practicing designers from a practice-based and theoretically sound (i.e., phenomenology and ecological psychology-inspired) understanding of interaction design. After elaborating the design exemplars of this dissertation in Part II, in Part III the design propositions are further reviewed in relation to their implications for addressing human capabilities, their design-practical notions, commonalities, and consequences for *designing*. The first chapter of Part III, Doing Design Research, however, will elaborate and reflect on the above mentioned reflective transformative approach taken to conduct my *design research*. That is, I will show how the taken approach is used to generate knowledge, and how it relates to other approaches within design research.

Part II: Designed Exemplars

In what follows, I discuss four designed exemplar projects that take on the theoretical ideas outlined. I elaborate on their design context and challenges, their interaction design and implementation, their consequences for usage, and their relation to the earlier established perspective on respectful embodied interactions. The first three designed exemplars (i.e., the Augmented Speed-Skate Experience, the Sensible Alternative, and the designs for empathic interaction in an independent living context) are presented as compositional wholes. They are designs that have been developed for use and have been validated as such.

By contrast, the fourth designed exemplar (i.e., the Sensible Door) serves to explore opportunities that emerged from the other three exemplars. My aim was to bring elements together and explore them in a context and approach in which several products and entities would function as a system. As such, this last exemplar serves as a platform for exploring design particularities that fit with the envisioned perspective on respectful embodied interactions more than it does as a compositional whole that serves a particular use function. In this respect, the evaluations and insights from this fourth exemplar reside on different levels, in that, they explore (networked) system behavioral qualities.

The following project was developed according to the phenomenology-derived prerequisites that people are *unique* and that meaning emerges *in* interaction. The project conducted as industrial design student was mainly solution-driven, i.e., the design process was aimed at fulfilling use requirements rather than gaining academic insights. In terms of this dissertation, the project is used to reinforce and expand on the *status quo* of interaction design theory on embodiment and establish design-practical insights for applying the proposed solution.

Augmented Speed-Skate Experience[17]

In this chapter, I describe the Augmented Speed-Skate Experience (Stienstra, 2009) project, an applied movement sonification used as an auditory interface for professional speed-skaters. For this project, I designed and developed a system that provides professional speed-skaters with real-time feedback on speed-skating technique by offering access to an extra sense modality, i.e., sound. With this, the 'complexity' is incorporated directly by the athlete and not through an external system generating representational or derived judgments of how to improve speed-skating technique.

On a theoretical level, this interactive artefact explored (the conditions for) mapping information directly to the body. This was done through the evaluation of several sets of continuous parameter mappings in a field-lab setup. The results from these qualitative evaluations showed that the movement sonification mappings caused *trans-modal convergence* (Stienstra, 2009), resulting in actual improvement. For the Augmented Speed-Skate Experience, I designed a movement-sonification mapping of speed-skating technique that was informative, motivational, non-coercive, robust, and easy to apply. Feedback was designed according to existing natural acoustic conventions that inherently coupled to the speed-skater's actions. This coupling allowed for complex 'about-content' to be assessed and embodied by the athletes, thus enabling them to improve their skating technique (Stienstra, Overbeeke & Wensveen, 2011[b]).

[17] This chapter is build upon snippets of (a) Stienstra, J.T., Overbeeke, C.J. & Wensveen, S.A.G. (2011). Embodying Complexity Through Movement Sonification: Case Study on Empowering the Speed-skater. In *Proc. of CHItaly'11,* (pp.39-44). New York: ACM Press and (b) Stienstra, J.T. (2009). *Augmented Speed-Skate Experience, Applied Movement Sonification.* Eindhoven: Eindhoven University of Technology. Audio visual: 10.13140/RG.2.1.4949.1361

Design Context and Challenge

For this project, developed throughout 2008 and 2009, I reached out to the TVM Schaatsploeg, a world-class professional speed-skating team led by head coach Gerard Kemkers, who has been responsible for bringing out the best of Sven Kramer, Erben Wennemars, and Ireen Wust, among other athletes[18]. This speed-skating team served as both client and expert, and was closely involved in and committed to the project. They provided their knowledge, equipment, and the necessary facilities.

[18] These athletes are known to be the best of their generation. Sven Kramer and Ireen Wust collectively tally 7 Olympic Gold medals, 89 World-cup victories, and 40 World Championships, to date.

The client was extremely interested in the development of a measurement platform with which to gain insight into the technique of speed-skating and thus improve their training methods. To them, it was important to acknowledge the individuality of each athlete and to arrive at a solution that could be used in an actual professional setting without adjustments to equipment or environment.

Basically, speed-skating is all about speed – being the fastest over a set distance using speed-skates. The athlete's target is to achieve and reproduce a perfect speed-skate stroke. This stroke is experienced as 'flow', as the athlete is able to transfer all energy via the ice into the forward direction, producing a sensation of the whole body becoming one with the ice. Theoretically, the athlete should prevent having both speed-skates on the ice at the same time, as the power distributed through the push-off speed-skate will be lost in the leaning speed-skate. For the athlete, it is difficult to feel this front–back and left–right distribution of power during the stroke.

The nature of this kind of '*about-content*' (i.e., the appropriate '*schwung*') can hardly be assessed using computer systems; models of an optimal technique are non-existent, and systems are not yet understanding. The human body, on the other hand, seems to be able to deal with complexity of the same nature as it emerges in real life.

Fig 3. Ireen Wust skating with the 3rd prototype, early 2008. This version was wired, computation was achieved on laptop that was carried along in the backpack.

In this project, I aimed at exploiting this inherent ability of the body by augmenting its inherent 'about-content' sources (e.g., pressure on the foot) through sound, i.e., making that pressure audible. The 'about-content' is therefore generated by and returned in real-time to the athlete, developing a loop within the system of the athlete. In effect, the Augmented Speed-Skate Experience incorporates unfelt 'about-content' into the experience of speed-skating.

The objective of the Augmented Speed-Skate Experience was thus to create an auditory mapping that would provide the speed-skater with informative, motivational, non-coercive, robust, and easy-to-learn feedback (Stienstra, Overbeeke & Wensveen, 2011[b]). In the first place, it was paramount to discover whether movement sonification (i.e., the form of auditory interface) could actually be used as intended, and whether it could bypass complex computing and representation (e.g., on a screen) in the embodiment of 'about-content'. In other words, in this work I explored whether a movement that is sonified can be recognized, learned, and reproduced. Furthermore, to design a movement-sonification mapping, I had to explore conditions for mapping auditory information to the body. This exploration focused on parameter selection and feedback methodologies within the chosen form of continuous movement sonification.

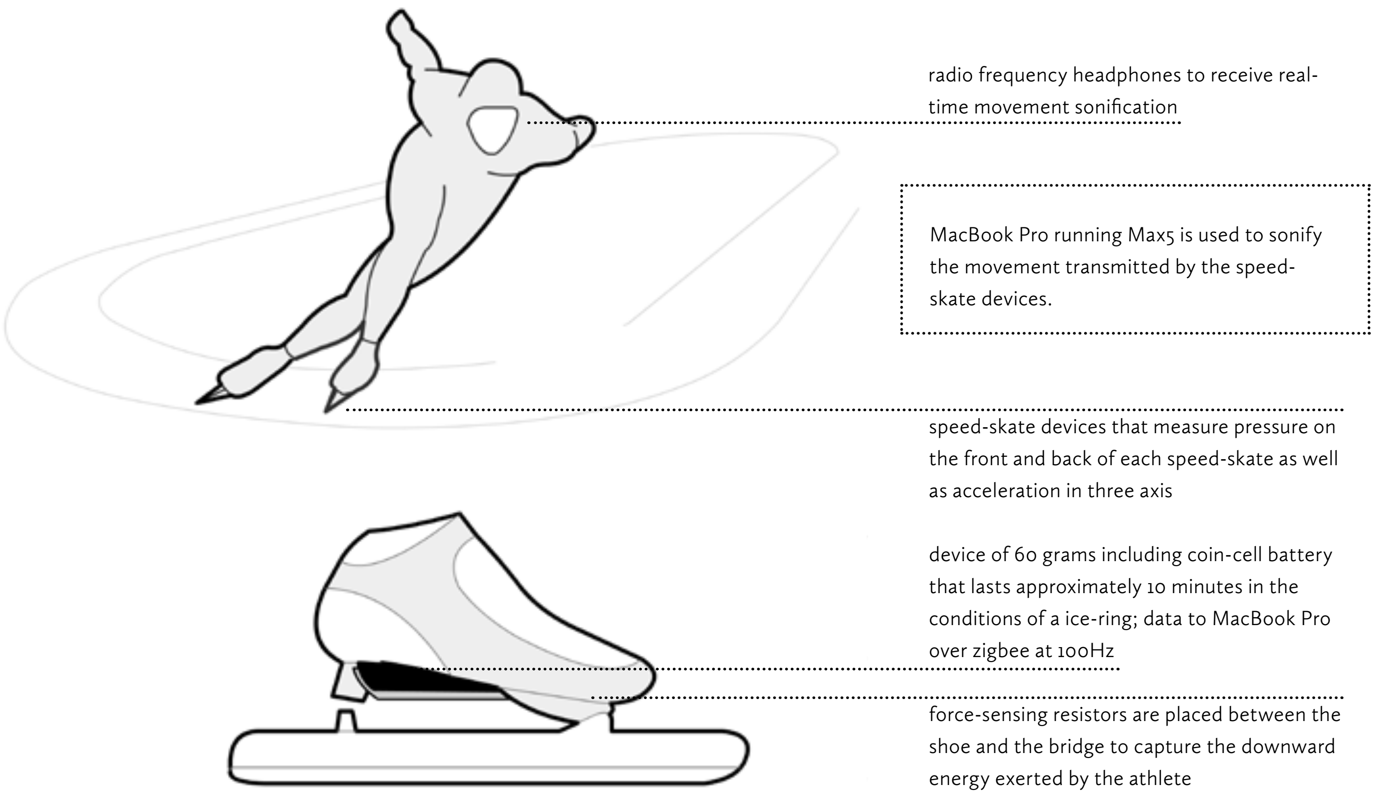


Fig 4. The Augmented Speed-skate Experience.

Design and Implementation

The platform consists of one pair of speed-skate devices, one for each speed-skate, with a continuous wireless connection to a central processor in the form of a MacBook Pro by Apple. MAX5 by Cycling '74 processes the movement data, obtained at an acquisition rate of 100Hz, into sonification with latency under 150ms. Weighing only 60 grams, the speed-skate platform does not interfere with professional speed-skating, allowing field-lab studies.

A radio frequency headphones deliver the soundscape to the athlete. This enables a real-time feedback[19] loop. Besides processing a sonification, the central processor records the movement data. The speed-skate devices are capable of measuring forces at the front and back of the speed-skate, distributed by the athlete in the vertical direction on the sagittal plane, and acceleration in three directions.

[19] In the case of the Augmented Speed-Skate Experience, the feedback converges with *feedforward*.

Movement Sonification

Sonification is the translation of any kind of data into non-speech audio. Sonification has been applied to a number of explorative and high-dimensional analysis tasks, such as navigation, aural supervision of health measurements, fossil classification, and software debugging by offering an auditory display (Henkelmann, 2007; Kramer, 1994). Sonification can also be used to enhance the performance of human perception in the field of motor control and motor learning (Effenberg & Mechling, 2001; Effenberg, 2007). Auditory bio-feedback can support motor perception and control in sports, medical therapy, and rehabilitation by offering supportive or new channels of proprioception (Henkelmann, 2007; Hermann, Honer & Ritter, 2006; Shea, Wulf, Park, & Gaunt, 2001).

Auditory Perception

The richness of acoustic information in almost every human activity, like the sound of a closing door, reveals information about the interactants' impact, material, stiffness, texture, and energy (Hermann, Honer & Ritter, 2006). Sounds have unique qualities caused by the materials' physical parameters, which result in different timbres. The kinetic and dynamic auditory properties caused by the action result in duration and amplitude. Auditory perception is well-suited for perceiving these time-critical structures about kinetic and dynamic movement data (Effenberg, 2005; Effenberg, Melzer, Weber & Zinke, 2005). Even though motor learning is dominated by the visual field, auditory perception offers unique subtle temporal resolution, as well as enormous integrative capacity (Effenberg, Melzer, Weber & Zinke, 2005; Effenberg, 2007).

These auditory perceptive abilities make movement sonification an appropriate method for providing supportive feedback on movement for motor learning. Movement sonification should be created by focusing on auditory perception and the integration of multi-modal perception for optimal motor control. The more precisely and concisely the perceptual process can be designed, the more efficiently the learning process can be arranged (Effenberg, 2005; Effenberg, Melzer, Weber & Zinke, 2005; Hermann, Honer & Ritter, 2006).

Fig 6. The force-sensing resistors are placed between the bridge and the shoe to capture down-ward forces expressed by the athlete.

Fig 7. Subsequent prototypes connected to MacBook Pro (Apple) over the zigbee protocol. The connection reached 100 meter distance, when the laptop was placed inside the speed-skate ring, the whole 400 meter track was covered.

Fig 5. Open device that shows the custom-build circuit board. An amplified analog force-sensing resistor measuring 100 kg measured at a rate of 100 Hz.

Sonificator
mapping 7 version 23

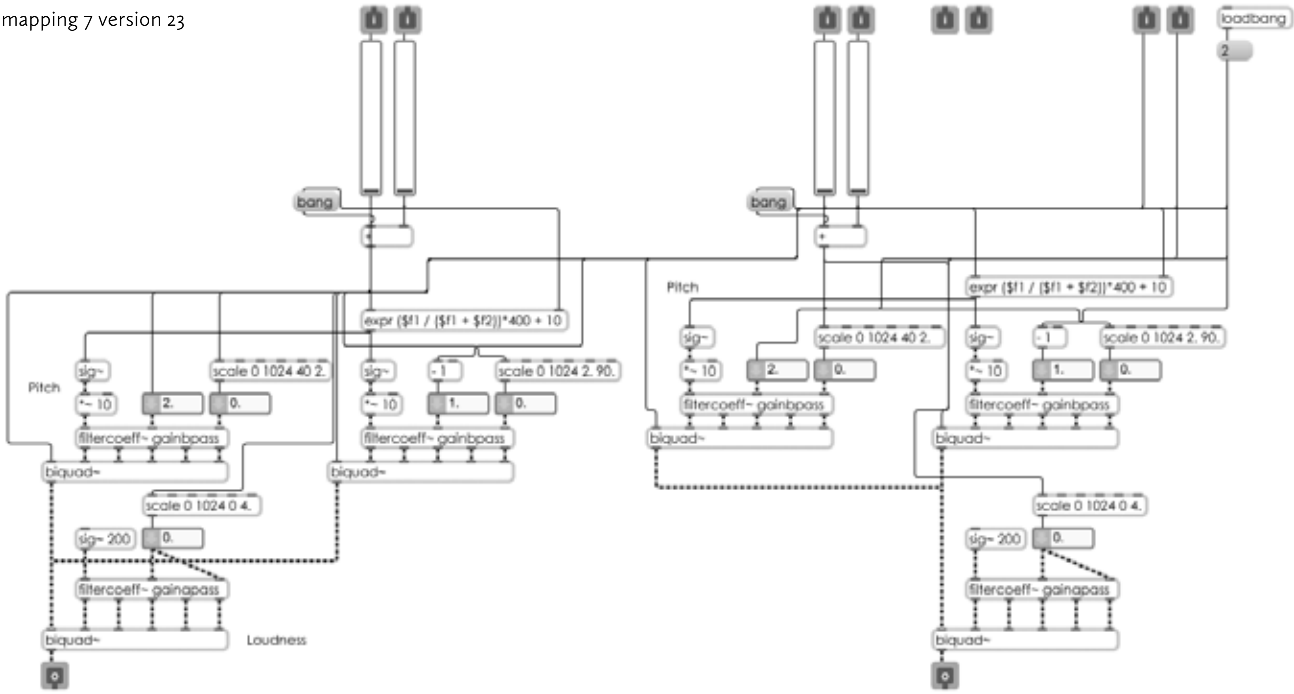


Fig 8. Max5 was used as software to create the different movement sonification mappings. It was developed in modules to enable exploration and tuning while experimenting at the speed-skate track. This screenshot shows the application of noise and bandpass filters on the (movement) data.

Sonification Techniques

Fig 9. Frouke Oonk using the Augmented Speed-skate Experience.

Sonification of data can be achieved through various techniques, such as audification, earcons, auditory icons, audio beacons, model-based sonification, and parameter mapping sonification (Henkelmann, 2007; Hermann, Honer & Ritter, 2006; Kramer, 1994). For this project, I used continuous parameter mapping sonification due to the lack of a model of optimal movement, the high demand for individual differentiation among the athletes, and the richness of the continuous movement data (Stienstra, 2009). I chose to apply band-pass filtering on the pink noise, which makes it possible to manipulate the central frequency of the noise, resulting in pitch modulation. Besides the central frequency, intensity of sound can be easily manipulated to increase the volume. The great degree of interaction between the intensity and the bandwidth of the filter provides additional parameters to manipulate within one stream of sound. The final manipulation parameter is the spectral slope of the filter, which can be used to generate speed perception. Pink noise band-pass filtering has a very natural wind and wave-like sound that allows very complex and rich information to be used.

The Auditory Interface's Layers

Parameter mapping takes place in three layers of the design. To conceive a sonification that would allow the athlete to discover and reproduce the sensation of a perfect speed-skating experience, I needed to identify the appropriate physical movement dimensions to measure. Within the movement-sonification design, this is described as the data acquisition (a), which focuses on the continuous measurement of pressure at the front and back and acceleration in three directions for both feet.

The second layer of parameter mapping is the movement data interpretation (b), which considers data-stream comparison, combination, deriving, and scaling. The ten respective raw movement data streams provide an almost endless set of opportunities. Theoretically, the measurement of acceleration in any direction would provide information on the acceleration, speed, or even jerk. Combining acceleration streams can provide the direction and speed of a speed-skate. When combining both speed-skates, the direction and speed of the athlete can be derived. Applying similar translations for the measured pressure provides new data streams, such as pressure changes, balance per speed-skate, athlete overall balance, change of balance, and so on. Even more complex data streams representing the forward speed over pressure or derived parameters such as the stroke frequency could be considered further.

Together with the last layer of the parameter mapping, which closes the feedback loop by providing the actual sonification (c), the second layer is essential for the movement-sonification design. With all these opportunities for different movement sonification mappings, it is important to narrow down the parameters used in order to provide a rich yet informative and non-coercive soundscape.

Interaction Design

The movement-sonification mapping consists of two separate continuous auditory data streams, one for each side (left and right speed-skate), creating a spatial convergence between action and reaction.

The amount of pressure exerted on the skate is sonified through the intensity and loudness of the band-pass filter. This sonification ranges on a continuous scale from the absence of sound when there is no pressure to intense loudness when there is full pressure. Foot balance is mapped through modifications in the central frequency, i.e., balancing on the backside of each speed-skate translates into a low sound, whereas balancing on the front side of the foot translates into a high-pitched sound.

Consequences for Use

The movement sonifications were used and evaluated by a professional speed-skater in context over several sessions (Stienstra, 2009; Stienstra, Overbeeke & Wensveen, 2011[b]). For about twelve hours on the ice in the speed-skate arena, I tuned the Augmented Speed-Skate Experience to the athlete, conducted field-lab studies in the form of with-without sessions, measured the data, evaluated several mappings on the ice, and conducted follow-up interviews. These activities generated a variety of insights for design and implications for the theoretical foundations, further discussed throughout the work. Here, I briefly introduce the main outcomes and implications of the applied movement sonification for the speed-skater.

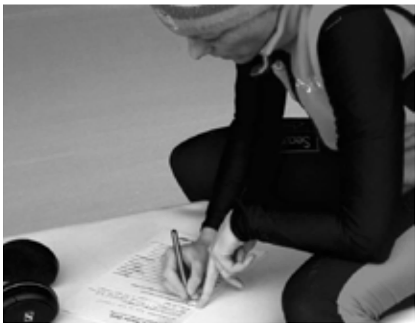


Fig 10. Frouke Oonk assessing one of the auditory mappings after a few laps trying a mapping. These assesments were combined with the

First, after a few laps of exploring, the speed-skater was able to continuously direct the speed-skate technique in such a way that the soundscape was created as intended. In other words, the movement sonification allowed the speed-skater to not only distinguish the stroke rhythm, front and back balance of each speed-skate, global balance, and amount of force exerted on the ice during the stroke, but also control it. The speed-skater found the auditory interface to be non-coercive and informative about the progress of the complete speed-skate stroke, as the sonification matched the movement intuitively. Over time, more and more dimensions of the speed-skate stroke progress became clear (Stienstra, 2009) in the direct feedback loop, such as the switch between speed-skates and the shift in force around the corners.

The athlete really enjoyed the process of exploring, discovering, practicing, and improving her speed-skate technique, and was further able to discover and reproduce the sensation of a good stroke. “I have not speed-skated this well in years” (Ik heb in jaren niet meer zo lekker geschaatst). Subsequently, I explored the reproducibility (Stienstra, 2009) of a specific speed-skate stroke and the empowerment of a specific technique of speed-skating. The results indicated that the movement sonification was recognized and learned, and converging modalities were experienced (Stienstra, Overbeeke & Wensveen, 2011[b]). The sonification of movement was perceived and interpreted as intended by the athlete. This gives me the confidence that the system worked in the way I intended it to. That is, the Augmented Speed-Skate Experience enabled athletes to easily reproduce a technique that feels most productive in the given situation.

The feedback that was designed according to existing natural acoustic conventions inherently coupled with the speed-skater's actions, allowing for complex 'about-content' streams to be assessed and incorporated by the speed-skater. The movement sonification augmented that which could not easily be sensed, enabling the speed-skater to improve her technique in real time.

Concluding Remarks

I consider the Augmented Speed-Skate Experience to be a respectful interaction design for the following reasons. First, the solution allows athletes to be in control of their actions. The 'system' does not persuade the athlete to move in a certain manner toward a certain technique; the speed-skater merely utilizes the self-generated additional 'about-content' to develop the technique to its optimum *in situ*.

Second, the solution distributes the additional 'about-content' to an underused channel. Even though the bodily skills (perceptual-motor and emotional) are already heavily used in the act of speed-skating, addressing the cognitive would take the speed-skater out of his or her flow. While gliding over the ice, the speed-skater is not distracted from the activity, and the solution becomes a seamless part of the act. This takes me to the third argument.

The 'about-content' is offered in such a way that existing streams of dealing with 'about-content' are used. The Augmented Speed-Skate Experience addresses bodily skills in a way that it is of an embodied nature. The convergence of the additional 'about-content' over the auditory channel with the 'about-content' available in the proprioceptive system enables the speed-skater to integrate the extra sense in the system. This convergence is enabled by the qualities of the movement sonification, and in particular the directness of the feedback (i.e., enabling convergence) and the coupling of expressive form.

Despite that only one design was made, different athletes create their meaning with the Augmented Speed-Skate Experience. For each athlete, unique characteristics of the speed-skate technique are brought forward to perception and empowered the speed-skate technique meaningfully. In this sense, the design respectfully addresses the uniqueness of people.

Sensible Alternative[20]

The Sensible Alternative (Stienstra, Overbeeke & Wensveen, 2011[a]) concept was designed in the fall of 2009 to enable smartphone users to navigate between applications. It was designed to provide an alternative embodied manner of interacting with smartphones to counter the heavy reliance on people's *cognitive skills*, i.e., remembering menu structures, hierarchies, and so forth.

In short, a touch-sensitive spot was added to the back of a smartphone[21], opening up an alternative layer of interaction between human and machine on top of hierarchical system architectures[22]. This spot enables access to functionality through rich expressive and embodied interaction (i.e., utilizing our *perceptual-motor* and *emotional skills* to bypass the cognitive load of use embedded in the system hierarchies), and further explores *contextuality* and relevancy from an action-possibility-dependent and use-dependent perspective.

Design Context and Challenge

Smartphone interface and platform developers have tended to focus more and more on 'naturalness' in interface design. Enabled by acceleration sensors and a multi-touch screens, smartphone developers were able to provide a mobile phone platform that allowed for 'natural' interactions, such as swiping through maps and a more embodied manner of steering in games. Apple's iPhone operating system and its interaction style characteristics were used as the starting point for the development of the Sensible Alternative concept.

The interface of the operating system that was chosen as departure, is experienced as user-friendly and intuitive (Ullrich & Diefenbach, 2010); however, there are some interaction style elements that I intended to address with the design. The first characteristic was the manner of accessing applications, which, back in 2009, was done via spatially ordered application icons in a Home menu. In order to navigate the system, users were required to build a cognitive model of understanding functions coupled to locations (of icons).

[20] This chapter contains parts from (a) Stienstra, J.T., Overbeeke, C.J. & Wensveen, S.A.G. (2011[a]). There is More in a Single Touch: Mapping the Continuous to the Discrete. In *Proc. of CHItaly'11,* (pp.27-32). New York: ACM Press and (b) Stienstra, J.T. (2010). *The Sensible Alternative, Associative Navigation Interaction.* Eindhoven: Eindhoven University of Technology. Complementary footage: 10.13140/RG.2.2.32916.71043

[21] Since 2013, four years after the conception of the Sensible Alternative, LG, Xiaomi and Huewei have started implementing buttons on the back of their smartphones.

[22] Force touch, as first unveiled by Apple in 2014, is now used to enable functionalities similar to my work. The difference, however, is that I sought to utilize expression exerted whereas force touch utilizes a more discrete approach to pressure exertion, i.e., three discrete pressure thresholds can be used to access three layers of functionality. Google and Apple more and more start to integrate their applications around a current context as evidenced in Google now.

The second characteristic I attempted to address with the Sensible Alternative concept was the lack of data integration in the smartphone. Moving from one application to another to access functions mostly required users to memorize the content and manually enter it in the newly opened application. This forced people to approach content via separate applications, mostly guided through complex layers of abstractions, hierarchy, and related menu structures all requiring a cognitive understanding of functions.

Similar to other attempts in the field of human computer interaction, the Sensible Alternative aimed at matching the human holistic, associative, and continuous experience to the discrete, hierarchical, and procedural computations incorporated into the product's architecture. My intent was to move away from the cognitive overload caused by hierarchical and menu structures that force the spatial and sequential learning of information, toward the body's capability of handling the kind of complexity achieved with the Augmented Speed-Skate Experience.

One of the foci for human computer interaction became to relieve users from hierarchical or cognitive overload. Several attempts have been made over the past decades to provide and explore an alternative to mainstream (cognitive) approaches towards interaction design. These initiatives can be found both on a theoretical and a practical level, as well as in different areas, such as graphical user interfaces, digital media, natural interaction, tangible and embodied interaction. For example, Bannon and Bødker (1991); Kuutti and Bannon (1993; 2014); Buxton (1994); Rauterberg and Steiger (1996); Ishii and Ullmer (1997); Seaman (1998); Dewdney and Ride (2006); Shaer and Hornecker (2009); Ullrich and Diefenbach (2010); Ishii, Lakatos, Bonanni and Labrune (2012).

Design and Implementation

To bypass the hierarchical navigation of the smartphone's interface and the resulting cognitive overload, I designed an interface that would map the body's capabilities to the system's capabilities. In this mapping, I embodied the access of functions and depth (i.e., the layeredness of applications in revealing more information) in the navigation's hierarchy. In the design, the back of the smartphone is equipped with a pressure sensitive button that enables the user to 'push-through' enriched application icons relevant for use. The visual appearance of the icons is inherently connected to the amount of pressure exerted on the button. In this way, the convergence of perceptual-motor streams with actions in terms of dynamics, expression, and depth over time is achieved.

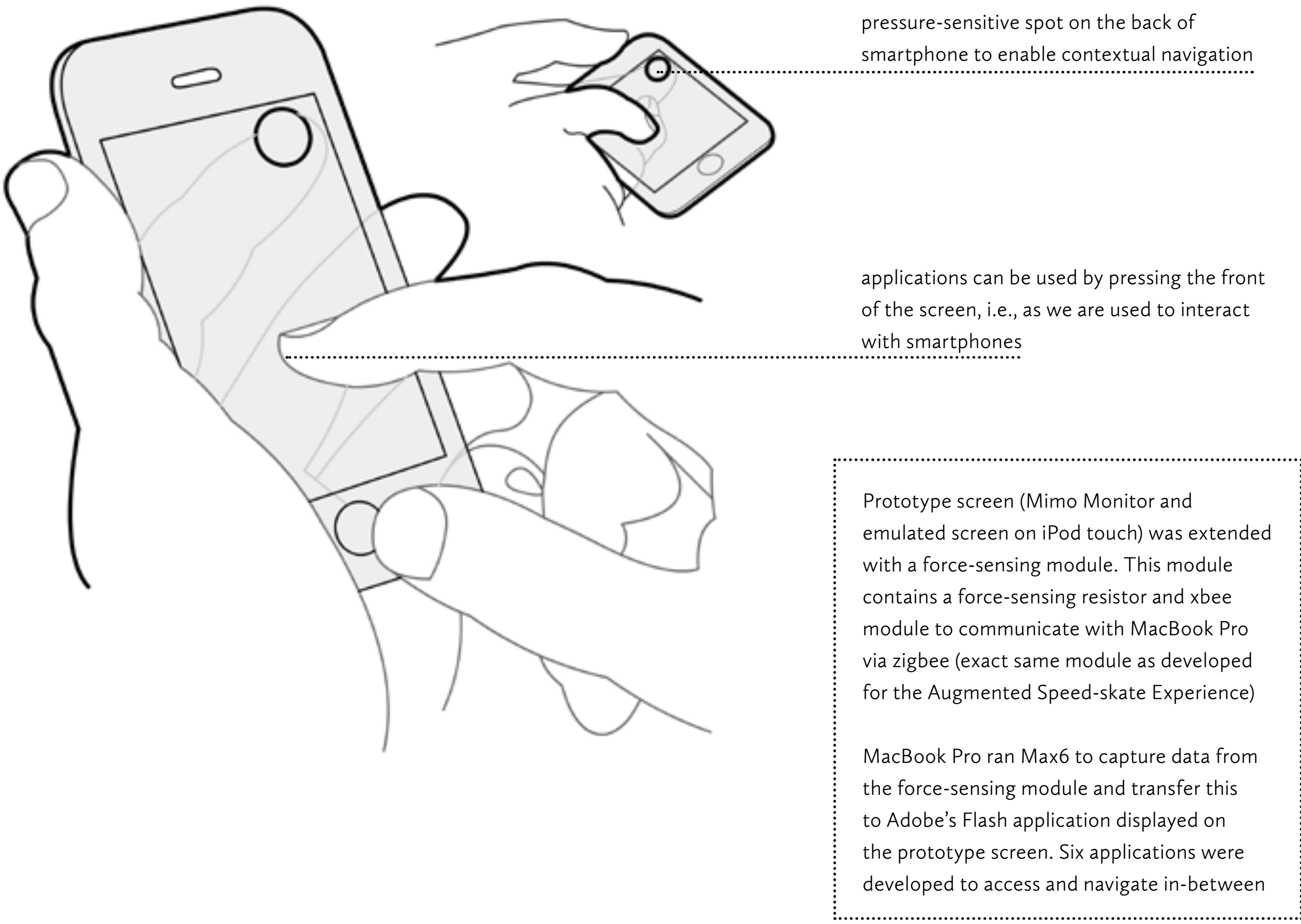


Fig 11. The Sensible Alternative's components are limited to a smartphone extended with a pressure sensitive area. The prototype was developed on a MacBook Pro on which an additional navigation layer was integrated in the operating system.

Calendar The calendar application is used to view, add and edit events in the calendar. The prototype is limited to viewing events scheduled in one week only.

Trein The Trein application is used to plan and view train travelling schedules and disruptions. Within the prototype this is limited to viewing.

Contacts The Contacts application allows us to search, edit and view contact information of people. The prototype merely allows for viewing specific contacts.

Weather The Weather application shows the weather forecast on locations that can be added. In the prototype only a few weather forecast on predefined locations can be accessed.

Mail The Mail application is used to send receive and read e-mails. In the prototype a predefined e-mail can be read.

Maps The Maps application can be used to pan and zoom over maps. The prototype allows for limited zoom and pan over limited locations via a *push-and-arrive* principle due the lack of multi-touch.

Fig 12. The Sensible Alternative's six inter-connected applications that were rebuild and extended in Adobe Flash (actionscript 3.0)

Fig 13. Consecutive screenshots of the mail application. More pressure on the back is applied from top to bottom. This reveals more information and access to relevant applications.

Applications that enlist specific functions are suggested on the basis of, on the one hand, content-type action-possibilities in the form of likelihoods and, on the other, user-made and personalized action-possibilities. Applications run as usual, i.e., they function as we know them from operating systems without the Sensible Alternative, and can be accessed through their common touch screen controls. Suggested applications can be (1) explored by a simple nudge; their content can be (2) revealed by a persistent nudge; or they can be (3) accessed through the front by touching the relevant icon.

In the figures to the left, three consecutive screenshots of the interaction layer are shown. On the top image, little force is exerted on the pressure-sensitive spot, which causes relevant applications to appear. Applications such as the Calendar, Map, Weather, and Train relate to the email that is presently in use, as the email involves a meeting request. If more pressure is applied, more information related to the email and related context appears in the icons, such as the actual weather forecast for the event and train itinerary suggestions.

As shown in the figures the pressure-sensitive spot on the back of the phone is pressed increasingly over the subsequent screenshots, causing the relevant application icons to appear and more information to be given. The Sensible Alternative resolves navigation in a complex structure by providing direct access to applications that are most relevant for the user *in situ*.

Interaction Design

The pressure-sensitive area on the back of the smartphone can be pressed at any time. By doing this, application icons that are relevant based on overlapping content-types appear through the running application. The pressure-sensitive area is not limited to 'on' or 'off', but is sensitive to gradations of pressure exerted by the user.

The amount of pressure placed on the back of the smartphone is mapped to the amount of information available on the screen. In the first place, this concerns the appearance of the icons, namely that the most relevant applications come in earlier as they need less pressure. Less relevant applications require more force to be pushed through the application that is running. In the second place, the icons dynamically grow and expand to provide additional widget-like information. Again, the more the back of the phone is pressed, the bigger the icons grow on the screen.

Furthermore, the expression of how the icons appear is mapped to the way the pressure-sensitive area is addressed, i.e., pushing slowly brings the icons forward in a slow and controlled manner, while a wild push makes the icons appear wildly. Application icons that are strongly related to the context appear first, but are smoothly followed by their fellow icons. As the pressure is released, icons disappear in a pleasing manner, leaving a trace of which applications are relevant for the user. In effect, most relevant application icons will disappear after the less relevant ones, icons 'fall back' into the running application when the pressure is released.

I am in a rush; for the next meeting I need to travel. While looking at the details, I swiftly bring in the contact application to find out more about the attendees, the minutes I need to catch up on, and the weather forecast. Good, it will be sunny; perhaps we can find a spot in the sun. There it is, the suggested public transport; if I start walking now, I could easily make it to the train.

Defining Relevance in Context

In the worst case scenario, all available application icons would appear in the screen when the pressure-sensitive area is fully pushed, because all applications relate to all other applications. This would result in visual clutter and information overload. In this design concept, the idea that governs the relations between applications is primarily based on shared content-types. This establishes relations between applications that are able to compute currently available content (i.e., contain content of a manipulable content-type), providing content-dependent action-possibilities.

Shared Content-Types

The relations between applications are based on shared content-types as the starting weight of the *likelihood* that represents the relevance. According to this principle, applications are related to one another based on what they can do with certain content-types. Applications can share content-types such as time and location, which can then be separated respectively into years, months, days, hours, minutes, and other periods describing time phases, and the world, continents, countries, states, provinces, cities, neighborhoods, streets, homes, and other location scales. Other content types are, for example, numbers, names of people, companies, and events. These enable various relations throughout referencing applications such as mail, news bulletins, stock information applications, and video and audio libraries.

Time and location are considered content-types that vary in size and dimensions and, as described before, are scalable. By manipulating these dimensions, it is possible to zoom in and out. For location, this is most likely to be carried out in the Maps application, while time scaling is most likely to be accomplished in the Calendar. The main idea is to share available content with applications that can do something with it, focused on its scale. This requires a system infrastructure that understands content-types, their scale, and which applications are suitable to handle them. In addition, these relevant applications need to compute these data on the fly, even before appearing as associated icons that contain computed data.

Initiating Likelihoods

Besides the shared-content and action-possibility weight, a secondary weight that influences the relevance (i.e., likelihood) is a learning weight based on frequency of use in specific contexts. This creates personalized relations between applications. If applications are not accessed often, they lose relevance compared to frequently used ones. When relations form, people are provided with their unique personalized relevant applications. New, little weighted relations can be initiated via the regular Home menu. Frequency of use informs context dependency, based on the actual time and place of used relations. For example, the relevancy relation weight (likelihood) of setting the alarm clock grows and becomes available late in the evening.

Accessing Application Depth

Application icons appear according to their relevance and the amount of force that is used to push in the applications. This provides the user with the opportunity to view all possible related applications or just the most relevant. Furthermore, the icons contain information that does not require the user to enter the applications, as information is provided in a widget-like manner. For example, the Train application icon gradually shows more information that might be useful: at first the icon, later expanded with a proposed travel itinerary.

The same goes for what at the time was a static 'sunny, 23 degrees' icon for the Weather application. In the Sensible Alternative, the Weather application dynamically shows the temperature and weather conditions on the location and time that the user is concerned with in the running application. For example, the Weather application icon shows the different weather conditions and temperatures that are related to the time and locations of events in the Calendar.

Revealing Information

The feature that enables the user to drag the related application icons allows for the spatial ordering of application access. It is possible to align and order the appearance of the applications based on preference of use. This feature further implies that the location of the icon can be meaningful. As for the Weather icon in the Maps application, the temperature and weather conditions (forecast when time is considered as well) are shown and change dynamically when the icon is moved (dragged) over the map.

The Weather application icon that is pushed in from the back when using the Maps application can be dragged over locations on the map. In doing so, the icon shows the weather information depending on its position on the map.

Contact information is usually accessible through lists based on the alphabet or relevance. Contact persons can be accessed via the Maps application, as they can be pushed in based on where they live, work, or are meeting. In this case, the contact image icons of the actual people appear on the map instead of the generic Contact application icon.

Fig 14. Sensible Alternative running on a smartphone that runs a screen emulator that displays the visuals of a MacBook Pro on iPod touch. The touch-sensitive sensor is attached to the back and currently pressed. Icons of weather, maps, contact and mail applications are pushed through the running calendar application. These applications are most relevant given the *contextuality* given by the calendars shared and available content, and use.

Consequences for Use

For exploration, confrontation, and evaluation purposes, I created a prototype focused on a limited set of applications and proposed principles. With this implementation (Stienstra, Overbeeke & Wensveen, 2011[a]), I illustrated the power and potential of the expressive interaction layer to open up cognitive information through our *perceptual-motor skills*. I introduced the prototype to a group of eighteen experts in walk-through sessions (Preece, Rogers & Sharp, 2002).

The Calendar, Train, Contacts, Weather, Mail, and Maps applications were rebuilt on the basis of the original versions available on the smartphone operating system (anno 2009). On top of that, the interactive application layer (i.e., the layer that connects the applications through likelihoods of relevance) with the push-through interaction and the physical button were added to replace the smartphone's standard Home menu.

The walk-through sessions (Stienstra, 2010 pp. 65-69), in which the experts engaged with the experienceable prototype, revealed that high-level cognitive information could be opened up through our *perceptual-motor skills* by mapping the bodily experience of interacting to the experience of the cognitive output. By using shared content-types between applications in the Sensible Alternative, the experts confirmed that the prototype enabled them to bypass searching, as content was shared across applications. For instance, when viewing a location, weather maps are related and can be accessed through the interface directly. In a hierarchy-inspired interface, this would require leaving the Map application via the Home button to search for the Weather application icon, enter that application, and search for the location in another layer of the hierarchy before arriving at the forecast itself. In other words, the Sensible Alternative bypasses the hierarchy by cutting off sequences of interaction steps, as well as the cognitive overload of remembering information.

Fig 15. Prototype with sensitive pressure area on the backside of the screen.

The experts assessed the interaction guided by 'pushing for more application suggestions and its order of relevance' as an understandable, highly pleasurable, and natural experience (Stienstra, 2010 pp. 65-69). Consisting of seamless two-handed interaction, natural push-in application icon appearance interaction, relevant application suggestions, personalized relevance behavior, take-along content, widget-like application-depth access opportunities, and 'action-possibility based application navigation', the design results in a faster way of switching between applications, bypasses hierarchical menu infrastructures, offers a self-learning tailored menu, and provides a pleasurable and natural application access experience (Stienstra, 2010; Stienstra, Overbeeke & Wensveen, 2011[a]).

The designed and prototyped interaction layer of the Sensible Alternative exploits the advantages of the continuous and discrete powers of man and machine by opening up context-dependent functionality in a *perceptual-motor* engagement.

Concluding Remarks

I consider the Sensible Alternative to be a respectful embodied interaction design, as it redresses the balance of skills utilized in the engagement with smartphones. Instead of predominantly addressing the user's *cognitive skills*, the Sensible Alternative redistributes some of those engagements to the perceptual-motor and even *emotional skills*. In effect, expressive ways of pushing are used to provide 'expressive-relevant' application suggestions.

This is not yet another metaphor inspired interaction paradigm. The Sensible Alternative is a truly context and use-sensitive operating system that exploits one's expressivity in accessing the depths of information available on smartphones in an engaging manner – **Bill Buxton** (expert session, 2010)

Furthermore, application access is shaped by the individual user *in* interaction. That is, the application relevancy that develops through use respects the user's unique engagements with the phone. Contrary to how most smartphone operating systems allow users to establish certain settings and orders or groups of applications, i.e., in a defined and fixed manner, the Sensible Alternative truly uses and conforms to the dynamics of use in shaping (and constantly re-shaping) these points of access.

Finally, the Sensible Alternative provides users with insight into the application's digital and *synergistic* possibilities. Taking *effectivities* and *affordance* as the point of departure for how applications come to grips with the content and content-types of other (running) applications, the design enables people to utilize the qualities of the digital realm in a continuous manner.

Designing for Empathy Within an Independent Living Context

The Accompany project was an EU FP7/2007-2013 n°[287624] funded research project to develop a number of assistive functionalities in a smart home environment with the purpose of facilitating independent living for elderly people. Within the framework of the project, I proposed several phenomenology-inspired principles as interaction designer. The main vehicle of research was the Care-O-Bot in its (smart) environment – a service robot and smart home designed to serve elderly people in their daily activities and enable them to live independently (Amirabdollahian, Bedaf, Bormann et al, 2013).

As interaction designer, my objective was to enrich the somewhat deterministic robot with something to empathize with, i.e., enable people to empathize with the robot. I here followed the phenomenology-informed view on *empathy* and *social skills*, as outlined. The robot and smart environment were built by the consortium to accommodate independent living. I designed for the bodily (not cognitive) capabilities of elderly people in their vulnerable yet independent living. First, I briefly introduce the three directions in which this particular form of healthcare was applied. These are further elaborated in the subsequent chapters, following a similar structure as the previous chapters describing the Augmented Speed-Skate Experience and the Sensible Alternative (i.e., design context and challenges, design implementation, interaction design, consequences for use, and closing remarks).

As mentioned, this particular work was carried out in the context of the Accompany project. As such, my contribution was part of a work package led by the University of Siena in which empathy for robotics was explored, developed, and evaluated. The proposed ideas were further integrated into the Care-O-Bot in close collaboration with University of Hertfordshire and Fraunhofer Institute. Evaluations within the Accompany project were conducted in collaboration with consortium partners at University of Twente, Hogeschool Zuyd, University of Hertfordshire, and Maintien en Autonomie à Domicile des Personnes Agées (Madopa).

Squeeze Me

In order to speak to the sensitive side of the elderly people, the robot movement had to be reconsidered. The design of the Squeeze Me was proposed as an addition to the tablet that is used to control the Care-O-Bot. The addition concerns a pressure-sensitive spot that captures the expression of the user which translates the expression exerted into the movement expression of the robot. Whereas the movement of robots is generally predefined, i.e., it has a fixed pace and predefined path, I sought to make the robot more expressive. To do so, I designed expressive behaviors that provided an intimate engagement between person and robot. The elderly person asks for help (i.e., any kind of functionality that the robot can perform) by squeezing the remote control, and the robot moves accordingly. In other words, when the person squeezes the control in a gentle manner, the robot moves gently.

This relation was extended through a 'moody interaction' in which the robot could ignore the elderly person if it was abused (i.e., squeezed to get rapid help all the time). If the robot ignored the person, the person would start to adjust his or her behavior by being kinder.

Move Me The behavior and character of the robot's movement was further explored with the Move Me interaction. Here, the robot's behavior is negotiated between the elderly person and the robot. In interaction, the robot and person negotiate who goes first through the door. This is not achieved through verbal dialogue, but through the 'understanding' and synergy of each other's movements.

Sensible Interface The elderly person can use the robot to perform tasks that make life easier. For example, the robot can walk with the elderly person, turn on and off appliances, fetch a drink, and so forth. For the elderly person to access these functionalities, I conceptualized a graphical user interface that shows what the robot can actually do in the given context.

Instead of providing the elderly person with a list of possibilities, the Sensible Interface only shows those functions that are possible (i.e., physically with respect to the robot and the artefacts in the smart home) and desired (i.e., based on an estimation of need). For instance, help with cleaning the coffee cups is only offered when the cups are actually dirty. When an elderly person needs his or her medicine, the desire for it will likely increase over time. In turn, the button on the Sensible Interface screen grows with the desire or need. This makes it easier for the user to access functions that are more relevant. In the case where the medicine is fully ignored, the caring robot takes the initiative by actively reminding the patient and eventually offering the medicine 'in person'. Furthermore, the respective relevancies of the functions the robot can execute develop and become more personalized over time through the interaction with the elderly person. Evaluations showed that the elderly person and robot took care of each other.

The Sensible Interface incorporates the dynamics of use and the environment. By further extending the Sensible Interface with an expressive mask (Stienstra, Marti & Tittarelli, 2013), the elderly user became capable of seeing through the eyes of the robot (Marti & Stienstra, 2013[b]). In addition to the artefacts in the environment, the functions are given, which allows the elderly person to both navigate through a remote space with the robot and see what the robot can actually do (i.e., in terms of the robot's possible actions related to for example the fridge or coffee machine in sight).

A mask representing the 'feelings' of the robot in context indicates whether the robot is out of battery, whether something is blocking the robot's sensor, or whether the user was rude in squeezing the control. The design features ensure that the user interface shows only the possible actions, allow the user to see through the robot's eyes, and enable the user to interpret the robot's 'feelings'. This empowers the elderly user to better understand the 'feelings' and capabilities of the robot in context. User confrontations showed an increase in the user's empathy and intuitive use of the control of the robot in the smart environment.

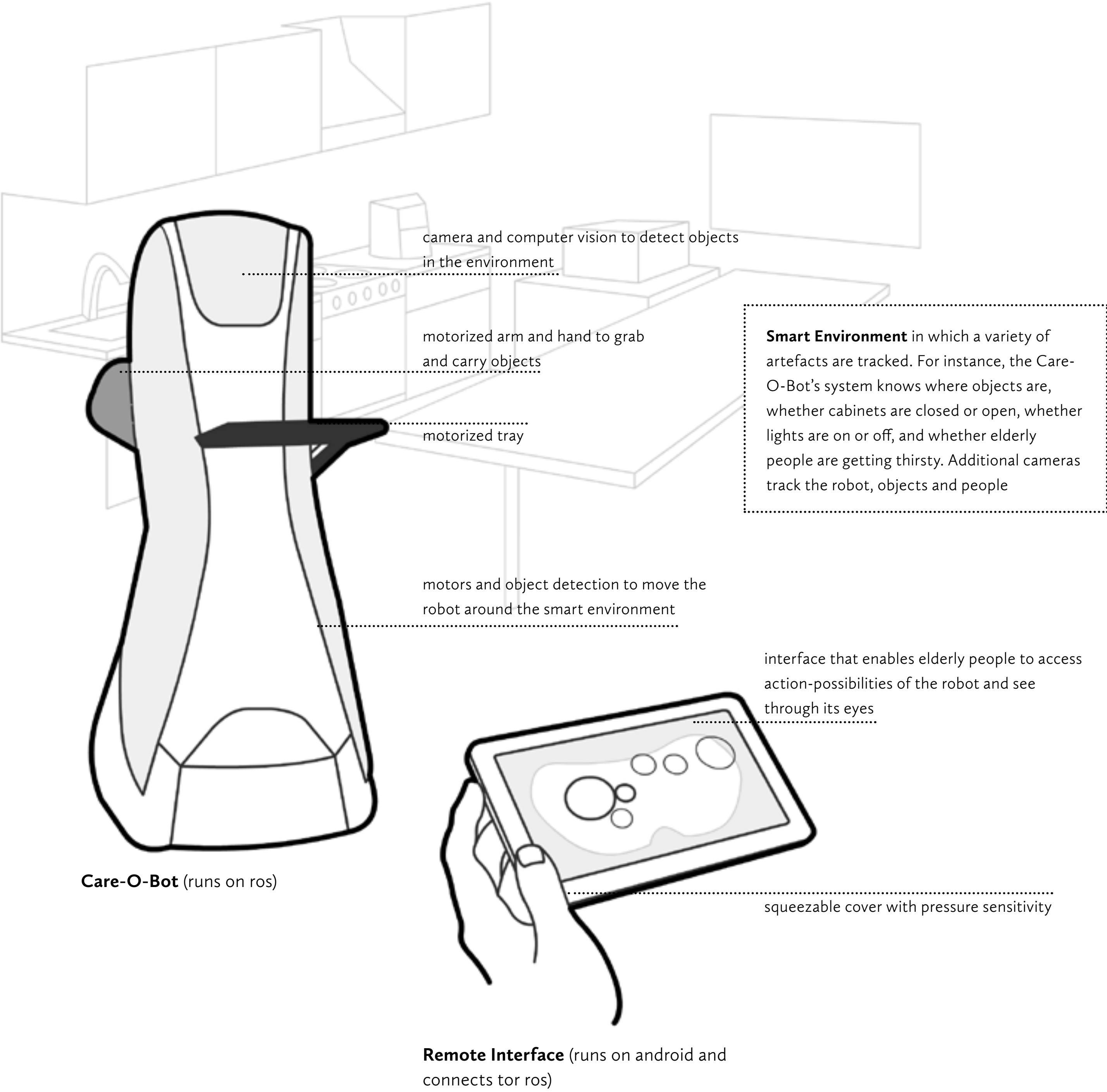


Fig 16. The Care-O-Bot, smart environment and the remote interface's main features.

Nothing so clearly and inevitably reveals the inner man than movement and gesture. It is quite possible, if one chooses, to conceal and dissimulate behind words or paintings or statues or other forms of human expression, but the moment you move you stand revealed, for good or ill, for what you are. **– Doris Humphrey**

Squeeze Me

The Squeeze Me (Stienstra & Marti, 2012; Marti, Tittarelli, Sirizzotti & Stienstra, 2014) was designed for the Accompany project[23]. The aim was to nourish an empathic relationship between the (elderly) person and the Care-O-Bot. Expressiveness as the means to constitute empathy within a human and robot context was the starting point for the design. The interaction focuses on the moment in which the user demands support from the robot. Put simply, the robot will respond in the manner that it is asked to respond. To avoid some confusion here, I do not mean that the robot executes what the person wants in terms of functionality[24]. Instead, I mean that the robot approaches the user based on the manner of expression put onto the Squeeze Me device.

[23] The work was conducted in a collaboration between the University of Siena and the consortium partners at the University of Hertfordshire and Fraunhofer Institute. While the conceptualization, explorations, and development of small robots and different devices took place in Siena, the concept as a whole was embraced by the consortium partners of the Accompany project and integrated into the Care-O-Bot by them as such.

[24] The robot does what it is asked in terms of functionality as well. The aspect of functionality, however, is dealt with by the Sensible Interface.

Design Context and Challenge

The underlying aim of this design exemplar – the constitution of empathy within a human and robot context – was approached with the intention of bringing together the applied phenomenology-inspired interaction design principles, such as the ability of natural, rich, and embodied interaction to provoke empathy in the field of robotics. Hence, the work aimed to address the *emotional skills* of people by making the robot expressive. The robot, as vehicle of investigation, could express itself in a variety of ways. For instance, the robot has lights, can make sound, and can move through space. During the explorations, I chose to focus on the robot's locomotive qualities as carriers of expression. I felt that the use of locomotive qualities would provide a rich repertoire of possibilities for addressing the user's feelings. Seeing that most robot movement behaviors are characterized by predefined movements, fixed pace, awkward transitions, and so forth, this expressive modality has been underexplored. Put bluntly, robots' movements are in general bulky, shocky, too fast, or too slow; they move like robots ought to move.

It was my aim to bring some charm, some subtlety to that movement in a way that would touch the feelings of people and make them appreciative of the movements of the robot. Instead of implementing a smooth, predefined dance to be performed by the robot as a sort of play, I sought to encourage empathy by involving the user in the movements. In other words, the Squeeze Me design's goal was to extend human behavior to the robot's behavior in a meaningful manner. As a starting point for this challenge, the work tackled the first moment of engagement between human and robot, the moment in which the human asks for help from the robot[25], in order to make the robot expressive in consonance with the human.

[25] This idea is further extended to all of the movements the robot makes and further explored in the Move Me exemplar.

Design and Implementation

Fig 17. Squeeze Me prototype connected to android development environment in order to map and tune the sensitivities of squeezing to the movement behavior of the robot.

The Squeeze Me consists of a squeezable area attached to the tablet that is used to control the robot. When the area is squeezed, the robot is told or asked to come near. While the focus is on getting attention from the robot, the assumption is made that the robot can follow up on the requested tasks. In an early iteration, the squeezable area came in the form of a pressure-sensitive spot utilizing a force-sensing resistor (Stienstra & Marti, 2012) similar to the one used in the Sensible Alternative. The pressure exerted by the user was captured by the sensor and sent wirelessly (over wifi) to the robot via an arduino. The robot in turn carefully planned the movement from its location to a location near the elderly user, using one of the predefined movement profiles. Consequently, the robot would move toward the person in accordance with the user-informed expressive movement.

The current implementation of the Squeeze Me, developed iteratively (Marti, Tittarelli, Sirizzotti & Stienstra, 2014), overcame some of the apparent philosophical and practical issues arising in the earlier design. The current device consists of a squeezable cover for the tablet and the tablet itself. In contrast with the early iteration, this cover provides inherent feedback when it is pressed. In effect, the material and physical qualities of the cover convey a better sense of how it is being pressed. This development overcomes the delayed coupling between squeezing and the actual movement of the robot. This approach is further elaborated in the direct movement of the robot eyes on the tablet, i.e., when the tablet is being squeezed, the eyes of the robot open on the screen according to the way the tablet is being squeezed. Furthermore, attempts were made to override the planning mechanisms in the system architecture in order for the robot to react as promptly as possible to the requested help. This was done by preparing the robot for movement and kick-starting it before the planning procedure takes over. The preset movement profiles were also abolished and replaced by an open, non-restraining form of movement.

A similar design was made using auditory cues as the input for the expressive movement (Stienstra & Marti, 2012; Marti & Stienstra, 2013[a]). This design, called Call Me, was rejected from follow-up explorations, as it was determined that the use of auditory cues raised the expectation that the robot could actually listen to what was being said. Instead, the Call Me merely listened to the intensity of someone's speech, as well as the surrounding noise, and ignored the content of what is spoken.

Fig 18. The robot moves according to the way the tablet is squeezed. Resulting in a variety of movements from gentle to aggressive.

Interaction Design

In its most basic form, the Squeeze Me mapping design causes the robot to move in a way that is consistent with the manner in which the device is pressed. For instance, when a light nudge is given, the robot gently approaches. By contrast, when the device is grasped and squeezed firmly, the robot moves in a hurry, ready to be of service.

Unfortunately, at first, the direct mapping provoked 'misuse' of the design. If the user squeezed firmly, the robot would always be there quickly. So why should the user bother being gentle? To avoid this behavior, a dynamic 'moody interaction' mapping

Fig 19. Squeeze Me prototype developed with a material that provides inherent feedback when it is being squeezed.

was developed. An amplifying and reductive mapping layer was added to the directly mapped relation between the pinch and the robot movement. This layer shifted the direct mapping toward less expected mapping throughout the day (through and *in* interaction). In practice, this means that if a person insistently continued to squeeze aggressively, the robot would start to be less helpful up to the point of turning its back on the person. In effect, the robot would make it clear that this kind of behavior was not desired. The dynamic adjustments of expressive mapping, sometimes even inverting the input toward response, provide a vivid and lively interaction. With a natural relationship as its reference, the moody interaction evokes denial, over-enthusiasm, and stubbornness in the robot, and requires the elderly user to adjust his or her behavior *in* interaction.

The *moody interaction* that emerged in the design process does not play much of a functional role during interaction. As such, one might wonder as to its benefits. I position the design as a provocative construct that challenges the reality in use and sociality. Its role is to explore sociality in human–robot interaction and reflect on values, some of which are ethical. In this way, I aim at making interaction expressive, embodied, and responsive through a continuous action-perception loop without resorting to a previous representation or plan for the interaction itself.

Consequences for Use

With the Squeeze Me I explored the possibility of achieving, by design, an enrichment of the user's experience by producing an empathic relation as the emergent and dynamic outcome of the interaction. The use of the prototypes showed that empathic demeanors in human–robot interaction could be achieved in a direct, perceptual way, and not necessarily mediated by the use of complex and predefined procedures or sequences of actions. In other words, the direct (expressive) movement of the robot initiated by the user's (expressive) squeeze spoke to the feelings of people (Marti & Stienstra, 2013; Marti, Tittarelli, Sirizzotti & Stienstra, 2014). The proposed design does not require the representation of complex internal states and inferential mechanisms in the robot in order for an empathic behavior to emerge. It basically relies on coupling and mapping actions and their effects through a continuous action-perception loop that exploits the richness and continuity of the user's embodied skills. Users were capable of expressing themselves with the direct mapping. At the same time, the moody interaction caused a curious social interplay or resonation between person and robot as underlined by the following situation:

He refuses to come! What happens if I keep insisting? Maybe he ignores me because I am being rude and he prefers to avoid me. (smiles) He behaves like my wife[26]… Let me be gentle again **– 75 Year old user**

[26] Personally, I would like to believe that this evidences the ground for a complex yet empathic relationship between person and robot.

Concluding Remarks

With respect to the phenomenology-inspired design perspective of respectful embodied interaction, the Squeeze Me and 'moody interaction' paradigm is respectful from the following perspectives.

First, the interaction design allows for rich-expressive interaction. The interaction design utilizes the expression the person puts into the engagement instead of ignoring or flattening it. The constrained landscape of expressions the elderly user can exert on the device, which then translate into a related movement of the robot, allows and provokes the elderly person to explore the expressive dimension. This exploration provides a background against which the user's self-reflection stands out. In other words, while engaging with the device, the elderly people are able to give meaning to their own expressions. However, despite the expressive freedom offered, i.e., the elderly person can squeeze gently, roughly, or in any manner in between, the 'moody interaction' paradigm persuades the user to adopt normalized behavior, as illustrated by the resonating behavior.

Second, the Squeeze Me interaction paradigm addresses the embodied skills of the elderly person more than the *cognitive skills*. In itself, this is not respectful *per se*; however, if one takes into account the disruptive and unsettling nature of discrete and predefined movements (i.e., sturdy movement transitions and impersonal movements) when continuity and expressivity are not applied, the bodily skills addressed by movement qualities in the interaction point to the respectful nature of the design. With the Squeeze Me, the way the robot moves does not disrupt the engagement the person has with it; the qualities of movement do not draw unnecessary attention and blend seamlessly within the situatedness. It has to be noted that elderly people that had difficulty squeezing, preferred a more cognitive way of interacting (i.e., clicking as uncontrolled exerting pressure resulted in uncontrolled and unpleasant robot movement) while a more appropriate perceptual-motor solution was not present.

Third, as the first point already indicated, the interaction design is open for interpretation. This openness allows elderly users to develop their own dialogues and stories regarding what is happening when they interact with the robot. The interaction design is not a fixed, predefined, and predefining paradigm. Moreover, engagement and empathy develop over time, emerging *in* interaction as the 'moody interaction', i.e., the contextually dynamic behavior shifts from an expression-coherent squeeze to movement mapping.

What the philosopher called foresight I call the perception of an affordance
– **James Gibson** (1986, p. 232)

Move Me

A second way to increase the elderly person's empathy for the robot was explored by means of applying perceptual-crossing derivatives (Marti, Iacono, Stienstra & Tittarelli, 2014), or more precisely, through reciprocal engagement. As part of the Accompany project, the robot was equipped with a movement behavior called Move Me that negotiates *in* interaction who is to go first when the robot and person are moving alongside one another. With this work, I hope to inspire design thinking to shift from discrete, procedural design mechanisms to continuous, action-driven mechanisms when addressing the interaction between humans and systems.

Design Context and Challenge

With this exemplar, I explored the possibility of achieving negotiated interaction between the user and a robot in a home environment. My aim was to empower empathic relations between the robot and person, and to enrich the user's experience as an emergent and dynamic outcome of the interaction. In exploring this notion of negotiated interaction with the robot, the concept of 'perceptual-crossing' was taken as the main source of inspiration for design. Perceptual-crossing is the recognition of an object of interaction, which involves the perception of how the behavior of the object and its perception relate to one's own. For example, perceptual-crossing in human–human interaction occurs when two people catch each other's eye; in the case of mutual touch, kinesthetic, or acoustic interactions (e.g., proto-conversation with babies, dialogue, choral singing etc.); and resonance of movements.

The idea of perceptual-crossing is directly rooted in Merleau-Ponty's phenomenology of perception (1962) and functioned as the inspiration for the robot to negotiate its movement in context. The application of perceptual-crossing was indicated as the deliverable for the project. However, the primary reason to design the robot's movements with such qualities, unlike applying perceptual-crossing in for example the expression of light, was the observation that the qualities of the robot's movement are inescapable yet directive in the user's holistic perception of the robot, as indicated before. In other words, the way the robot moves speaks to the senses and has an unrecognized influence on the user's perception of the robot. At the start of the project, the Care-O-Bot moved only according to a predetermined path with a fixed speed and unplanned *directionality* (i.e., the robot drove backward, sideways, and so forth in an arbitrary manner).

From Perceptual-Crossing to Reciprocal Engagement

This phenomenon highlights the reciprocal nature of our perception (e.g., perception requires action) in the emergence of meaning. Perceptual-crossing, as coined by Auvray, Lenay and Stewart (2009; Lenay, 2010), and further explored by Marti (2010, 2012; Marti & Stienstra, 2013b) and Deckers (2013; Deckers, Lévy, Wensveen, Ahn & Overbeeke, 2012; Deckers, Wensveen, Lévy & Ahn, 2013) in the field of interaction design, revolves around the phenomenon in which two people look at each other and recognize that they are seen by each other when their eyes meet. In itself, this phenomenon may be experienced intensely, but does not convey utilizable functionality as such. When applied to interaction design it does establish grounds for engagements to start as it confirms whether user and product have each other's 'attention'.

Perceptual-crossing, theore, is applied primarily to initiate a ‘conversation’, as it provides the grounds for a shared context. It is often extended through the phenomenon in which a person sees what the other person is looking at. For example, I see in your eyes that something is happening behind me. In the social sciences, this is referred to as joint visual attention. With respect to perceptual-crossing, this dimension thus expands the spatial context of a negotiated interaction.

Research into perceptual-crossing in the psychological field of the enactive approach to social cognition (Iizuka & Di Paolo, 2007; Di Paulo, Rohde & Iizuka, 2008; Iizuka, Ando & Maeda, 2009; De Jaegher, 2009, Froese & Di Paulo, 2010) has focused on one- and two-dimensional simulation models in which uncertainties are avoided. In these simulation models, the movement behavior of a single actor is simulated. It is common that users validate whether perceptual-crossing can be achieved with these behaviors in certain dimensions, such as speed, direction, geometry of movement, and modality. Furthermore, the simulations are focused on defining the limitations of non-holistic systems.

Auvray, Lenay, and Stewart (2009) carried out experiments in which subjects were able to distinguish animate objects from inanimate ones with the same appearance and movement only by perceiving very simple tactile stimuli. Empirical evidence from their experiments supports the central role of dynamic mutuality and shared intentionality in shaping several aspects of an ongoing interaction. A fundamental insight to be drawn from these experiments for the design of empathic interaction is that the interwoven nature of interaction must be shared and constituted (in)between the subjects.

Deckers (Deckers, Lévy, Wensveen, Ahn & Overbeeke, 2012) investigated perceptual-crossing with artefacts. She designed and built the PeP, “Perception Pillar”, which incorporates different perceptive behaviors in the form of a dynamic light design. The PeP is able to detect a person’s presence, perceptive action, and expressivity. It allows for reciprocity, in that, the subject is able to perceive the perceptive activity of the artefact. Deckers tested the PeP under the hypothesis that if perceptual-crossing occurred between the subject and object, the subject’s feeling of involvement would increase. The experiment showed that it is possible to design the perceptive activity of an object in a way that allows for the perceptual-crossing between subject and object and for sharing the perception of an event. It was concluded that perceptual-crossing in the design of the PeP positively influences the user’s feeling of involvement.

The research in and application of perceptual-crossing has predominantly explored subject–object relations (i.e., imbuing the object with subjective qualities); yet, the background (i.e., the context of action, the intentions of both subjects toward the environment) has played a relatively minor role. I see an opportunity in pushing the perceptual-crossing paradigm toward *contextuality*. For this reason, I pursue an interaction paradigm in which two entities (person and artefact) go beyond the awareness of a shared context and come to share intentions (understanding and acting upon them). In effect, I shift a perhaps weakened form of the pure perceptual-crossing paradigm toward utilizable functionality by integrating the *contextuality* and multiplicity of the interactants’ intentions. This utilization of perceptual-crossing in interaction design I call *reciprocal engagement*.

Design and Implementation

Three forms of reciprocal engagement were explored and implemented in the Care-O-Bot and similar robots[27]. All of these forms were designed to empower an empathic relationship between the person and the robot; but, they differ in terms of their mutual involvement. The three forms were chosen for their feasibility (i.e., to be implemented in the robot) and carefully defined to build upon one another. They took perceptual-crossing as the point of departure, going beyond the mere initiation of interaction to explore functional purposes, such as negotiation, initiative, and empathy.

[27] Consortium partners at the University of Siena and University of Twente, who took part in the Accompany project, implemented the reciprocal engagement design-concepts. My role as interaction design (researcher) in this was the conceptualization of the notion of reciprocal engagement informed by phenomenology of perception.

The first form of reciprocal engagement is the initiation of movement. In practice, a behavior was designed that picks up the elderly person's initiation of movement and acts upon it by stepping aside so that the person can pass. The second form of reciprocal engagement explores how this behavior can be sustained over time (i.e., maintained through mutual understanding while walking). The third form explores how the continuous empathic relation can be used to negotiate which party (robot or human) will take the lead *in* interaction. These three implemented forms of reciprocal engagement allow for the negotiation between robot and person with a functional purpose, e.g., moving away to instantiate acts, providing support and a sense of togetherness, and negotiating decisions when objectives do not correspond – situations that can benefit from a sensible movement.

Fig 20. Design researcher walking alongside robot. The robot embodies an array of sensors on its side-view coupled the motors that enable the robot to respond directly to the pace of the person.

The Move Me exemplar relies heavily on the robot's sensors and actuators to respectively estimate the intention of the person and act upon it by moving. The robot must grasp the person's intention to get up, move forward faster or slower, and so forth. Different approaches were taken to achieve this, with the different robots restricted by their possibilities. To achieve this reciprocal engagement, or in some way a mutual understanding, both entities, i.e., robot and person, must be immersed in a shared context and 'grasp' the intentions of the other. The 'grasping' and acting upon in this paradigm go hand in hand, in that, they happen at same time in the active-perception loop.

Interaction Design

For the first form of reciprocal engagement, the Move Me behavior of the robot is as follows: when a person stands up, the robot that is stationed in front of the user will promptly move backward to make space. In the second form, the robot intends to keep up with the person. If the person walks slowly, the robot moves slowly alongside. If the person walks quickly, the robot does so as well. The third form is somewhat more complicated, yet it builds upon the relation established in first two forms. What is designed in the behavior of the robot is that when the person and robot are both heading for a door opening that is too tight to move through side by side, the moving alongside behavior is abandoned and the robot either takes the lead or follows based on what is 'negotiated' along the way.

Consequences for Use

The forms of reciprocal engagement implemented in the robot were evaluated in a variety of ways (Marti, Tittarelli, Sirizzotti & Stienstra, 2014) with young and elderly people. The results of the experiments in which the three forms were implemented were compared to the behavior of the robot when no reciprocal engagement was implemented (e.g., the robot moves away on its own, goes from one to location to the other, and passes through the door opening without paying attention to the user). The expectation that the reciprocal engagement would be desired over the more ignorant behavior of the robot was confirmed in both a scenario-based evaluation with seventy people (Marti, Iacono, Stienstra & Tittarelli, 2014) and a follow-up experiment in which six people actually engaged with the robot. The results from the evaluations showed that the reciprocal engagement, especially the first two forms, i.e., making space and walking along in a sensible manner, was highly appreciated in terms of its social value. The more complex behavior, however, opened up an ethical debate regarding the role of the robot, namely whether the robot should behave in a submissive, dominant, or supportive manner.

Concluding Remarks

Compared to how most robots move about, this robot considers the person. This stretches beyond object or person recognition, leading to routes that avoid obstacles. Rather, the Move Me behaviors involve users in their own movement with the aim of supporting people physically and emotionally. In addition to this added functionality, I consider the designed behaviors respectful in the way they address human skills.

The robot does not prescribe or script behavior of people, but negotiates it *in* interaction with the robot in a reciprocal manner. That is, the robot's movements support an elderly person by taking the momentary skills into account, i.e., dependent of whether a person is having 'a good' day, up for a walk alone, or having a day when he or she requires much more support and time to arrive at the other side of the room, the robot negotiates its movement alongside the elderly person depending on the context.

This negotiation of pace, walking alongside, takes place in the natural flow of movement. For instance, the robot does not signal red, green, or orange to indicate its speed or whether the person has to go faster or stop, nor does the user need to communicate with the robot in that devious manner of pressing buttons. On the contrary, based on the pace of movement, the robot supports the user and stays near. Communication of sorts takes place on a perceptual-motor level. The reciprocal engagement of the Move Me behaviors implemented in the robot affirms the intentions of the person and acts upon the actual movement of the person appropriately, e.g., by staying alongside, making space, speeding up to pass first, or slowing down to let the person go through the door. Therefore, I consider the robot to possess a *social skill* that allows it to be addressed by the person.

Sensible Interface[28]

[28] This chapter contains parts of (a) Stienstra, J.T., Marti, P. & Hummels, C.C.M. (Forthcoming) Sensible Interfacing: Action-Possibility Driven System Design. *Submitted to International Journal of Design*, and (b) Marti, P. & Stienstra, J.T. (2013[a]). Exploring Empathy in Interaction: Scenarios of Respectful Robotics. *GeroPsych, 26*(2), 101-112.

In this chapter, I present the Sensible Interface (Stienstra, Marti & Hummels, Forthcoming), an action-possibility-based graphical user interface used to control an assistive robot in a smart environment. This theory-inspired system design utilizes the Gibsonian notions of *affordance* and *attensity* and Merleau-Ponty's notion of maximum grip to provide access to context-relevant functions in a smart environment. In this system-design exemplar, I explore several consequences of a phenomenology-inspired and ecological psychology-driven approach to designing for both the system architecture and interaction paradigm. Here, I present the design, its design context and challenges, its implementation, and reflections based on qualitative user confrontations with the Sensible Interface.

With this work I hope to inspire design thinking to shift from discrete, hierarchical, and procedural design mechanisms toward continuous, contextual, action-driven, and embodied mechanisms when addressing the interaction between humans and complex systems.

Design Context and Challenge

The presented system design case was developed in the context of the Accompany project, a project that developed a number of assistive functionalities for a smart home environment with the purpose of facilitating independent living for elderly people. The main vehicle of this research was the Care-O-Bot, a service robot designed to serve elderly people in their daily activities and enable them to live independently.

Over the past couple of decades, graphical user interfaces have been grounded in several metaphors, such as the desktop and tree-view metaphors, aimed at bridging our tangible world and the digital world of computing (Moggridge, 2007). The acknowledgement of embodiment (Dourish, 2001; Harrison, Tatar & Sengers, 2007) in human-technology fields in recent years has allowed embodied interaction paradigms to find their way into the design of user interfaces. Some characteristics related to those common metaphors, such as representations and hierarchical clutter (i.e., overwhelming hierarchical structures), have been re-evaluated from the perspective of a direct-interaction paradigm (e.g., touch screens allow for direct control of what is visualized, such as pinching and swiping). Nonetheless, current interface designs tend to stick to their metaphors and overlook the opportunity for the embodiment of action in the environment.

The aim of the Sensible Interface design was to provide an interface that would be engaging and contextually relevant and grounded in the theories for interaction design. That is, the aim was to explore *contextuality* in a graphical user interface between humans and robot in a (smart) environment from a phenomenological perspective, building in particular on Merleau-Ponty's notions of intertwining and maximum grip (Merleau-Ponty, 1962; Merleau-Ponty, 1968; Dreyfus, 2004) (i.e., when grasping something, people tend to grab it in such a way as to get the best grip on it, which closely relates to Gibson's notion of *affordance* (Gibson, 1986; Michaels & Carello, 1981)). The approach I take towards designing intelligent products and systems focuses on the experience of people, and thus provides access to functionalities in a continuous, holistic, and activity-driven manner as opposed to discrete, predefined, and event-driven ways. In the subsequent sections, I discuss the alternative robot user interface resulting from this design challenge.

Design and Implementation

The design of the Sensible Interface consists of a smart environment, the robot, and the actual interface used to control the functionalities of the robot that all revolve around the person. In the following part, I elaborate on the qualities of the project's elements and how they fit together within the system architecture[29]. This is followed by several examples illustrating the multiplicity of possibilities opened up by the action-possibility-driven system design.

[29] The system architecture of the Care-O-Bot was developed by Fraunhofer Institute and the consortium partners at the University of Hertfordshire in previous versions of the robot. It was decided to continue with these efforts and abandon a possible system architecture that would be informed by a direct perception perspective as developed by Gibson (Michaels & Carello, 1981), Brooks (1991), and Pfeifer and Bongard (2007).

Smart Environment

The robot surveys the household applications, tools, ingredients, lights, window blinds, and so forth that it can manipulate in the environment. An elaborate sensor network is used to gather information about their location and status, e.g., the ingredients, temperature, and fullness of the coffee machine, the dirtiness of the coffee cups, floor, and tables, or whether the lamp is on or off.

In addition to acquiring information about the manipulable environment, the sensor network gathers information about aspects that are not directly manipulable, such as the people living in the environment (e.g., their physiological states of being hungry) and the surrounding conditions (e.g., temperature, brightness provided by the sun, and so forth). Information is gathered and updated continuously and not judged in the process of gathering. The states are simply stored as raw data. In other words, the hierarchy of what elements are embodied in a certain context is not predefined. As later elaborated, the relevancies of the states of the surrounding objects, environment, and subjects emerge at the moment of interaction, in its dynamics.

Robot

For the system design case, the functionalities of the Care-O-Bot (Amirabdollahian, Bedaf, Bormann et al, 2013) and the objects available in the project's smart environment were utilized. Yet, I aim to push functionalities beyond what is currently possible in order to stretch and validate the qualities of the holistic approach to designing action-possibility-driven systems. The omnidirectional driving robot has an arm with seven degrees of freedom and a three-finger gripper. It is equipped with a carrying tray. Furthermore, the robot utilizes the environment detection of the smart environment to navigate within the space and toward objects and people. With a camera functioning as the eyes of the robot, people and objects can be recognized. These data are merged with the sensor network. The robot can fetch, carry, and manipulate objects. Speech communication is left out in order to make sure that people's expectations are respected in terms of what the robot actually understands and what it is able to do. The robot can bow slightly and further express itself through movement.

Interface

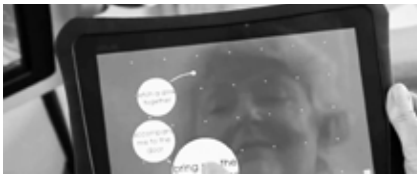


Fig 21. The Interface of the Sensible Interface that shows action-possibilities that are useful to the elderly user based on user desires, needs and capabilities of the robot in the environment. Graphical User Interface design by Michele Tittarelli.

A portable tablet is used as a remote control panel to access the robot's functions in the smart environment. As elaborated before, the smart environment and its devices contain a variety of functionalities accommodating the everyday life of people. These functionalities range from discrete light sources that merely provide on/off functionality (thus admittedly contradicting my phenomenology-inspired design beliefs) to continuously controllable window blinds that can be opened, closed, or set to anywhere in between. Several products in the smart environment do not allow for actuation on themselves, such as the lights, window blinds, coffee machine, and so forth; however, they do allow use by the robot in order to serve the desires of the person. These 'manipulable' products are evaluated by the robot and can be accessed through layered functionalities (e.g., a cup can be used for coffee, tea, water, or with more complexity for coffee with milk and/or sugar). The portable interface attends to the four types of functionalities (discrete, continuous, artefact-bound, and stacked) to be executed by the robot in the smart environment. The possible functionalities can be executed by pressing the labels representing the functionalities on the tablet. The most relevant functionalities appear larger and in a more central location than the less relevant functionalities.

Action-possibilities and their likelihoods

In order for the robot and smart environment to assist the person in his or her daily activities, I took action-possibilities (as derived from Gibsonian *affordance* and attensity) as the point of departure. In other words, what the person is able to make the robot do, is given by what the smart environment and robot can do either autonomously or in collaboration with the person, i.e., by what the bodily capabilities of the robot in relation to the environment and given situations affords. *Attensity* as grade of *affordance* is used as limitation, because the amount of affordances available in the space where people and a smart environment meet is uncountable due to the rich human skillset and bodily opportunities in relation to the forms and functions inherent in the environment and products[30].

[30] For now, the action-possibilities of the robot in the smart environment are limited by the restricted bodily capabilities of the robot.

The focus lies primarily on providing a person with access to the functions to be performed by the robot. Action-possibilities are thus defined by what the robot can do with the products in the smart environment and are performed through scripts. Despite the robot's limitations, the number of action-possibilities would still boggle one's mind, e.g., turning on the light, turning off the light, playing jazz music, lowering the volume, making coffee, cleaning the coffee machine, getting a bottle of water, opening the bottle of water, disposing of the bottle of water, taking out the trash, opening the door, closing the door, peeking through the window blinds, making the room a little lighter, supporting the user walking to the kitchen, and so on. In light of this great number, the use of 'likelihoods' restricts the number of action-possibilities to the most relevant (Stienstra, Marti & Hummels, Forthcoming).

System Architecture

For practical reasons regarding implementation and the technological constraints imposed by the multidisciplinary Accompany project, the parameters of the smart environment and robot are centralized in one database. This database contains representations of the objects and their qualities or the statuses of measured parameters. In order to achieve a dynamic interface that is able to accommodate an ever-changing context, data gathering and storage require a similar nature. Therefore, the database is capable of handling a continuous change of locations, environmental statuses, robots, and people involved. The database architecture was further prepared in the form of triplets that in essence describe the relations between the objects. In effect, the representations of the objects properties, people's desires and capabilities of the robot in the real world captured in the database described actionable relations. The database structure takes the role of arbitrary and limited *affordance* and *attensity* descriptors.

Interaction Design

The Sensible Interface was implemented[31] in the Care-O-Bot platform and smart environment for a series of scenarios (Stienstra, Marti & Hummels, Forthcoming; Amirabdollahian, Bedaf, Bormann et al, 2013; Marti & Stienstra, 2013[a]). The graphical user interface displays the action-possibilities that are relevant in situ, grounded in the dynamic contextual likelihoods of desires and actionable possibilities. The most relevant action-possibilities appear big and are thus easy accessible; the less relevant ones are smaller and less centralized. If the robot is located in a different location, the elderly person can choose to see through the eyes of the robot (Marti, Iacono, Tittarelli & Stienstra, 2013; Marti & Stienstra, 2013[b]) and have the action-possibilities displayed on the related artefacts (e.g., the action-possibility that concerns coffee-making is displayed on top of the coffee machine or the coffee cups on the table). The ability of the user to see through the eyes of the robot is further extended with an expressive mask that provides insight into how the robot is 'feeling'. For this, contextual and interactional factors are incorporated into the engagement with the Sensible Interface (Stienstra, Marti & Titarelli, 2013). For example, when the robot is out of energy, the mask slowly turns darker, or when there is too much light for the robot or the smart environment to identify the location of objects, the mask closes its eyes to show that the user needs to do something about the light level. This mask and seeing-through provide extra cues about how the robot 'feels', and provide the basis for the user to understand and relate to changes in the environment.

[31] The Sensible Interface was implemented as part of the Accompany project by the consortium partners at University of Siena, University of Hertfordshire and Fraunhofer Institute on top of the Care-O-Bot's system architecture.

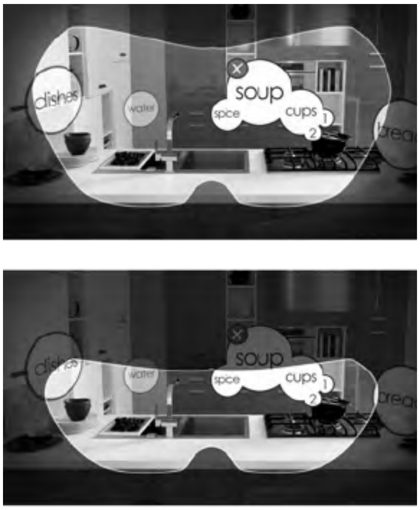


Fig 22. Seeing through the eyes of the robot with the expressive mask. The shape indicates that the robot is unhappy with the ongoing situation (i.e., the trash bin has not been emptied) and the robot is soon going to run out of energy as indicated by the view going darker. Action-possibilities are displayed on the objects in the kitchen. Graphical user interface design by Michele Tittarelli.

Consequences for Use

The Sensible Interface was implemented in the Care-O-Bot platform and tested as part of the key evaluation of the Accompany project in which several elements were evaluated. As such, the test used a confined and 'scripted' scenario through which subjects were guided. In what follows, I summarize the results, focusing on the consequences for use from more open evaluations of in-between versions of the Sensible Interface and the seeing-through and expressive-mask functionalities.

The main evaluation of the Sensible Interface was conducted in the form of an experienceable walk-through session with a seventy-five-year-old healthy user (Marti & Stienstra, 2013[a]) and analyzed using interpretive phenomenological analysis (Smith, Flowers & Larkin, 2009) for qualitative data. This methodology focuses on personal meaning and understanding the first-person perspective through intersubjective inquiry and analysis, and aims to situate personal meaning in context. It seeks to solicit personal, spontaneous views without potential bias of priming through overly structured questions. The results of the evaluation were highly nuanced and offered a fine-grained understanding of the feelings of the older person, his perception of what was going on, and what really mattered to him during the real-life experience (Marti & Stienstra, 2013[a]). Interestingly, the participant viewed his interaction with the robot as a way to reflect on his skills and reappraise the home environment. In effect, his experience with the interface made him aware of which actions he took for granted.

I saw the world through the robot's eyes. It was as if I did the action myself. It was as if he knew my intentions . . . If I can take the robot's perspective I can reflect on the environment around me. For example, I'm used to switching the light on and off. I do this automatically without thinking. I don't "see" the world around me any longer . . . my actions are out of habit. If I see the environment around me through the robot's eyes, I actually see the objects around me, I reflect on what was left in a certain place. I feel more active, and this helps me to remember where I left an object. Interacting with the robot shapes my memories and my intentions. This is not simply an interaction with the robot, but rather a robot-person-context interaction.
– 75-year-old user

During the walk-through session with the experienceable prototype, the participant mentioned that he felt he was entering into a relationship of mutual respect with the robot. This was attributed to the fact that the interface is very clear about what the robot can and cannot do in a given situation. In a way, the robot carves out a presence, i.e., from something that is merely there as a moving servant to an entity that the user can engage with, as evidenced by the following quote from the same elderly user: "We can engage in a relationship, in mutual respect. I do not feel alone... He can learn my habits, and I can learn what he can do for me".

Following the user's observations, I would not claim that the robot becomes a part of life to act through in an embodied manner, e.g., as in the Augmented Speed-Skate Experience or Squeeze Me exemplars. Users clearly engage with the graphical interface rather than with or even through the robot. The graphical user interface is very much in between the person and the robot as an interference, i.e., it breaks the flow of a continuous engagement.

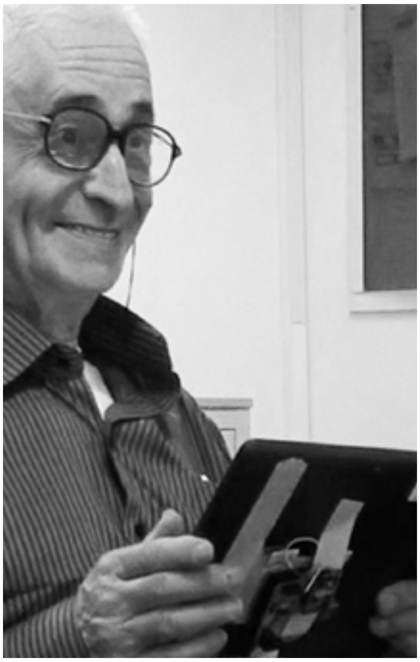


Fig 23. Elderly user interacting with one of the first prototypes that consisted of a force-sensing resistor attached to a tablet that controlled a robot in a simulator environment (similar to what is seen on the figure below).

Fig 24. The squeeze me, expressive mask and Sensible Interface were prototyped in simulator environment before being transferred to the Care-O-Bot.

Users do not argue when the Sensible Interface does not offer to turn on a light that is already on. However, they may not so easily understand when the interface does not allow for a cup of coffee (i.e., does not offer direct access) due to for example the fact that the cups are dirty. Although the relevant action-possibility to 'clean a cup' is shown centrally on the user interface, it does not fully help the user to understand the situation. Despite the fact that this uncertainty can elicit resistance and frustration (and thus lay the grounds for an empathic relation) from the elderly users who want to know more, the interface lacks the basis for adequate explanation or negotiation when things fail. However, this lack of insight into the feelings of the robot is somewhat addressed by the seeing-through view and expressive mask elements.

Evaluations with sixty subjects, involving with- and without-video scenarios of static and empathic masks followed by questionnaires (Marti, Iacono, Tittarelli & Stienstra, 2013), showed that the expressive mask did induce an empathic relation between person and robot. In effect, the mask enabled perspective taking and as such provided insight into the robot's feelings and capabilities. The mask representing the 'feelings' of the robot in context indicates on a feeling level whether the robot is out of battery, whether something is blocking its sensor, or whether the user was rude with his or her squeezing. The user interface showing only the possible actions, the seeing-through view, and the expressive mask empowers the elderly user to better understand the 'feelings' and capabilities of the robot in context.

The evaluations did not show that the elderly people grasped the nuances and subtleties of the system to their fullest extent, i.e., the dynamic quality of the context-dependent system. This was due to the limited time they spent with the robot, which in itself was rather limited in its action-possibilities. Based on our observations we remain hopeful that, while engaging with the Sensible Interface *in* context, rituals emerge over time. They emerge with subtleties in dynamic negotiation, not through mere repetitions. The system and users dynamically attune to situations. It is thus not about what the system 'thinks' about the user's feelings and how it should act upon the given situation. Rather, both user and robot adjust their behavior dynamically so that new meaning can emerge. This 'mutual understanding', however, takes time, as it requires both person and system to experience and attune to the subtleties that are opened up. Furthermore, likelihoods need time to develop and break free of their pre-informed robot-artefact affordances, and find an equilibrium *in* use before the design can be fully appreciated.

Engagement with the Sensible Interface promises to increase the user's empathy toward the robot (Marti, Iacono, Tittarelli & Stienstra, 2013) and intuitive use of the control of the robot (Marti & Stienstra, 2013[a]) in the smart environment. The Sensible Interface promptly offers relevant action-possibilities to elderly people based on what the robot can do in relation to the elderly person and environment, and what the elderly might desire or benefit from.

Concluding Remarks

The Sensible Interface is considered respectful for a variety of reasons enabled by the action-possibility-driven interface along with the expressive mask and seeing-through the eyes functionality. Most importantly, the Sensible Interface provides insight into what the robot can do for the user. In effect, the robot can be used to support the elderly person by performing certain functions, but at the same time the interface shows what the robot can do and enables the user to infer what the robot cannot. The Sensible Interface addresses the user's *social skills* by providing insight into the possibilities of the robot and its moods so that the elderly person can help the robot too.

The Sensible Interface utilizes the action-possibilities available to the robot within the environment. The designed action-possibilities, however, are only meaningful for the user to the extent that the robot extends the possibilities or meets the desires of the human. Actions irrelevant to the user could also be performed by the robot, but are not considered. The likelihoods are thus driven by both robot *affordance* and human interest. Furthermore, higher-level functions that would mainly address the elderly person's *cognitive skills* when applied in a traditional manner are addressed via the resonance between the elderly person and the robot through shared viewpoints. This provides the elderly person with insight into how the robot can possibly assist him or her, in a continuous flow of interaction *in situ.*

As the Sensible Interface attunes itself to use, to the capabilities of the robot and the elderly person's preferred ways of being, the exemplar becomes highly personalized. It is shaped by the preferred use of the person and respectful of the user's unique and robot's limited capabilities. It is not a generic solution. Rather, it appreciates users' unique engagements with their environment. Furthermore, the interface is unobtrusive and listens to what the person wants it to do; it attunes its likelihoods through use and consequently suggests what might be most relevant.

More than an assistive aid, the Sensible Interface offers a context for experience. The design serves to enrich this experience by stimulating feelings of engagement, emotional well-being, and comfort, thereby making living with the robot pleasurable and gratifying. The exemplar aims to offer rich action-possibilities and a context for experience that is meaningful for people. These values are lost wherever a purely functional approach prevails.

In the end, the Sensible Interface provides mere action-possibilities in context through simple textual representations. From a design perspective that considers *contextuality* anchored in phenomenology, the effort does not pivot around the graphical user interface *per se*, but around what happens in the dynamics of *contextuality* and relevancy in terms of how the participants (user, robot, and artefacts) dynamically reciprocate with one another in a respectful manner. The displayed action-possibilities are those that are meaningful for the synergy between robot and elderly person. These are analogous to how we, as people, perceive the world in terms of *affordances*, i.e., contrary to seeing a chair, we perceive an opportunity to sit.

Sensible Door[32]

With the Sensible Door (Stienstra, Hengeveld & Lévy, Forthcoming) project, I attempted to bring together several of the ideas and implementations developed earlier, and to explore some of the remaining questions that needed to be addressed. The designed door, which originally started off as a calendar, aimed to tackle intersubjectivity and interconnectedness. That is, I aimed to explore how technology could be used to (socially) mediate 'about-content' between people in a bodily manner, while the technological components also communicate according to phenomenology-informed principles. I further used this exemplar to reorganize and reassess my phenomenology-informed insights by confronting them in the design process of this holistic system, while making as few concessions as possible to the system architecture. This was done with the intention of running into both design-practical and philosophical questions in the process. For this reason, the Sensible Door was posed as platform for exploration and that it remains a work in progress. It is crucial to emphasize that the purpose of this exploration was of an entirely different nature compared to the previous exemplars, i.e., the previous exemplars focused on acquiring insights from the result rather than exploring a wide variety of opportunities and limitations during the design process.

The Sensible Door addressed the experience of people in using products, processes, and systems from the phenomenology-inspired point of departure. In particular, it sought to find relevant indicators of behavior on a methodological level in interaction. In effect, the Sensible Door explored dynamic, open designs for interaction that could adjust to the skills of the interactants in context by fitting its functionalities and capabilities to the continuous and social nature of our being-in-the-world.

Design Context and Challenge

The design of doors has often been used to illustrate the mismatch between human capabilities and the designed. For example, Donald Norman (1988) and later Bill Gaver (1991) described the mismatch between the 'pullability' of a door handle, while the doorframe merely allows the door to be pushed. Furthermore, automatic doors, whether revolving, sliding, or hinged, have proven to be ambiguous in their 'body language' to human actors (Ju & Leifer, 2008). Also, Ju and Takayama (2009) showed that doors convey emotional messages in their opening swing, even when they are technology driven. MacLean and Roderick (1999) designed a haptic active doorknob that combines torque and thermal output to explore the means of expressing behaviors.

[32] This chapter contains parts from Stienstra, J.T., Hengeveld, B.J. & Lévy, P.D. (Forthcoming). Exploring Sensible Interaction: Designing the Sensible Door. *Under review at The Design Journal.*

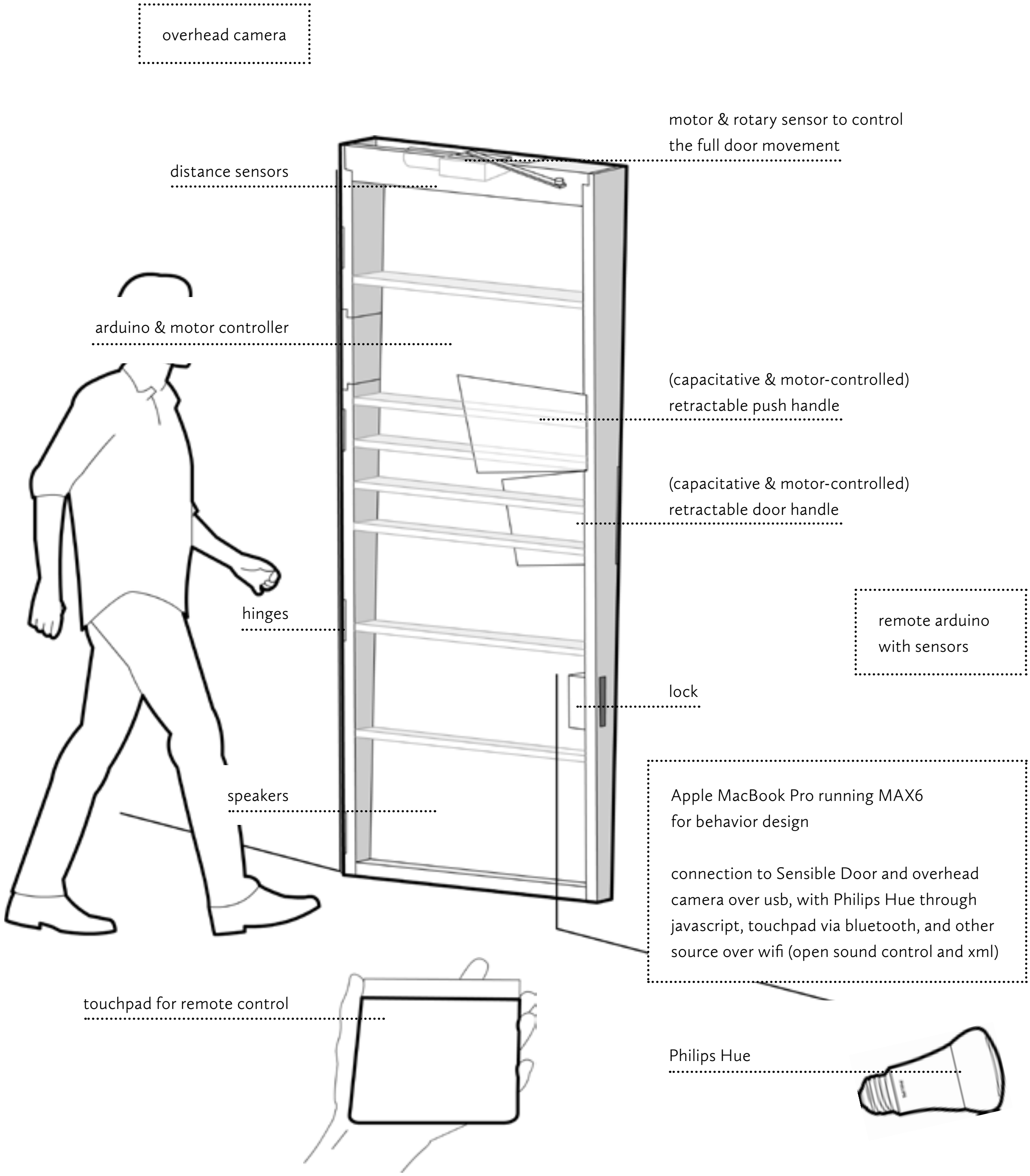


Fig 25. The Sensible Door's components with MAX6 as central processor in the investigated behavior designs and design process.

What these automatic doors have in common is that they serve as mere space separators. That is, they ignore the notion that between one side and the other there may possibly be two different (social) contexts. Despite the fact that automatic doors are actuated, none of them take on an active social role (e.g., taking into account whether one is a small girl or a big guy, in a rush or relaxed, wants to be disturbed or not, etc.). This was echoed by Bruno Latour (1992), who noted that automated doors lack any social awareness and called for the use of 'active technology'.

I approached the design of the Sensible Door through an iterative, incremental process. Through several iterations, following a reflective transformative design process (Hummels & Frens, 2009), I shed light on the role of a socially intelligent door in our daily lives by producing incrementally rich and detailed experiential versions (Stienstra, Hengeveld & Lévy, Forthcoming). The door was tested in a lived-in open-plan office environment in our department where actual people were working.

Investigating the current design of (automatic) doors, I identified the following aspects of use as starting points for my (re-)design:

I wished to design beyond the obvious functionality of a door, i.e., granting or denying access from one space to another. I believe that doors serve a myriad of social functions in our daily lives by mediating meaningful particularities on both sides of the door, i.e., the spaces and their inhabitants.

Walking through a door is a moment of transformation. Long before reaching the door, we can already see that, when it is closed, it keeps us from the action-possibilities on the other side; by contrast, an open door invites us to enter. A half-open or opening door might indicate a subtle availability. Seen from the other side, this can be an invitation to leave. In other words, the door's position or state of transition holds meaning that transcends a mere discrete open- or closed-ness.

When one arrives at a closed door, manually pushing or pulling the door handle or bar holds meaningful information. A heavy, resistant door tells us something distinct from a smoothly operating one, or one that is actually locked. The direct feedback of opening informs not only the person entering through the door, but also the inhabitant of the space to be entered. Whether the person opening the door is exhausted, aroused, shy, or angry has already been conveyed by the movement and sounds of the door.

Given these aspects, I believe in the inherently rich characteristics of the door in mediating the 'about-content' of people and their contexts. I further argue that doors should be utilized in such a way as to address people's *social skills* even more so through the use of technology. Accordingly, I aimed for the Sensible Door to embody the social functionalities of a door that make it such a rich mediator of contexts, rather than to reduce its characteristics (i.e., blindly automating it to events). The socially intelligent door I designed served to explore technology as an active agent in embodying contextualized social behavior, and addressing the continuous and expressive nature of our being-in-the-world.

Tracks of Investigation

With this exemplar, I focused on two tracks of investigation: (a) how the door functions in direct interaction with people and (b) as a socially skilled and context-understanding active mediator or actor.

The first track of investigation built upon the direct interaction as explored in the Augmented Speed-Skate Experience and Squeeze Me exemplars, seeking to shed light on how the qualities of movement *in* interaction can be utilized to create reflective, inhibiting, and inviting behaviors (Stienstra, Bruns Alonso, Wensveen & Kuenen, 2012) that can be used to direct people's behaviors. In effect, this track explored how the door, as an active agent, could act upon the intentions of a person *in* interaction.

The second track of investigation focused on *contextuality*, on when to act appropriately in a given yet dynamic situation, as explored in the Sensible Alternative and Sensible Interface. Here, the role of the door becomes an active mediator of 'about-content' between one side of the door and the other (Stienstra, Hengeveld & Lévy, Forthcoming).

Both tracks of investigation were explored in context. However, none of the explorations were aimed at proposing solutions to concrete use problems. Instead, my primary aim was to arrive at theoretical insights pertaining to interaction design and consequently their implications for design practice. The compositional whole took the form of a door that embodied phenomenology-inspired principles of continuity, expression, and context-driven agency.

Design and Implementation

The Sensible Door consists of several elements as found on any other door, e.g., a frame on the wall, and a surface and hinges that allow the door's surface to open and submerge into the wall. However, the door is enhanced with several elements that are found in automatic doors, as well as sensors and actuators that enabled me to explore contextualized social and rich expressive behaviors. In the subsequent sections, I briefly describe the additional elements and characteristics that shaped the Sensible Door as an exploratory platform.

Retractable Pushing Area and Door Handle

First of all, the door can be opened and closed manually. For this, the Sensible Door has door handles in place. As Donald Norman (1988) suggested, a pressable surface encourages pushing and a pullable handle encourages pulling. These basic principles of *affordance* led me to design a push area and a pullable door handle on the outward-turning and inward-turning sides of the door, respectively. As I wished to play with affordances in the explorations, I made the push area and door handle automatically retractable into the surface of the door, which would thereby remove its affordance to push or pull (e.g., transforming the door into a wall or automatic door).

In order to know whether a person is physically in touch while interacting with the Sensible Door, I embedded capacitive touch sensors in the push area and door handle. These sensors provide analogous data about the amount of surface touched (e.g., whether it is with one or two hands, or even as the hand approaches, as the capacity in the air is picked up).

Actuation The main actuating part of the Sensible Door is a motor that is strong enough to open and close the door. It can even push or pull a person in or out of the door's path with remarkable force. On the basic motor control level, I implemented real-time control of the voltage in both directions and short-circuits for motor friction (continuously scaled from a non-differentiable to a reasonable yet push-through-able friction). Together with angle measurement (a rotary sensor on the motor that provides continuous data about the door's position), the motor, and thus the door as a whole, is capable of expressing a variety of real-time controlled and anticipated behaviors.

Sensing and Control Both sides of door are equipped with distance sensors to support autonomous behavior and anticipate incoming or outgoing people. The behavioral layer of the system architecture mainly takes place in MAX6 and is informed by a variety of continuous feeds from the door's position, pressure exerted on the door, distance sensor, overhead camera, and so on. Furthermore, since the Sensible Door was intended to be a platform for exploration, external feeds are supported. Nearby wifi-connected devices capable of streaming OSC messages and external devices that communicate via a real-time UDP connection can provide the system with data (e.g., information about the weather, someone's calendar, or other feeds that might be used to determine a certain human–door interaction behavior).

Fig 26. The pushing area is located to afford pushing. The pullable door handles retracted into the surface of the door on the left. On the right, they become actionable.

Fig 27. The Sensible Door present in the open work space. The look and feel of the door were in the form of an experiment in building rather than experiment in progress. This invited people to 'act normal' rather than being part of an experiment.

Fig 28. A remote touch pad was used to explore movement behaviors of the Sensible Door. The position, angle, and touch-size of fingers were tracked and translated into dimensions such as sturdiness and gentleness. In turn, the Sensible Door would resist or smoothly corporate. The expression exerted on the touch pad was directly mapped to the behavior of the door.

Interaction Design

The main characteristic of the Sensible Door is that it actively behaves *in* interaction. The core characteristics of the Sensible Door are the behavior designs in which I explored the door as a mediator of people's (movement) behavior and a socially skilled and context-understanding entity. In the following, I present a selection of the various behavior designs that were explored.

Behavior Designs for the First Track of Investigation

The first behavior that was designed mirrors the expressive opening of the door: when the interactant opens the door aggressively, the door closes aggressively (slamming shut behind the enterer); when the interactant opens the door gently, the door closes gently. A second behavior anticipates the entering interactant based on his or her walking speed: the door opens at a pace that corresponds with that of the person. A third behavior utilizes the amount of pressure exerted on the door handle: the door's movement essentially matches the pressure exerted.

Forms of inhibiting, direct, and inviting mappings.

With these base behavior designs, I implemented inhibiting and inviting behaviors, e.g., pushing back the enterer or opening in advance. In addition to these inhibiting and inviting behaviors, I explored other mappings such as a 'spring' behavior and 'reversed' mood. The spring behavior made the door feel like a spring on its hinges, i.e., the further it was opened the more forcefully it would return to the closed position. The reversed mood, in contrast to the inhibiting and inviting behaviors, reversed the door's mapping to exhibit counter behavior. In practice, if the door were opened gently, it would slam back wildly, and *vice versa*. Here, I thus respectively investigated the behavior of people when interacting with increased resistance (or even pushback) in opening or closing the door behind them, and people's response (*in* interaction and afterwards) to the unexpected behavior of the door, such as a moody slam or enthusiastic swing.

The behaviors of *mirroring, inhibiting,* and *inviting* seem random but can be used to transform the behavior of people entering through the doorway. However, such behaviors must be applied in a socially relevant manner, which brings me to the second track of investigation.

Four paradigms of socially and contextually embedded interaction were explored in the Sensible Door: the influence of one's business (through the calendar), the crowdedness of the space (influenced by the noise in the space), daily rhythms (influenced by the sun), and personal relationships (based on interpersonal hierarchies)

Behavior Designs for the Second Track of Investigation

To start the second track of investigation, I connected a calendar to the door, informing the door about the occupation of the space in terms of usage, i.e., whether a meeting is at its peak, informal, ending, private and so forth. The behavior of the door was mapped as follows: if a meeting was about to end (as indicated by the schedule on the calendar), the door would automatically open slowly, indicating that the meeting was about to end. This would be visible from both sides of the door. If the space was not to be disturbed, the friction would be mapped to "unwillingness for disturbance", making it more difficult for outsiders to enter. If one were to enter anyways, it would indicate to those inside that it was an urgent matter.

A second exploration concerned the smoothness of opening and welcoming behavior mapped to contextual information derived from the environment. Here, I explored three ways of informing the *contextuality*, namely (a) the surrounding noise (whether the space was informally crowded during a break or occupied by hardworking researchers), (b) the sunlight (whether the door is welcoming on bright day), and (c) the personal relations between door-enterers and inhabitants (e.g., distinguished colleagues coming to visit or students delivering design work). The mappings here were thus not directly human-driven (but driven by use-of-environment, surroundings, and personal relations, respectively); nevertheless, the mappings perhaps made an impact through the social fabrics of interwoven life, i.e., the door influences people's behavior in terms of a *background relation* (Ihde, 1990; Verbeek, 2015).

The third paradigm for exploration of the Sensible Door was a moody interaction similar to the one applied in the Squeeze Me exemplar. For this exploration, the door was not to socially mediate between spaces, but have its own mood generated on the basis of previous encounters. In short, the door would start off with a medium level of resistance or friction. When pushing the door open, the resistance would decrease if the door were pushed fast. The resistance of the door would increase if it were pushed slowly. In itself, this behavior seems counterintuitive; but what happens here is that the Sensible Door gives in to the needy ones (those entering quickly) and holds back the people who are unsure (those entering slowly). This response will increase or decrease over time depending on the behavior of the person. In practice, when the person who entered quickly wants to leave the space again, he or she is held back. When the door is pulled quickly, friction increases, but when the door is pulled slowly, the friction decreases to allow the person through more easily. In the case of the person who entered slowly, leaving more quickly is supported. These mappings were based on the assumption that fast and slow relate to a desire to enter, i.e., moving in fast relates to being certain about entering while moving slower equals to being less certain about entering. Therefore, the moody interaction explored subtlety, as well as how to design for smooth or abrupt transitions of behavior within the realm of a single-meaning context (i.e., the door's desire to keep the eager in and the unsure out).

A fourth group of behaviors – and the most challenging in terms of design mapping – concerned the attempt to make the door provoke a person to be courteous toward other people. By utilizing the top-view camera to distinguish directedness of people (based on shoulders and walking pattern), the behavior of the door in terms of smoothness of opening and even helping (by automatically giving in and opening) was mapped not to people's orientation with the door but with each other. In other words, if two people arrived at the door, opening would be smoother when the person grasping the door handle stepped out, turned his or her body, and allowed the other to pass.

Consequences for Use

The Sensible Door was implemented in an open-plan work environment at my department of Industrial Design. The following general observations and measurements were made regarding people's (i.e., students, staff, and guests) engagements with the door when the previously mentioned behaviors were applied.

A main observation concerning the first track of investigation was that people were moved (physically) by the expressive behavior of the door. In particular, they could be slowed down by the inhibiting behavior designs. It seemed possible to inhibit the enterers in their movement through subtle behavior designs utilizing a back-pressuring movement of the door. The movement data revealed changes of behavior in people's movements and in the pressure they exerted when opening the door. In effect, the pressure exerted was used as measurement for behavior change while at the same time it was used in the direct mapping of the door behavior design. I consider this in-loop measuring to be a valuable tool for measuring behavioral change.

Applying the designed behaviors in a relevant manner was explored with the second track of investigation. Results indicated that the relevancy for a door to act as a social mediator through gracious movements, back-pressure, moodiness, and so on was highly context-dependent. In line with Ju and Takayama's (2009) work, it became apparent that the self-opening behavior of the door (i.e., acting upon the movement of people entering) could provoke a variety of interpretations. Consequently, making the door, with the different context-informers, provided valuable insight into how to tackle this designerly issue of *contextuality* on a practical level. It turned out to be a major challenge to implement a mix of behaviors and accommodate a variety of context-informers (i.e., letting the environment, direct interaction, hierarchical relations, and so forth influence the behavior of the socially mediating door), and to address the design from an activity-driven approach rather than an event-driven approach. However, the design benefited from expressive behavior that could attune itself to the (attuning-)preferences of users. It furthermore helped if people approached the door comprehending that it was a social mediator as opposed to a door exhibiting quirky (malfunctioning) behavior. In such cases, people tended to be more responsive to the door's behavior.

Concluding Remarks

The Sensible Door is respectful toward people in the sense that it reflects the behavior of the interactant, as well as that of the space or the inhabitants. It does so by taking the particularities of people in two different contexts and communicating this richness, thereby allowing people (on both sides of the door) to capitalize on their *social skills* by understanding and acting upon the intentions of the other.

This 'about-content' communicated in its richness, whether it concerns the 'engaged-ness' or 'crowdedness' of the people in the space or the awareness of someone else when opening, comes in an embodied form. It addresses the *social skills* through our *perceptual-motor* and sometimes *emotional skills*, without lapsing into symbolism requiring cognitive comprehension and taking people out of their flow.

To expand a bit on the first claim made, i.e., that the Sensible Door reflects the user's behavior and further capitalizes on the *social skills*, usage of the door showed that as people moved through the rich expressive door – which took in and reflected this expression – it enabled people to get a grip on how they behaved. This contrasts with doors that are lenient or insensitive to expression. As the Sensible Door becomes an extension of expression, whether it is the reflection of a person's anger in the opening swing, the anticipation of the rush of an incoming person, or resistance to keep out an unwanted guest, the rich socially mediated expression provides the means for another person to act upon the person that enters as well.

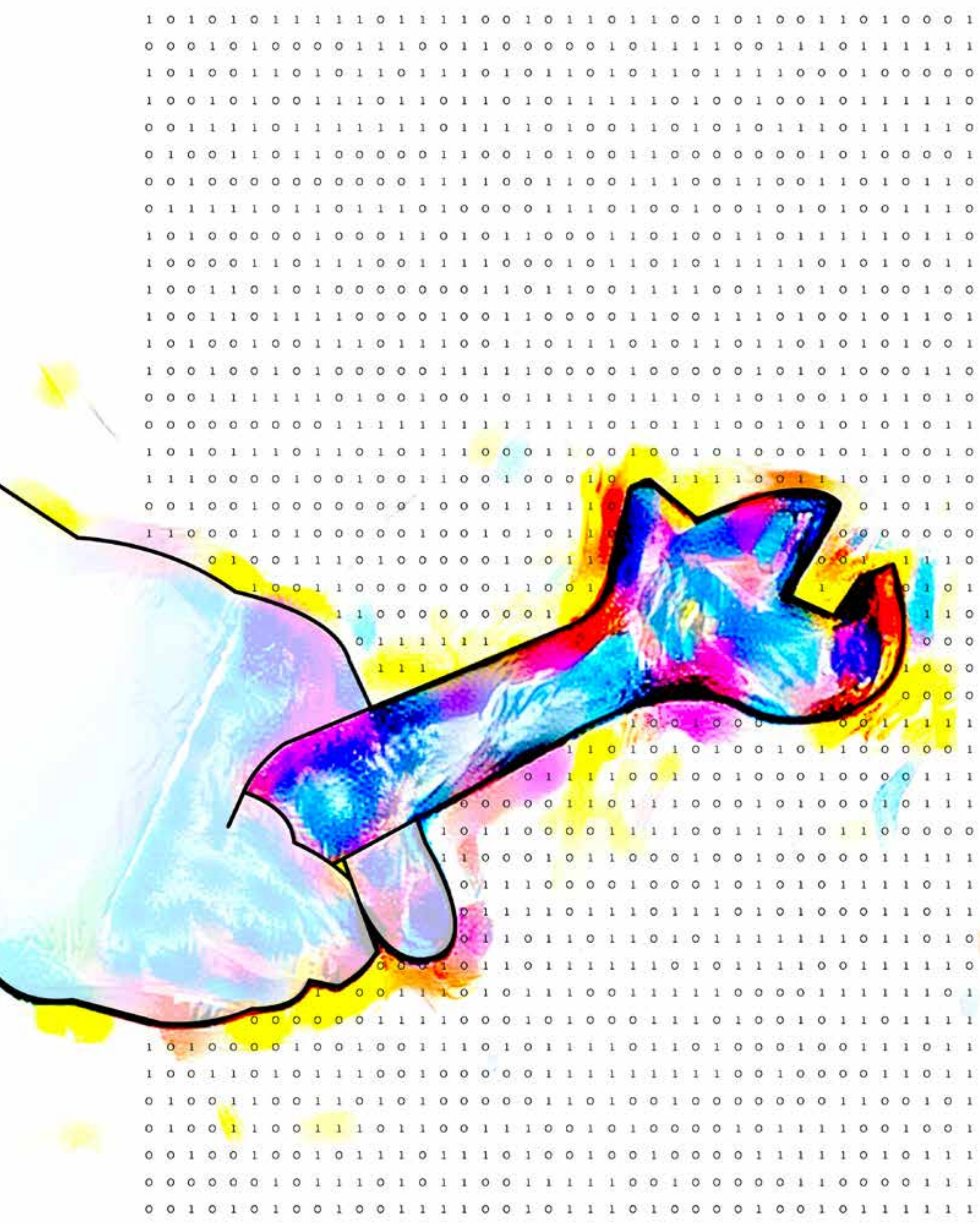
Part III: Annotations & Reflections

In Part II, I discussed four designed exemplars that were directed by the theory established in Part I. In this closing part; I elaborate on how the theory and its derived approach for design found its way into the designed exemplars. That is, I reflect on the consequences of an approach to designing for interaction that is inspired by the phenomenology of perception and ecological psychology.

This part is divided into three chapters: Doing Design Research, Respectful Embodied Interactions and Supportive Design Approach & Tools. The first chapter, Doing Design Research, expounds my approach to design research as staged in Part I and executed in Part II. I scrutinise my phenomenology and ecological psychology-inspired approach to design research and reflect on the way it relates to similar approaches that focus on the interplay between theory and design. This chapter explores the methodological questions and approaches to design research that fit a *respectful embodied interactions* approach to design. Consequently, I reflect on the role of the prototype, subjective evaluation and the design researcher's attitude.

The second chapter, Respectful Embodied Interactions reflects on the way the exemplars designed and described in Part II reveal themselves *in* interaction in relation to a phenomenology and ecological psychology-inspired approach. I articulate key insights that relate how people interact with the exemplars to the theoretical stance taken as well as related theories, and how this relates to other frameworks for design that share ambitions (e.g., natural interaction, persuasive computing, and ubiquitous computing). I expound *Interactive materiality* as a definition that captures interaction design characteristics that are embodied in the exemplars. The second chapter elaborates what Respectful Embodied Interactions are really about, what it means to people and how it relates to other work.

The third chapter, Supportive Design Approach & Tools reflects on the tools and methods that were used while designing the exemplars. This chapter discusses the limitations of available tools to support designing for respectful embodied interactions and describes practical, supportive tools and approaches, so called *designerly handles* to enable exploration and *reflection-in-action* when designing for respectful embodied interactions. Thus, this closing chapter primarily focuses on its implication for designing; for the creation and development of products and systems, instead of focusing on the implications of phenomenology and ecological psychology for design research, as is done in the first chapter of Part III.



Phenomenology is a project of sober reflection on the lived experience of human existence–sober, in the sense that reflecting on experience must be thoughtful, and as much as possible, free from theoretical, prejudicial and suppositional intoxications. But, phenomenology is also a project that is driven by fascination: being swept up in a spell of wonder, a fascination with meaning. – **Max van Manen** (2014 p. 12)

Doing Design Research[33]

[33] This chapter contains parts of Stienstra, J.T. (2015). Embodying Phenomenology in Interaction Design Research. *Interactions, 22(1)*, 20-21.

In order to apply the core values of the informing theory in my interaction design research – a discipline heavily influenced by the mainstream sciences – I believe it takes more than applying the theoretical insights derived from phenomenology to design: I attempted to take phenomenology beyond using it as inspiration for interaction design theory and tried to embody the phenomenological stance, to absorb myself in it, to live it in my approach to both design practice and design research. In doing so, I hoped to uncover its treasures and pitfalls and further the discipline in the process. This provoked me to stay faithful to the sometimes bold beliefs derived from a philosophy that can easily misunderstood. Likewise, it required me to resist falling back on the type of Cartesian thinking that I was trained in and that forms a part of the foundation of my training as a design researcher.

In this respect, designing and doing design research from a phenomenology and ecological psychology-informed perspective is subject to both mental and practical challenges. The most persistent of them are discussed in this chapter. Within this chapter, I clarify these challenges and propose ways to address them. In effect, I point out some of the major discrepancies between my approach and those that I am confronted with in doing design and design research. Consequently, I propose manners to deal with these discrepancies by turning to compatible approaches in design research, and use my own work to exemplify this. After elaborating the approach taken, I address a few topics that are central to phenomenology and ecological psychology, and pinpoint how I addressed them in my work.

Approach to Design Research

Generally, research is known to have several purposes such as exploration, description, explanation, prediction, control, interpretation, and criticism. To what is traditionally expected from a dissertation, in the Netherlands and beyond, I took an unusual approach – so I've learned. I did not seek intellectual satisfaction in finding greater credibility, reliability or generalization. Rather, I placed emphasis on investigating individual understanding (i.e., discover how people make sense of what I design in an idiographic way) while being intimately involved with my design research process (i.e., I focus on the process of designing rather than the result). First and foremost, I am driven by curiosity and seek to investigate a worldview that inherently opposes the *status quo*. That, however, is not to say that I aim to criticize *per se*. Rather, I devise an alternative perspective on interaction design. In what follows, I elaborate the designerly approach taken to reveal the consequences of a phenomenology of perception and ecological psychology-informed perspective on interaction design research.

Background & Ambitions

We (mankind) tend to strive toward control and away from the natural or nature. To do so, we reduce complexity and make things simpler when it comes to reality as we experience it (Abram, 2010; Buchanan, 1992; Maeda, 2006; McCullogh, 2004; Norman, 2013; Thackara, 2005; Rauterberg, 2014; Rauterberg & Feijs, 2015). Yet, both design (in some circumstances aimed at changing reality) and phenomenology (aimed at understanding reality) acknowledge and embrace the rich qualities of our *being-in-the-world*.

As argued before, phenomenology as a philosophical field struggles with the traditional sciences, as it profoundly opposes some core scientific ideas. Interaction design and its 'designerly approach' (Cross, 2001; Buxton, 2007; Moggridge, 2007) also faces issues with the traditional sciences. Schön (1983), among others (Simon, 1969; Stolterman, 2008; Stienstra, Bogers & Frens, 2015), argues that the field of design is incommensurable with the underlying philosophies and principles in the area of science. Interaction design approaches are newly developed and attuned to the designerly way of doing; however, most of these approaches have roots in other academic fields, such as engineering, social sciences, and the traditional arts (Carroll, 2003; Rogers, 2004). Even though these approaches have been successful in their own fields, these borrowed approaches do not always turn out to be successful in design practice, as they are generally not appropriate to the nature of design (Rogers, 2004; Saariluoma & Oulasvirta, 2010).

Science has proven to be successful in dealing with complexity in the process of uncovering the mechanisms and structure of reality. Nevertheless, the underlying principles embodied in scientific methods and approaches are generally not transferable to and suitable for design (practice). A somewhat general premise in traditional science is that problems should be reduced and addressed under controlled circumstances. Such approaches ultimately aim at universality. By contrast, design, and especially one's experience of it, is of a rich, holistic nature that is situated and specific. Therefore, design cannot be simplified, universalized, or reduced (Norman, 2004; Rogers, 2004; Stolterman, 2008).

The traditional role of making in interaction design research has arguably been to produce artefacts that can be used as instrumental or quasi-experimental empirical evaluations. The making itself and its design choices have generally not been detailed, and the knowledge contributions have been mostly located to the outcomes of the experiment. In recent years, however, our research community is starting to show some awareness of the dilemma and some ambition toward leveraging the knowledge outcomes of making **– Jonas Löwgren** (Löwgren, 2016 p. 32)

Challenging the Status Quo

For me, the biggest challenge in exploring the consequences of a phenomenology and ecological psychology inspired approach through several exemplars was to actually challenge the *status quo*. By nature, the phenomenological stance conflicts with the approaches dominating my environment. Such approaches have made me accustomed to generalizing, discretizing, objectively measuring, and so forth. Moreover, these methods of analysis are thoroughly present in the structures of my work, the books I read, the expectations for documenting my work (i.e., this written, somewhat structured form of dissertation), the colleagues I engage with, etc. In short, there are many influences that can divert me from what I aim to overcome. In retrospect, the major contributing structure that enabled me to explore a phenomenology and ecological psychology-inspired approach to design, insofar as I succeeded, was the opportunity to evidence my contribution through the act of making as the main generator of knowledge.

For doing design research, of which this work is the result, the perspective taken first and foremost points to the subjective nature of being, to the uniqueness of people in their engagements with 'their worlds'. Unlike science and its mainstream research approaches that focus on generating knowledge through fundamental research, the phenomenological perspective demands a holistic, continuous, ever-changing, and contextual approach to research. Phenomenology as a philosophy offers a way of looking at the world as it appears in our direct, holistic, and contextualized experience. However, doing (design) research aimed at furthering design insights that depart from a phenomenological perspective, requires a rigorous change in how one approaches research: a change of mind, a change in doing (Stienstra, 2015).

Briefly, phenomenology-inspired design research in itself demands an appreciation for and focus on the unique subjective experience of people without lapsing into generalizations, user-models, mathematical descriptions, guidelines, and other Cartesian-inspired distractions grounded in rationalism, objectivity, and reduction. Likewise, taking philosophy as a point of departure, design research is about overcoming 'Cartesian' drawbacks and rejecting several fundamental tenets of the traditional sciences as we know it. For instance, it is difficult to find space for subjective qualities of uniquely skilled people in their engagement with a product, and a rich idiosyncratic design process. Those ideas do not match ideas that design research has inherited from other sciences that aim at more measurable, objective, and generalizable results (*nomothetic*). The conflicts that emerge in doing design research in such a way are revisited and elaborated upon in the following sections.

[34] This work inescapable took shape in the form of a reflective transformative research approach, after being trained by Hummels and Frens' *reflective transformative design process* (2009; 2011). In the course of the dissertation, the approach adopted a particular fit with *concept-driven interaction design research* (Stolterman & Wiberg, 2010).

In what follows, I first elucidate my design research approach[34] and show its compatibility with aspirations embodied in a phenomenological approach. This is done by discussing my approach to research in relation to similar design research approaches, defining its particularities (i.e., the role of the prototype and prototyping as generators of knowledge) and through illustrating its qualities and shortcomings that emerged through its application in this research. This is followed by a series of pointers for doing design research while designing for respectful embodied interactions in particular.

Related Approaches to Interaction Design Research

The approach for this work took the form of a critical retrospective on a range of design concepts, in order to challenge my theoretical and conceptual foundations of interaction design. This approach is in line with earlier retrospectives on tangible products (Djajadiningrat, Overbeeke, Frens & Wensveen, 2004), skills and expression (Djajadiningrat, Matthews & Stienstra, 2007), and sets of concepts to promote awareness of energy use in everyday life (Mazé & Redström, 2008). My approach and presentation form relates to what has recently been put forward as 'annotated portfolios' (Gaver, 2011; Bowers, 2012; Gaver & Bowers, 2012), in that, I try to go beyond being descriptive and generative, and work toward explanatory or even predictive theory. Stolterman and Wiberg (2010) call this 'concept-driven interaction design research', where the focus of the interaction design is on theoretical advancements.

The concept-driven interaction design research approach aims at manifesting theoretical concepts in concrete designs (i.e., grounding the design both conceptually and historically in the theoretical considerations). Furthermore, this approach is characterized by a theoretical point of departure rather than an empirical one (e.g., a hands-on design exploration and development of artefacts approach), and an orientation toward theory rather than a specific problem, user, or use context.

The concept-driven interaction design research approach closely relates to what has been put forward as the research-through-design approach (Koskinen, Zimmerman, Binder, Redström & Wensveen, 2011). This is broadly defined as an approach through which to acquire knowledge by designing, building, and evaluating highly experiential prototypes in context (Wakkary, 2005; Frens, 2006; Zimmerman, Forlizzi & Evenson, 2007; Hengeveld, 2011; Deckers, 2013). The purpose of research-through-design is not about evaluating the functioning artefact, but rather about generating knowledge for making design decisions (Gaver, 2012). In design research, several forms of research-through-design have emerged, each with a different focus on filling the gap between theory and practice – a persistent challenge in interaction design research (i.e., since theory is by nature abstract, accounting for a multiplicity of instances, it is difficult to translate and operationalize).

'Strong concepts' (Höök & Löwgren, 2012), 'design patterns' (Tidwell, 2005), and 'annotated portfolios' (Gaver, 2011; Gaver & Bowers, 2012) primarily depart from practice (i.e., design cases) in generating so-called intermediate forms of knowledge between theory and practice (Löwgren, 2013). As such, these types of research through design are situation-specific and, like Archer's (1995) research through practice, difficult to generalize from. The concept-driven interaction design research approach departs from this and intends to inform theory in the first place. Although all of these approaches are design-oriented and lead to designs, the overarching purpose of this latter particular design process is not to create more desirable artefacts, but to theorize. In other words, the work does not seek to solve problems in situation-driven research, but to explore theories of interaction with the overall aim of improving and widening the range of theory and knowledge. Examples of this approach are the work Ståhl (2014) and Deckers (2013). Respectively, they investigated interactional empowerment, and the phenomenological idea of perceptual-crossing into interaction design practical notions (Ståhl, Löwgren & Höök, 2014; Deckers, Lévy, Wensveen, Ahn & Overbeeke, 2012).

My work aims to clarify the consequences of phenomenology for the act of designing, even though its primary objective is to develop and sharpen interaction theory and come to an understanding of what respectful embodied interactions are about. Therefore, I consider my work to be concept-driven interaction research. Nevertheless, this work might result in what Dalsgaard and Dindler (2014) call 'bridging concepts', thus calling out and opening up space for design practical consequences. A bridging concept is posed as an intermediary form of knowledge that inhabits the middle ground between theory and practice, and can foster the exchange between the two. However, Dalsgaard and Dindler suggest that both 'strong concepts' and 'concept-driven interaction design research' can serve this particular purpose, namely to bridge theory and practice to its full extent.

Similarly, my work could be seen as a programmatic approach to design research (Redström, 2011) in which a direction is formulated, experimented with, and reformulated. If my work is considered as such, my respectful embodied interactions manifesto compares to Hobye's (2014) take on Gaver's Homo Ludens as a manifesto. In essence, my work is developed as continuation of the 'Aesthetics of the Impossible' program as established by the late Kees Overbeeke (2007) and his Designing Quality in Interaction research group. The difference nonetheless is that my work has a strong emphasis on theory, and the experiments take the form of in-context experienceable products. In other words, my work is guided more by the theoretical insights approached from the philosophical stance rather than by the pragmatic outcomes of experiments.

Playing a pivotal role between theory and practice are the concept-designs for the concept-driven interaction research approach. Designed concepts are used as the carriers of knowledge, but are also responsible for establishing conceptual frameworks and challenges for the future. They have knowledge embodied within them; they express qualities in a complete composition. Stolterman and Wiberg (2010) describe concept-designs as explorations of conceptual futuristic ideas that set the agenda for forthcoming investigations. By contrast, prototypes are cast as manifestations of specific ideas for specific design solutions, used to explore the particulars of a design in relation to the desires and needs of a well-defined group of users. The main quality of a concept-design is its character, i.e., the overall organizing principle that makes up the composition of the design as a whole (Nelson & Stolterman, 2003).

Stolterman (2008) argues to ground the "designerly approach" in design practice and in the situated and the concrete in order to embrace its own rigor and discipline (Fällman & Stolterman 2010). While my work on developing an interaction design theory is primarily phenomenology-driven, I seek to propose a phenomenology-inspired designerly approach derived from design practice (i.e., by actually designing in the situated and the concrete) and theory (i.e., by being informed by phenomenology more than by practical applicability). To this end, I thus commit and accommodate my design practice to what I believe best fits with the philosophy.

Within my explorations, the proposed concept-designs have found their inspiration and restrictions in the established theories of ecological psychology and phenomenology of perception, with the overall aim of making this abstract design theory, derived from the theories, relevant to design practice. The range of concepts I present in this thesis shows how the design exemplars are both historically and conceptually grounded in previous design work and theory. This is done to strengthen the argument for the relevance and extensibility of the generated design-relevant knowledge (Forlizzi, Zimmerman & Evenson, 2008). The concept-designs are further reviewed in relation to their implications for addressing human capabilities, their design-practical notions, commonalities, and consequences for designing.

According to Stolterman (2008), designers' skillful activity of inquiry and action through which they cope with complexity in the real world is better served by providing design practitioners with (a) precise yet simple tools or techniques, (b) frameworks that do not prescribe but support reflection and decision-making, and (c) individual concepts that are intriguing and open for interpretation and reflection, instead of providing them with prescriptive methods and approaches. It is my aim to support the acting designer's judgment (i.e., the designer's primary tool for dealing with design complexity) in a situated, designerly way.

Methodological Activities

Stolterman and Wiberg (2010) follow Zimmerman, Forlizzi, and Evenson (2007) in proposing methodological activities that resemble any design process and require knowledge and skill. They argue that the activities of design can be exploited as a way to do research and to produce knowledge akin to producing a design. In concept-driven interaction design (Stolterman & Wiberg, 2010), these (research) activities are described as follows: (a) concept generation, (b) concept exploration (going beyond the initial idea to explore the unknown), (c) internal concept critique (examining the construct on the basis of its uniqueness, groundedness, and expressiveness), (d) design of artefacts (crafting the artefact that embodies the theory), (e) external design critique, (f) revisiting the concept, and (g) concept contextualization (relating and evaluating this new concept against the current body of concepts and theories in the field in order to show how it contributes to previous work). The activity of revisiting the concept involves an element of iteration, even though the activities are presented in a specific order.

This somewhat phase-sequential approach to designing might aid in arguing a conceptual construct, in that, following and describing a process will most likely produce a coherent argument. However, such an approach does not resonate with the way I have become accustomed to working, how I reveal the design space, opportunities, and critical paths. As the methodological activity 'revisiting the concept' proposed by Stolterman and Wiberg (2010) implicates, the concept-driven interaction design research approach is likely to undergo revisions and redesign following critique. To me, the critique or reflection (either external or internal) followed by iterative improvement is at the core of my process. I take the liberty of labeling my way of working, that is, my approach to designing as well as to doing research, as a reflective transformative process, as elaborated by Hummels and Frens (2009; 2011). In other words, I have adopted a reflective transformative research approach through which the earlier stated methodological activities of the concept-driven interaction design research find their way into the iterative design process. This design process is aimed at developing a vision of an interaction design theory as opposed to producing a concrete design as the approach was intended.

Iterative Reflection as Validation Mechanism

The reflective transformative research approach is a fair description of my way of working, yet it holds a few unforeseen consequences that should to be addressed. In the first place, the design (research) process with all its activities and all its arguments for specific design decisions are difficult to document considering that it is a highly iterative approach that requires constant reflection while switching between activities of making, thinking, integrating, envisioning and exploring and validating in context. It is difficult to constantly monitor unspoken decisions that come quite naturally once the approach is embodied. Furthermore, it is difficult to remain in the flow of the work once one steps out of the reflection-in-action mode of working. I do not aim to justify a laziness of sorts; in general, I do believe that the conceptual constructs are documented well throughout this dissertation. For instance, the path toward the 'moody interaction' conceptual construct is described according to the core insights and decisions made. However, it must be recognized that many unspoken, tacit, or less prominent design (research) decisions were lost in the crafting of the written form of this research. I think that falling back on the most apparent insights following reflection-on-action is sufficient for me as a designer to direct my own process. It is the constant validation (in context) of the conceptual constructs with the highly iterative reflective transformative approach that confirms, rejects, and in most cases tunes the grand insights made explicit in the process. I consider this highly iterative validation to be an opportunity when constant documentation makes it challenging to remain in the flow of *reflection-in-action*.[35]

[35] Although video time-lapse, tagging, and other forms of continuous documentation can be used, they hardly capture the essential design decisions and thus require additional annotations to be made in the process.

Confronting the Theoretical Anchor

In the second place, Stolterman and Wiberg (2010), proposed external design critique as a methodological activity. In practice, this activity – that consisted of peer-reviews and design crit sessions with users and experts – took place during the validation in context of my approach. In principle, I promote this activity, which is why I confronted users and experts at various stages of the design (research) processes of the exemplars, gaining valuable insights (Hummels & Frens, 2011). Yet, maintaining a critical stance towards and reflection on the theoretical intentions, i.e., validating the conceptual and theoretical assumptions embodied in the design itself, turned out to be slightly problematic. For instance, it is desirable to engage in in-depth discussions concerning an in-between prototyped artefact in order to flesh out certain characteristics that are consequences of taking a phenomenology-inspired approach.

Regardless of the level of expertise of the external critic – whether he or she is a user or expert – it is challenging to have a discussion of the desired depth when it comes to philosophical stances that at times contradict themselves. Furthermore, it is tempting to steer discussions toward pragmatic analysis over a thorough theoretical confrontation. For instance, the *moody interaction* is more easily discussed in terms of functionality or ethical consequences, i.e., 'this does not make sense, the robot should just do as I say' or 'isn't it easier to just program an if/then sequence or use orange, green, and red light-emitting diodes to indicate the mood of the robot?' than in terms of the designed characteristics that make the technology and person resonate *in* interaction.

Turning to an autobiographical attitude (Neustaedter & Sengers, 2012; Desjardins & Wakkary 2016) for my interaction design research turned out to be useful when I could solely rely on my own design skills making design-pragmatic choices. As my research aimed at developing theory-informed and design relevant insights, I relied on an intimate understanding of the theoretical anchor. It was crucial to assure that I'd be able to flesh out its salient aspects.

As elaborated earlier, I find it fruitful to acquire insights from the data-in-use, data that speak to the ongoing engagements with the dimensions at stake. Furthermore, although the people consulted in the validations do not necessarily require a profound background in phenomenology or ecological psychology, they do need to be open to acting with the designs and expressing their feelings. That is, despite my thorough belief in the primacy of action, I do recognize that people have become increasingly disengaged from their bodies in the world. This is something I implicitly attempt to restore through this work and encounter when I invite people to engage with my exemplars. People have grown disengaged and accustomed to not using their hands; instead, they merely contemplate and express themselves in terms of discrete formulations, i.e., they articulate themselves *gnostically*.

In order to make use of people's bodily capabilities, I confined the engagements between people and their artefacts to their bodily skills, i.e., functionality could only be accessed through bodily engagement. The exemplars, at all stages of their design, involved an experienceable component of a compositional whole. This means that all prototypes could be experienced holding interactive qualities.

The compositional whole of the designed exemplars was framed by the theoretical considerations in question, which in most cases focused solely on utilizing the *perceptual-motor, emotional,* and *social skills.* I aimed to not be distracted by more cognitive manners of engagement that could fulfill similar functionalities, but undermine my attempt to reveal consequences of a respectful embodied perspective.

Roles of the Prototype

To me, a prototype (Houde & Hill, 1997) can serve several purposes – from proof of concept to a means of exploration, from low-fidelity exploration to high-fidelity probing. So far, I have considered the prototypes of my work to function as physical hypotheses, as tangible forms of the challenged theories or concepts, i.e., embodying the ideas informed by the phenomenology of perception and ecological psychology. Wensveen and Matthews (2015) distinguish four roles of a prototype that I consider to be embodied in my exemplars: the prototype as experimental component, as means of inquiry, as research archetype, and as vehicle of inquiry. Frens and Hengeveld (2013) argue along similar lines, emphasizing the role of making as inspiration and elaboration in the process of prototyping. Theory helps us make strategic choices about how to proceed (Halverson, 2002). In accordance with this description about the function of theory; it is my belief that a prototype should help us make strategic choices about how to proceed as well. In what follows, I focus on certain qualities and decisions related to my design process that supported me in utilizing the prototypes as constructs for furthering the interaction design theory.

Fidelity of the Prototype

Simply put, the fidelity of the prototype should follow the function of the prototype (Frens & Hengeveld, 2013). This allows designers to invest a proper amount of time in their work without over-doing it. For example, for the Augmented Speed-Skate Experience exemplar, a variety of prototypes were made. The first one involved a force-sensing resistor that was taped to a shoe and connected to MAX/MSP to generate some 'bleeps'. This prototype was used to convince the TVM Schaatsploeg to participate in the project. The prototype was functional, experienceable, and with two hours of work, highly effective. A subsequent prototype involved using a laptop while the athlete was speed-skating in order to validate the stability and range of the sensors. Even though the engagement did involve people, the focus of the prototype was on tuning the sensors before actually downsizing the whole device. When I started to gather data in conjunction with the athletes and apply the movement sonification, I had to deliver a prototype that was lightweight and would not disturb the normal activity of speed-skating. It was a worthwhile aim to produce a prototype that would not be noticed by the athletes for the purpose of conducting with/without validations.

Open for Exploration

Crucial to my design process is enablement of opportunities. Exploring and sometimes validating these opportunities in context directed the design research process. As such, the prototypes of the exemplars often had easily adjustable qualities, for example, the physicality of the Sensible Door, the physicality of the Squeeze Me exemplar, and so forth.

In order to enable opportunities, the design decision that concerned the sensitivity of engagement, that is, the feedforward loop and other kinds of mappings, were always left undetermined and easily accessible for fiddling and tuning.

For instance, the Augmented Speed-Skate Experience had a fixed set of sensors as well as speakers in the interaction loop. The movement sonification mapping, however, was left open for me to explore several kinds of mappings (Stienstra, 2009). This was also the case for the Sensible Door in which the two tracks of investigation and the design's interaction qualities were explored through mapping a rather fixed set of sensors and actuators.

In addition to using the Augmented Speed-Skate Experience prototype as means to explore different mappings, I used it to validate the implications of the work – for design-practical, rather than scientific, purposes, that is. While I used the different mappings to investigate the influence of the mapping dimensions on learnability and coerciveness, the same prototype functioned as means to explore the reproducibility and limits of the athletes' movements (Stienstra, Overbeeke & Wensveen, 2011[a]). Even though it did not serve any particular purpose as far as the speed-skating technique was concerned, asking the athlete to lean back on the speed-skate as much as possible both with and without the auditory feedback did reveal an unexpected result: the feedforward of the Augmented Speed-Skate Experience exemplar might empower athletes to stretch their limitations. With this experiment, I simply wished to validate my hunch that if athletes could be empowered to replicate their movements more precisely, the feedforward might also empower them to replicate a movement that was verbally directed to them. This two-fold evaluation – one that focused on the movement directed by the athlete and one that followed more explicit directions from me – enabled me to confirm that what I attempted to embody in the work was an implicit, inherent quality that was grasped *pathically* and *gnostically*.

In developing the Sensible Door, fidelity became an issue. In the first place, I aimed to create something that would blend into its surrounding environment. This was not possible because the technology clearly demanded a bigger structure. The struggle that remained was how to finish the door so that it could be used normally. I figured that a fully finished artefact placed in the realms of a university would scream 'research going on' and enforce a Hawthorne effect. Leaving it unfinished would potentially scream the same thing, yet also embody the idea of 'work in progress', i.e., researchers were working to set up a fully-fledged validation. I used this semi-finished state to conduct my research through observations of people using the capabilities of the Sensible Door. The approach has similarities with the Hidden Design approach that was developed by Industrial Design alumni at their design firm Afdeling Buitegewone Zaken. Hidden design hides the fact that the design is still in progress. The designers offers only the experiencable situation to the user in a way that feels realistic. This enables people to sincerely respond through their actions and behavior, to the ideas that are presented to them.

Fleshing Out Theoretical Implications

The purpose of theory in interaction design is multifaceted. Schneiderman (2002) identifies five roles and uses of theory. I consider that these roles and uses easily apply to the prototype or construct that is centralized in the concept-driven interaction design research approach. That is, it functions as (a) descriptive, identifying key concepts and enable distinction; (b) predictive, foreseeing and anticipating possible futures; (c) explanatory, revealing processes and relations; (d) prescriptive, direct; and (e) generative, empowering discovery and creation.

Making theoretical and practical issues emerge is pertinent to all prototyping activity. I use the process of making to develop an experienceable artefact, encounter technical and philosophical implications, and arrive at pragmatic solutions that can overcome these implications without parting from the philosophical stance. The original system architecture of the Care-O-Bot was unable to deal with continuous interaction without bypassing all security systems, and the motor of the Sensible Door was reluctant to be controlled in terms of gentleness. The act of making revealed a mismatch between technologies and the theory-informed approach to design. In the following section, I discuss a few approaches that helped me to fit the conventions embodied in approaches and tools with the ambitions embodied in phenomenology.

Respecting Uniqueness in Design Evaluation

User-model-inspired approaches to design tend to reduce people to grouped commonalities. Phenomenology however embraces the uniqueness of people, whereas the quantitative methodologies for design and research do not align with the characteristics of a complex world. Phenomenology-inspired design research thus demands an appreciation for and focus on the unique, subjective experience of people without lapsing into generalizations, user models, mathematical descriptions, guidelines, and other Cartesian distractions that emerge from rationalism, objectivity, and reduction (Davis, 1991).

Instead of utilizing design research to seek optimal solutions for the many, I seek to bring out the unique qualities of the individual: the qualities that reside in the interaction between product and person, the qualities that embrace the rich, expressive continuity of *being-in-the-(social)-world*. These goals necessitate the development of new evaluation approaches that encourage design thinking inspired by phenomenology (even though it is difficult to break free from the idea that evaluations are of lesser quality if they are not "objective").

The greater commonality or generalizability resides in the subjectivity that is incorporated into the theory; in the ever-changing patterns; in the sense-making; in the hallmarks of being; in the phenomenology of perception.

In what follows, I briefly outline the different approaches taken to evaluate the designed exemplars, clustered by their commonalities.

Forms of Evaluation

To evaluate my work, I took several mostly explorative approaches. None of them, however, had a traditional scientific form. The validations took place with the idea of gaining insight in, and giving direction to the design process, as opposed to making final substantive claims. This is arguably a weakness of the presented work, yet from a designer's perspective within the realm of phenomenology and ecological psychology, these choices were made to further the iterative design research process, and develop design relevant insights for both interaction theory and how to design for it. I see two distinct approaches to evaluate design whether it is directive for the process or aimed at evaluating implications of use. The first type of approach is indirect (i.e., insights are gathered from how users anticipate what a product or system might do based on a prototype or representation that cannot be interacted with), the second is direct (i.e., insights are gathered from direct experience of the actual experienceable prototype).

Indirect Evaluation

Indirect approaches to evaluating the impact of designs may employ movie scenarios, experience scenarios, and (non-interactive) walk-throughs. The Move Me was initially evaluated using movie scenarios in which sixty subjects were shown the designed behaviors next to the un-designed behaviors in similar situations. In doing so, insights were gathered as to whether the subjects appreciated certain behaviors over others. A scripted evaluation of the Move Me exemplar was also conducted with experienceable scenarios in which a user was walked through a situation, thus enabling the user to take a first-person perspective instead of a third person perspective as is the case with movie scenarios.

The reciprocal crossing of the Move Me could only be experienced in interaction, just as the Augmented Speed-Skate Experience only became meaningful when speed-skating. Although a video, taken from the first-person perspective of the athlete using the movement sonification, was useful in communicating what was happening, a simple experienceable prototype that embodied movement sonification in a similar manner was more effective for demonstrating the contribution of the work.

Direct Evaluation

For the Sensible Alternative I experienced that the open walk-through approach was valuable in gathering a wide variety of insights and perspectives (Stienstra, Overbeeke & Wensveen, 2011[b]). Similarly, a semi-structured, experienceable walk-through was also fruitful in evaluating the Squeeze Me and the Sensible Interface (Marti & Stienstra, 2013). These evaluations provided insights into the subjective experience of users. For instance, by having an elderly person engage with the Squeeze Me, it was found that the *moody interaction* was much more engaging than initially considered (Stienstra & Marti, 2012). Furthermore, it was noted in interaction that elderly people had trouble with the first prototype in terms of pushing the button promptly. This engagement with actual prototypes led to the redesign of the cover (Marti, Tittarelli, Sirizzotti & Stienstra, 2014).

Of all the exemplars, the Augmented Speed-Skate Experience was subject to the most thorough evaluation (Stienstra, 2009). It was developed up to a high-fidelity, fully functional, and experienceable prototype (i.e., it was developed towards making claims about use, after it served as directive for the design process. In this work, a field-lab setting enabled evaluations on several movement sonification mapping designs (Stienstra, Overbeeke & Wensveen, 2011[a]), the reproducibility of a speed-skate stroke, and the coerciveness of the most suitable mapping.

In order to do this field-lab testing, my prototype needed to be field-lab ready and fully experienceable, and not interrupting the 'normal ways of working'. I believe that field-lab evaluations hold the most value with regard to how an interaction will actually work, since you can get a subtle feeling for user, in this case the athlete, by looking at his behavior in context. Moreover, by placing the design process in the field, the design(er) researcher can quickly iterate and adjust the design based on behavior. This field-lab approach is closely connected to Experiential Design Landscapes (EDLs), i.e. environments, be it physical or virtual, that are part of society (e.g., designated area in cities, sports parks etc.) where a design research team meets people in their everyday life. In the Experiential Design Landscape, the team creates, introduces and tailors open, disruptive and intelligent propositions, called 'Experiential Probes' (Peeters and Megens, 2014).

The interpretive phenomenological analysis (Smith, Flowers & Larkin, 2009), as applied in the evaluation of the Sensible Interface (Marti & Stienstra, 2013[a]), is useful to reveal subjective particularities while users engage with an experienceable prototype. The approach relies on the users ability to articulate. As such it takes effort to make the interpretative analysis useful for directing the design process.

Beyond Efficiency, Experience

By nature, phenomenology does concern some sort of efficiency. A body-world fit sort of strives for efficiency in which our skills seek maximum grip with their environment (Dreyfus, 2014). However, this has little to do with the connotations inherited from mainstream engineering in which efficiency stands for a measurable minimum amount of unnecessary effort from input to output. In design research and evaluation, this legacy is traditionally found in usability studies that aim to show that one designed solution is more efficient than another, next to showing other aspects of usability such as satisfaction. They often depart from a nomothetic worldview, relying on quantifiable measures in an effort to derive laws that explain objective phenomena. A phenomenological perspective endorses an idiographic worldview, i.e., it embraces that people are *unique* and seek to understand meaning of contingent and subjective phenomena. In other words, the consequences of a phenomenology and ecological psychology-inspired design should not be expressed nor measured in terms of efficiency. Rather, the units of analysis should align with the purpose of development.

The phenomenology and ecological psychology-informed exemplars were not predominantly designed to make life more efficient, although the professional skaters could make their laps more efficiently with the use of the Augmented Speed skate. The phenomenological stance points to the subjective experience people have in their engagement and the exemplars aim at increasing the fits with their skills and enable well-being.

Therefore, I consider it inappropriate to evaluate the exemplars using generalizations and comparisons in terms of merely efficiency. To me, it is much more valuable to describe and understand the consequences of the interventions on people's experience and well-being in the world. These consequences should be measured against the background they were intended to impact. In the context of the robot, that background concerned empathy, as well as bypassing hierarchy and increasing the pleasantness of navigation for the Sensible Alternative. Both the Augmented Speed-skate Experience and the Sensible Door were aimed at change in movement.

Evaluating Pathic Dimensions

The field-lab evaluations of the Augmented Speed-Skate Experience and hidden observations of the Sensible Door were fruitful mechanisms for evaluation. In both cases, the 'about-content' used in the feedforward loop in actual engagement was also the context or material of evaluation. This allowed me to compare common patterns with those that emerged when the intervention was inserted, i.e., when the additional behavior of an artefact was added. One value of this approach is that one does not need to 'label' the dimension that is being measured while it is being used in the active-perception loop. The purpose is to show that a difference occurs in the dimension that is at stake rather than formally labeling what this means *gnostically*.

Formalizing knowledge on 'known' dimensions potentially removes its tacit value and steer the behavior away from the inherent characteristics of that dimension.

Holistic Approach

Design is concerned with meaning; in my work, design relates to the meaning that emerges between people and their artefacts. Yet, phenomenology acknowledges a complex *contextuality* that is informed by the background and uniqueness of the people involved. Measuring a certain dimension in the moment, in order to illustrate that an intervention impacts that dimension, should stand against a background of real use. Because people experience holistically, evaluations are better off contextualized. Moreover, such evaluations can provide the designer with real and context-dependent insights that could direct design decisions. For this reason, I strongly recommend creating fully experienceable prototypes that can be used to arrive at design- and context-relevant insights.

People have been using 'normal' doors all their lives. Thus, it is fair to assume that people have got used to doors to the extent that their established behavioral patterns may be difficult to break through via an intervention such as the Sensible Door. In an initial exploration, it was clear to see that people indeed adjusted their behavior when interacting with the door. They began to approach the door as a new experience of transition between the hall and the open-plan office where it was located. The clearest examples were when people approached the door in a quick attentive manner or sought to find another entrance after seeing the Sensible Door slamming (dangerously) hard against the frame as I was tuning its behavior. It should be noted that the door was rightfully addressed as a research project, and as such, people did engage with the door in an unnatural manner. However, when the Sensible Door was clearly a work in progress (i.e., it was clear that I was tuning it from nearby), people did engage with the door more naturally in the sense that they just did what they needed to do. In effect, they would go into the space for a particular reason and ignore the fact that the door was a vehicle for research; they would accept it as a 'to-be-finished' contraption. For this reason, it was decided to keep the door in a seemingly work-in-progress state, while actually measuring people's change in behavior as they engaged with the door's specifically designed behaviors and explored the theory-inspired compositional whole.

Data and insights were gathered in the process through observations and direct use of the sense data from the door. I further limited the questions asked to people coming in and going out, as I needed to keep up the idea that I was tweaking and programming rather than doing research. The collective of data and sources provided a comprehensive perspective that helped me as designer to proceed, i.e., data and observations of use helped me to take steps in the design process.

Attitude to Interaction Design Research

With a research-through-design approach, often, design researchers aim to flesh out implications of specific theoretical stances for design. The role of the prototype and prototyping in those endeavors has been widely acknowledged (Wakkary, 2005; Frens, 2006; Zimmerman, Forlizzi & Evenson, 2007; Hengeveld, 2011). In order to reveal useful implications, emphasis is placed on aligning use qualities of the experienceable prototype with the qualities embodied in the particular theory. Effectively, designing researchers use their making and thinking skills to reveal relevant insights that come along with a certain concept in order to offer alternative design solutions and ways to arrive there. It is apparent that the measure of success does not lie on efficiency or usability *per se*, rather, validation of the experienceable prototype is sought in line with the thematic core of the theory. In what follows, I discuss attitude characteristics that enabled me to do so.

Inherent in my work, I investigate the idea that it serves to commence the act of prototyping in alignment with the theoretical foundation as well.

I have mixed feelings about the natural attitude of the interaction design researcher who pursues to further the theoretical discourse. It is suggestible that the most productive way (in terms of insights) to approach concept-driven interaction design is a naïve and even undereducated way. The fewer you know the more you can learn – sort of say. To some extent I wish to underwrite this statement as I recognize a set of pitfalls that are difficult to bypass once a design researcher is conformed to common practice and its idioms.

In the first place, it is very tempting to read up with related work; to find other research that investigates similar strands or tackle the context from a different yet compatible perspective. For example, when developing a phenomenology-informed interaction design theory it seems worthwhile to seek inspiration in activity theory or other humanist stands that share certain characteristics (see Kaptelinin & Nardi, 2006 chapter 9). Similarly, when exploring a phenomenology-informed interaction design theory in the context of computer-supported cooperative work, it seems easy to use familiar software packages and protocols as a starting point for building experienceable prototypes. Even though I recognize the purpose and advantage of addressing design research in such a manner, I would argue that the subject of investigation, i.e., phenomenology-informed interaction design theory, is easily tainted by pragmatic application of relevant stances and unquestioned underlying premises of the technologies used.

As such, I tend to empathize with a design research approach that is ignorant to related work, stubborn in pursuing a single theoretical frame, and skilled yet sensitive to picking up discrepancies with underlying technologies. In other words, the design researcher benefits from incorporating a theoretical stance throughout all its endeavors (Stienstra, 2015). It might seem that I promote what is commonly known as uninformed, self-centered or simply bad research. On the contrary, I believe that the discourse of a design science needs to be taken beyond (a) fleshing out certain theory-informed insights. On the contrary, I believe that the discourse of a design science needs to be taken beyond (a) fleshing out certain theory-informed insights. One needs to be capable of (b) relating insights to those of others that came to similar ones (derived from different approaches), (c) pinpoint the fundamental and nuanced differences, and (d) relate those back to their source of knowledge production (the different approach). Ultimately, for the design research community as a whole, it might be worthy to (e) reconcile different perspectives as aspired by Saariluoma and Rousi (2014), and Henseler (2015). Consequently, I propose reconciliation as a step in service of (knowledge production for) 'doing design' rather than 'generating a uniform overarching design theory'. Furthermore, for the sake of pertaining an untainted theory, the four latter stages in which other research is acknowledged and adopted are more meaningful *after* completing the (somewhat ignorant) design research with the chosen theoretical stance. Mind you that this design research is performed by a designer who has extensive training as a hands-on designer within the academic realm. In the following chapters, I've attempted to provide a complete set of insights developed in hindsight.

The sensing body is not a programmed machine but an active and open form, continually improvising its relation to things and to the world … The body's actions and engagements are never wholly determinate, since they must ceaselessly adjust themselves to a world and a terrain that is itself continually shifting.
– David Abram (1996 p.49)

Respectful Embodied Interactions

In this chapter, I focus my reflections on the theory-informed interaction paradigm as it was explored and developed through the designed exemplars. First, *interactive materiality* is positioned to describe the underlying tendency of the work. Consequently, I elaborate how people interact with the respectful embodied interactions exemplars in relation to their design characteristics. These reflections revolve around recurrent themes (i.e., continuous interaction, expressive-rich interaction, and contextualized interaction) and are related to other work.

The themes are ordered from insights that relate to interaction as it deals with the experiencing body to how interaction occurs with respect to the artefact in a complex interconnected interactive system or product ecologies (Forlizzi, 2012; Bødker & Klokmose, 2012[b]). As such, the sections in this chapter expand from a bodily perspective toward a holistic perspective; from human-product interaction to human-product-ecology interaction.

To me, designing interactive systems refers to networks of interacting people and technology (Frens & Overbeeke, 2009). In such a complex design context wherein each system node adds meaning and functionality to the whole, computational technologies that operate in a discrete paradigm need to conform to the human continuous paradigm. From my humanist approach to interaction design, I see this discrepancy on which I elaborate. Against the previously presented theoretical backdrop of phenomenology, I further present a design perspective that proposes to bring the continuous and the discrete closer together.

Interactive Materiality[36]

In the third wave of human–computer interaction, interaction design has moved away from productivity and efficiency toward designing for experience (Bannon, 2005; Bødker, 2006). An experience cannot be designed directly, but may be approached through the role that artefacts play in affecting people's behavior. In the design of intelligent products and systems, the consideration that products affect behavior is even more relevant, as artefacts can adapt dynamically to the people with whom they interact. In this regard, persuasive computing (Fogg, 1998) is becoming relevant to interaction designers who want to explore how design can address societal issues through the transformation of behavior (e.g. Tromp, Hekkert & Verbeek, 2011). In this context, the exemplars with a specific overall – phenomenology-inspired – character fulfil their role.

[36] The following part on Interactive Materiality contains snippets from Stienstra, J.T., Bruns Alonso, M., Wensveen, S.A.G. & Kuenen, C.D. (2012). How to Design for Transformation of Behavior through Interactive Materiality. In *Proc. of NordiCHI'12, (pp.21-30)*. New York: ACM Press.

The convergence of feedback and feedforward sheds new light on the concept of persuasion. The examples provided in the framework of persuasion, as presented by Tromp, Hekkert, and Verbeek (2011), focus mainly on sign characters and illustrate a very static perception of the world. The examples in this thesis illustrate that products can change their way of influencing the user by addressing the action-perception loop. As such, they are difficult to classify according to the given dimensions. Therefore, I believe that Tromp, Hekkert, and Verbeek (2011) miss a great opportunity for a behavioral transformation that maintains a relation of embodiment with the product, i.e., without the need to shift to an alterity relation. When products become interactive, transforming their materiality can also seduce people to transform their behavior while remaining ready-to-hand. In contrast to current persuasive technologies that address people's *cognitive skills*, I argue that the transformation of behavior can also be achieved through an *embodiment relation* with the product or system by dominantly addressing the *perceptual-motor, emotional,* and *social skills.*

Consequently, I suggest that the abovementioned framework of persuasion, which now has two dimensions, i.e., salience (ranging from hidden to apparent) and force (ranging from inhibition to invitation), needs to be extended with a third dimension that distinguishes between static and dynamic. A distinction can be made between *static* informing products, and the *dynamics* of interactive and intelligent products and systems. We coined the term *interactive materiality* to highlight this distinction (Stienstra, Bruns Alonso, Wensveen & Kuenen, 2012; Lévy, 2013).

In contrast to current persuasive technologies that seem to dominantly address people's *cognitive skills,* I've shown that the transformation of behavior can also be achieved through an embodiment relation with the product or system by dominantly addressing the *perceptual-motor, emotional,* and *social skills.*

I consider two qualities to be paramount for achieving *interactive materiality*: *continuous interaction* and *expressive-rich interaction*. These are elaborated hereinafter.

Continuous Interaction

As I have framed in Part I of this thesis, when designing for respectful embodied interactions, designers must consider the artefacts, the context, and the body. Turning to Merleau-Ponty, Todes, and Gibson, the body and its active, continuous engagement with the world is constitutive of the emergence of meaning. In what follows, I turn specifically to how I ensured that the continuous nature of the engaging body was respectfully addressed in the designed exemplars.

Uniting Feedback and Feedforward

In order to achieve a designed-for interaction that is easily naturalized, one should closely map 'input' and 'output' in terms of the aspect of time (Neisser, 1976). With this, I do not mean the mere coupling of a button to a functionality; I consider time over a sustained, continuous realm like synchronous feedback systems. For example, in the Augmented Speed-Skate Experience exemplar, I mapped the input and output in such a way that the time aspect remained short throughout the engagement. Indeed, the promptness between action and reaction was at stake, just as it is in a mere button-to-functionality coupling (considered as event). Yet, what I valued was the sustained nature of the engagement, i.e., the continuity of one's movement mapped to the continuity of functionality over time.

In terms of the Interaction Frogger Framework (Wensveen, Djajadiningrat & Overbeeke, 2004), the aspect of time poses the question of when the feedback, action, or feedforward influences the others, i.e., if an action is performed, when does something that follows happen? Is this an immediate, delayed, or sustained occurrence? How long does it last and why? Shortening the mapped coupling between the input and output over time makes the interaction more direct. This is often perceived as more intuitive.

By mapping the time aspect in an immediate manner (i.e., a direct coupling) a convergence of action and feedback can emerge. By providing for direct continuous-sustained interaction, feedback and feedforward can unite.

When expressive-rich and continuous input is mapped to expressive-rich and continuous output, feedback and feedforward can unite. This enables a person to act, and at that moment affirm, appreciate, or acknowledge what the artefact did with that action. Moreover, in the same interaction, the person can adjust his or her action and consequently re-affirm, re-appreciate, or re-acknowledge how the artefact responded in turn.

This mechanism was applied in the Augmented Speed-Skate Experience, the Sensible Alternative, the Squeeze Me, and the Sensible Door exemplars. To illustrate this, I first show how feedback and feedforward converged in the case of the Augmented Speed-Skate Experience exemplar before elaborating on the consequences and design-practical pointers of this approach to continuous interaction.

For readability, I have dissected the process of what happens over time into distinct functional steps that take place in time. At any given moment, the speed-skating athlete is able to hear what kind of pressure is being exerted on the speed-skate. The meaning of this sound emerges *in* interaction, in the moment.

The athlete (a) exerts pressure on the speed-skate; this is (b) directly mapped into an auditory signal, (c) immediately picked up by the auditory channel as feedback, and consequently (d) used by the athlete to (a) exert pressure on the speed-skate, i.e., the feedback is used. Different amounts of pressure result in different auditory signals. As the athlete learns about how each type of pressure expresses itself in sound, it begins to function as feedforward, i.e., the athlete uses the continuous feedback and feedforward to direct his or her movements.

Uniting the Senses

Although synaesthesia – the overlap and blending of the senses – is often considered to be a pathological experience to which only certain people are prone, I consider synaesthesia (Cohen, 2013) to be valuable when respectfully designing for people and their skills. This is because it touches on a core quality of perception, of how people make sense of the world. Moreover, this simple yet profound quality of perception has far-reaching consequences when transferred to the act of designing. It requires designers to consider *contextuality* and perception, to consider more than the product's bare form and functionalities. For design, synaesthesia not only provides a justification for the application of multimodal interaction (Bongers, 2006), i.e., by applying multimodal interaction, the holistic nature of perception is attended, but also points to how multimodal interaction has to be given shape to become meaningful. By engaging with the world, our senses come to grips with how a 'low-loud' sound relates to 'big' objects and 'strong' impact.

These relations that evolve through interaction because of our synaesthetic capabilities, can be directive in design mapping.

The Coercive Character of a Body-World Fit

When a designed mapping allows expressive-rich interactions to emerge (i.e., when it aims at allowing people to engage with a product in an expressive manner utilizing their *perceptual-motor* and *emotional skills*), the design choices can still take on an undesired coercive character.

This pitfall became particularly clear as I was designing and validating the Augmented Speed-Skate Experience project in context. The design had a clear objective to provide the athlete with feedforward that would allow for self-reflection or tools to improve the speed-skate technique while gliding over the ice. In order to accomplish this, I sought to utilize the continuous and expressive qualities of the technique. As described earlier, the pressure exerted on the ice by the front and back of the speed-skates was measured continuously. These continuous values were then directly mapped to auditory information streams, forming a soundscape (i.e., the sonification of the continuous parameter mapping).

In early iterations of the design, the movement was sonified in the form of direct pitch manipulation. This meant that the speed-skater's movements controlled the frequency of the tone; leaning to the front would increase the pitch (i.e., make a higher sound), whereas leaning to the back would lower the pitch. Smooth transitions thus resulted in a smoothly gliding tone, while more abrupt movements led to more staccato shifts in tone.

This direct mapping in itself did not limit the athlete's speed-skating technique; all movements could still be completed. Different movements led to a wide spectrum of sounds, which allowed the athlete to determine what felt good and what did not. The sonification allowed the athlete to get a grip on his or her technique through this transmodal *skillful coping* and thus improve his or her speed-skate technique. However, the direct mapping was not entirely free of values; the 'smooth' transition sounds were more appealing than the 'unpolished' ones. In other words, some tones were more pleasant to hear than others. In practice, this could persuade the speed-skater to adjust the speed-skate technique to what sounded good, independent of whether this was beneficial to the overall purpose of gaining speed or winning a race. In most cases, and from a phenomenological perspective, this was not the case. During the validations of this movement sonification design at the speed-skate track, the speed-skater was persuaded to make smooth movements in order to make smooth sounds as well. This phenomenon was not seen in the validations in which the movement sonification was not applied (i.e., the device functioned for measurement only), nor did the athlete feel as if it was a desired stroke; the smoother stroke did not involve better control, but was rather an awkward movement. Nonetheless, the athlete stated that she was drawn to it.

The sound swings along with my stroke.
I am able to control the tone with my movements.
It is the smoothness in the music that attracts me.
I am forced to glide to my orchestrated flow.
I am moved.

Rauterberg (1995), influenced by the cognitive psychologist Neisser (1976), explains the phenomenon that people tend to be moved by information to the concept of incongruity. He argued that people are attracted to find a balanced amount of information to achieve a positive emotion. For phenomenology, this is called skillful coping in search for maximum grip (Dreyfus, 2002) and has less to do with emotions and more to do with *affordance* and *effectivities*.

Bypassing the Coercive Character

In order to overcome the undesired coercion of the designed mapping, I chose to utilize noise band-pass filtering instead of the direct control of pitch. Noise, pink noise to be precise, is rather 'meaningless', in that, it does not speak to our senses (and thereby actions) in a coercive manner. Pink noise has a logarithmic distribution of energy in the sound spectrum and is therefore better suited to the auditory perception of people (unlike white noise, which has a constant energy distribution across the whole spectrum). Pink noise is less sharp around the edges, which makes it less coercive. Accordingly, the athlete would not adjust his or her technique because of the unpleasantness of the movement-sonification. The applied pink noise band-pass filtering had a very natural wind and wave like sound, while preserving a very complex and rich spectrum of 'about-content'. The richness of the data generated by the athlete was preserved in the richness of the manipulated sound parameters, such as dynamics, loudness, tempo, and timbre.

During the validation sessions, the improved continuous movement sonification utilizing the pink noise band-pass filter mechanism did not produce the coercive effect of persuading the athlete to adopt a smoother movement for the sake of achieving a more pleasurable sound. Rather, the soundscape enabled the athlete to distinguish the stroke rhythm and front-back balance of each speed-skate, as well as the global balance and the amount of force exerted on the ice while skating. To the athlete, this designed mapping was non-coercive and provided a rich informative sonification of the complete speed-skate stroke (Stienstra, Overbeeke & Wensveen, 2011[b]).

In order to avoid the potentially coercive character of a design, one could start off with a somewhat 'empty' or 'meaningless' flow of 'about-content' – meaningless in the sense that it is open for sense-making *in* interaction, it adopts a blank paradigm with limited traces of pre-colored and already embodied values. This is a challenge, and most likely I still did not fully accomplish this with the 'empty' noise bypass filtering. Nonetheless, designers should seek out empty forms of 'about-content' when aiming to provide a feedforward loop that allows for the user's self-reflective sense-making *in* interaction with the designed product. In analogy to learning algorithms, either supervised or unsupervised, a user develops its target or reference *in* interaction while seeking for maximum grip (Dreyfus, 2014). In order to achieve this, the quality of the feedforward is crucial.

To bypass the by synaesthesia constituted coercive character of a mapping, a designer could utilize 'meaning-free' forms of feedback and feedforward. The design of mappings requires a profound understanding of the (blending of the) senses with all its sensitivities.

Utilizing the Coercive Character Using Constraints

As shown by the 'misuse' of an auditory mapping in the earlier iterations of the Augmented Speed-Skate Experience, a designed direct mapping can have persuasive qualities due to the body's desire to find a fit with the world. Interestingly, the coercive character in the behavior of a designed mapping can be actively exploited. For instance, once a speed-skater moves slightly off a preferred model, the model could be used to generate persuasive feedback and feedforward by, for example, mapping movements that are undesirable to undesirable sound. This will subsequently persuade the speed-skater to move according to the model in order to prevent hearing the undesirable sound. As learned from the Augmented Speed-Skate Experience, and from the stress-reducing toothbrush and pen briefly described hereinafter (Bruns Alonso, 2010; Bruns Alonso, Hummels, Keyson & Hekkert, 2013; Stienstra, Bruns Alonso, Wensveen & Kuenen, 2012), similar persuasions could also be achieved by designing with just-noticeable differences. In effect, subtle mapping can encourage a change in movement that is not noticeable for the user, but is nevertheless different.

For example, a toothbrush designed to guide the brushing process continuously takes the user's movement patterns and counters them to persuade the brusher to brush more accurately (Bruns Alonso, Stienstra & Dijkstra, 2014). Similarly, a pen continuously takes stress cues from the pen-holder *in* interaction (e.g., fiddling) and counterbalances them with subtle movements designed to calm the user (e.g., when a person rotates the pen in a stressed manner, the pen moves its center of gravity to produce a calming effect (Bruns Alonso, Hummels, Keyson & Hekkert, 2013)). Both designs explicitly utilize sustained continuous feedback to acknowledge the emergence of meaning *in* interaction, and how the interactive qualities of artefacts address *perceptual-motor* (the reciprocity between hand and toothbrush, as well as hand fitting pen) and *emotional skills* (the engagement with the brush, as well as the reduction of stress through counter behavior) of people.

For this kind of movement persuasion to work, the designed mapping must allow the person to remain in a ready-to-hand immersion with the product. It is essential that the product not grasp attention by disrupting the user's behavior. The disruption of behavior can be prevented by designing unobtrusive or subliminal mappings. This means that the mapping should not be noticeable in the way that the interaction becomes present-at-hand. As shown by Bruns Alonso (2010), the 'unnoticeable' pen movements are perceived, as verified by the user's dropping heart rate. In order to apply this type of mapping, the designer must have an in-depth understanding of and sensitivity to the chosen modality and sensorial system being addressed.

Having learned valuable lessons from the Augmented Speed-Skate Experience, the toothbrush, and the pen, I aimed to utilize that coercive power in the Sensible Door. By taking the pressure exerted on the door and creating gentle resistance, I was capable of slowing people down in their movement without them 'knowing' that the pressure exerted by the door persuaded them to do so. This effect was observed in the movement data and confirmed by questioned users. The effect of pulling people, i.e., making the door move faster when the person pushes the handle, rather than pushing him or her back, was more difficult to assess and needs to be further investigated. In addition to making the user enter the space more rapidly, the pulling-in behavior made him or her feel empowered and welcome in a way. This observation resonates with the work of Bruns Alonso (2010), who argues that physical empowerment on a perceptual-motor level can also influence the user's emotions.

The coercive character of synaesthesia, i.e., the fusion of senses, *in* interaction, of our drive to seek balance (*prise*) with the world, can be used to invite and inhibit people in their behavior. Designers that strive to transform behavior in this manner can address the *perceptual-motor skills* in such a way that it goes 'unnoticed'.

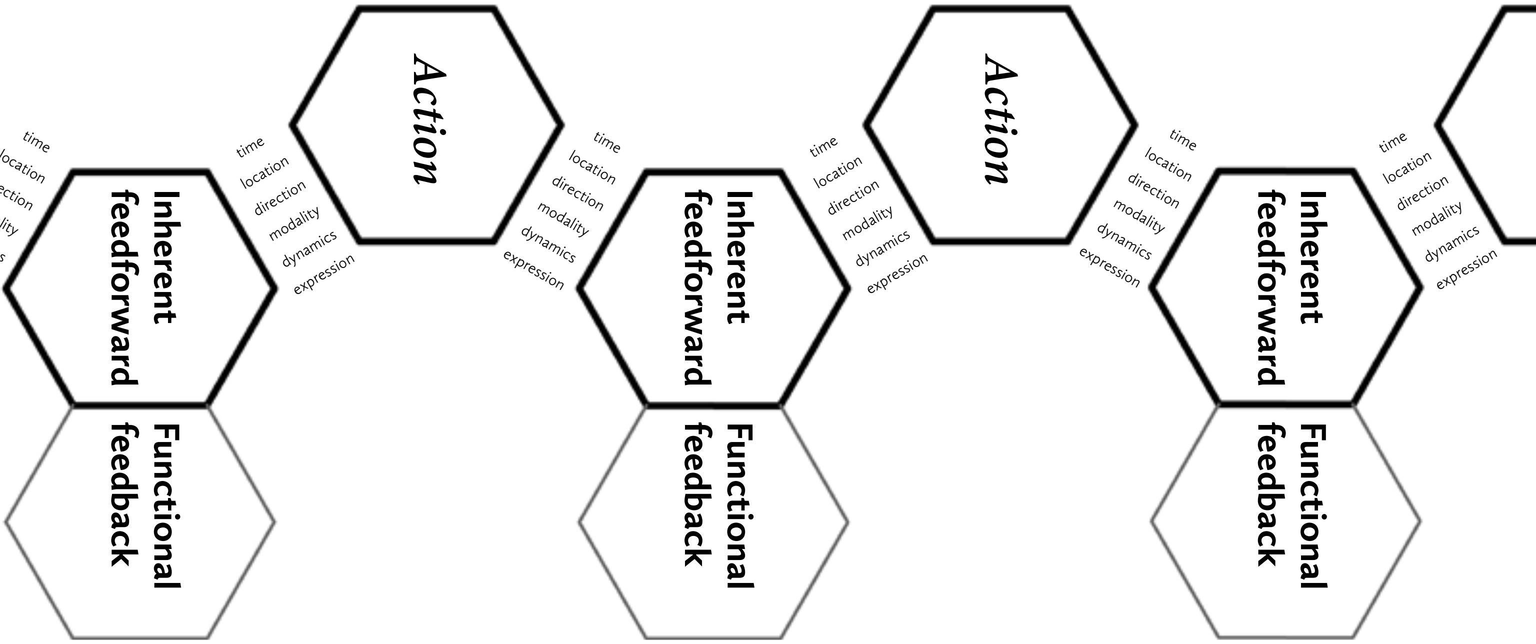


Fig 29. Interaction Frogger Framework+

We find ourselves acting in definite ways without ever having decided to do so. In responding to the environment this way, we feel ourselves giving in to its demands.
– Hubert Dreyfus and Sean Kelly (2007 p.52)

The Coercive Character of Limitations

As touched upon in Part I, limitations can also be coercive. Limiting an action-possibility by physically removing it is highly effective in manipulating people behavior. For instance, the Sensible Door becomes a 'Sensible Wall' when the door handle is withdrawn into the surface, leaving no action-possibilities for grasping (Norman, 1999). When designing for *affordances* (a body–world fit), it is crucial to understand the relationship between physical action-abilities and what is offered. In the Sensible Alternative and Sensible Interface, the sizes (and even disappearance) of the application icons or action-possibilities on the screen were a useful way to offer the user access; the bigger the icon or action-possibility on the screen, the easier it was for the user to access it. The reachability of functionality was coupled to relevancy in these designed exemplars.

It should be noted that any limitations that constrain functionality need to be mapped appropriately. With this I mean that, in cases a designer does not aim to be lenient, if an action-possibility allows or even affords to being pushed in expressive ways, what responds should act upon this expressive-richness. When the Augmented Speed-Skate Experience was equipped with a discrete feedforward, i.e., a mapping that merely produced seven tones instead of a rich soundscape, the athlete forgot to skate smoothly and the movement became slightly more clunky. This enforcement of discrete possibilities is very much in line with the limitations inherently posed by the 'up', 'down', 'left', and 'right' buttons of computers. These buttons coerce people to move accordingly, i.e., up, down, left, or right, instead of in any other directionality. At a certain moment, this correlation becomes embodied.

In the limited context of speed-skating, I see that the unintended coercive character of the soundscape meets the idea of irresistibility. In effect, the body is drawn to the activity based on its own action-ability and sense of good. Yet, in the context of the Sensible Door, the better the grip on the door handle does not improve the *attensity* and *irresistibility*. Rather, *attensity* is strongly informed by *contextuality*; it considers the holistic nature of situatedness, making it a challenge to design for, i.e., the designer has to consider a multitude of factors. For the Sensible Interface, I incorporated the idea of likelihoods to capture the relevancy of an action-possibility for the robot and user in context. In short, likelihoods are used as a means to create relevancy – the degree to which there is body–world fit in a given situation.

Designer Responsibility

Following Verbeek (2006, 2015), who argues that technology is moralizing, and Ross (2008; Ross & Wensveen, 2010), who explicitly designed an ethical stance into the AEI lamp, I acknowledge that technological interventions are most likely to be directive. As shown with the Augmented Speed-Skate Experience, it was possible to 'move' the athlete. Furthermore, the *moody interaction* persuaded people to behave in a certain manner, and the Sensible Door forcefully constrained and even coerced people to consider other people. Nonetheless, from the perspectives of the phenomenology of perception and ecological psychology, I consider the human and bodily engagement to be constitutive of the behavior of the technology and consequently the meaning that emerges *in* interaction. It is possible to make people change their behavior with the designed exemplars; however, it is the person that takes a stance in this. In the designed exemplars, it is the behavior of the person that is reflected. In designing for expression-rich and continuous interaction, people are equipped to act appropriately.

Design always has an ethical dimension. The impact of the Augmented Speed-Skate Experience could extend beyond simply changing the behavior and improving the technique of the speed-skaters. The questions 'what behavior should be transformed' and 'in what way' come before the matter of how to achieve the transformation. These questions require the designer to take an ethical position on the desired behavioral transformation, e.g., to improve well-being, reduce stress, encourage self-reflection, seduce the person toward a specific movement, etc. Although this process falls outside of the scope of this work, I want to stress the responsibility of designers to the world they are designing for.

To define another being as an inert or passive object is to deny its ability to actively engage us and to provoke our senses; we thus block our perceptual reciprocity with that being **– David Abram** (1996 p. 56)

Expression-Rich Interaction

As discussed in Part I, technology often reduces people's action-abilities to the mere expression of a bit. At times, it does not serve users when artefacts are lenient toward their behavior. If their expressive behavior goes unreciprocated, if it is flattened to a mere acknowledgement of their presence, people lose track of their being (Merleau-Ponty, 1968; Abram, 1996). In order for design to really address human capabilities, to respect them rightfully, it has to consider expression. This is a part of people's being-in-the-world that is often undervalued or unrecognized. In effect, interactive products hardly encourage users to express themselves beyond the press of a button; it is often not required. Yet, by allowing users to express themselves, they might come to learn that there is more to their *perceptual-motor* and *emotional skills*. In what follows, I indicate how expression is used in the designed-for expression-rich interactions of the exemplars. This is further tied back to the theoretical stance, as I discuss the qualities and consequences of opening up to expression-rich interactions.

Opening Up to Self-Reflection

The Augmented Speed-Skate Experience is an example of how 'about-content' that was previously difficult to assess could be embodied in use. Instead of utilizing a computer to deal with the complexity of the movement, the body managed the continuous flows of 'about-content' by merging them with the ongoing proprioception and other sense data. The device as such was transparent for the athlete. Despite a short learning curve, it seemed that the movement sonification got caught up in a ready-to-hand engagement, i.e., the athlete concerned him or herself with speed-skating, not with listening to the sounds. Technology mediated what was unfelt in a direct manner.

The expressive qualities of the movement and sound that were supported in the Augmented Speed-Skate Experience enabled athletes to improve their technique, as the auditory interface encouraged self-reflection. As the athletes were enabled to explore the soundscape and thus their movements, they could improve their technique as they started to build a background of 'what did and did not sound and feel good'. The expression-rich character of the mapping enabled this self-reflection.

The same expression-rich interaction qualities came into play in the Squeeze Me, the Sensible Alternative, and the Sensible Door. Through engagement, users were enabled to shape their own meaning with the (movement) behavior. Respectively, the users got a feeling for how the robot would move based on how the tablet was squeezed, the users got a feeling for how the application icons would emerge upon pushing them in, and the users realized that when they moved faster, the door would open more promptly.

Expressive-rich interaction allows people to express themselves. To impress the artefact and to affirm, appreciate and / or acknowledge how this was perceived. Consequently, how the artefacts expresses what impressed it, has the potential to impress the person using in turn. Expressive-rich interaction thus enables self-reflection if the artefact directly reflects the user's behavior, i.e., if input is directly mapped to the output.

We almost never (that is, without special devices) see a single color unconnected and unrelated to other colors. Colors present themselves in continuous flux, constantly related to changing neighbors and changing conditions – **Josef Albers** (2013 p. 5)

Enabling a Background of Experience

Meaning is never atomistic; it emerges *in* interaction, against a background, and in relation to former engagements. From a phenomenological stance, not a semiotic one, signs signify little in themselves; a sign expresses a meaning as a mark or divergence of meaning between itself and other signs. For example, to understand 'red', one needs to understand 'blue' and 'yellow'. 'Red' gains its depth once textured 'reds' are experienced. Practically, this means that artefacts that allow for expressive-rich interaction to take place do not only enable people to express themselves, but also develop a background against which meaning can surface.

In the context of the Squeeze Me exemplar, elderly people could express themselves to the robot by squeezing the device. By squeezing several times with different intentionalities, users experienced the consequences of their actions by means of the robot's movements. They learned, they developed a background of experience, according to which they could initiate and anticipate their next squeeze.

While any interaction enables people to develop a background of experience to which they can initiate and anticipate their future behavior, expressive-rich interaction aims at enabling a richer and more nuanced canvas. It enables a multiplicity of action-possibilities for people to explore, and skillfully cope with (Stienstra, Pul, Bruns Alonso, 2016).

Designing for meaningful interaction is inevitably about opening up spaces for and through engagement, opening up accessibility to functionalities. It is thus clear that it is necessary to open up the possibility of active engagement with artefacts, not to block people's perceptual reciprocity. It is obvious that, in order to provoke our senses and to actively engage with functioning artefacts, artefacts benefit from possessing active and dynamic qualities.

Related Work in Interaction Design

Throughout this work, the notion of respectful embodied interactions is developed and pushed as an overarching aspiration that unites several insights derived from phenomenology of perception and ecological psychology. Specifically, *interactive materiality* is suggested as a way forward and manifestation that respectfully addresses bodily skills and one's unique engagement with the world in a natural(izing) manner. Key characteristics are the enablement of *continuous* and *expression-rich* interactions that comply to the nature of *skillful coping*, i.e., our bodily ways of developing skill and dealing with complexity, in our everyday being-in-the-world and *here-and-now* engagements.

Respectful Embodied Interactions as Faceless Interaction

Janlert and Stolterman (2015) describe four influential thought styles[37] that articulate common understandings of the notion "interface". Interfaces are thought of as (a) *surfaces of contact* between matching objects, (b) *boundaries of an independent object,* (c) *means for controlling an object,* and (d) *means for expressions and impressions.* They furthermore pose an overarching and an alternative thought style in which the interface is considered as (e) a *channel of communication,* and (f) *faceless.* A thought style that suits Respectful Embodied Interaction does not resonate well with (c), means for controlling an object, a thought style highly influenced by Norman's concept of direct manipulation (Norman, 1986). Interfaces of this style manifest themselves with an emphasis on use, functionality and features, i.e., the traditional systems view evident in most ambient and ubiquitous computing. In contrast, Respectful Embodied Interaction, emphasize synergy, embodied skillfulness, and appropriateness; qualities present in thought styles (b) boundaries of an object, and (d) means for expressions and impressions. The latter in particular centralizes meaning, intentionality and emotions as derived from conversation metaphors (Hutchins, 1987) and found its way into interaction design in the form of expressive artefacts (Hassenzahl, Eckoldt, Diefenbach, Laschke, Lenz & Kim, 2013).

[37] A thought style (after Fleck, 1979) is a collectively accepted formulation that determines what a concept that is about.

Respectful embodied interaction reflects the thought style that deals with interfaces working as boundaries of artefacts embedding physical and digital materials, i.e., the interactive materiality that shapes/influences the behavior of people.

Moreover, Respectful Embodied Interactions as developed throughout this dissertation fit well with what Janlert and Stolterman (2015) frame as *faceless interaction*, a style of interaction rather than of interface. The phenomenology and ecological psychology-informed perspective for interaction design embraces similar characteristics such as the skillful immersion in ecological, contextual, or ambient realms. In hindsight, this dissertation revealed similar insights and points of interest independently. For example, faceless interaction and respectful embodied interactions reveal a potential role for behaviored artefacts and shape-changing interfaces, i.e., *interactive materiality*. Both perspectives flash out roles and character of designed artefacts and systems that appropriately respond to intentions of people.

Faceless interaction urges for balanced use of obedience versus control, independence versus autonomous and richness versus precision. As such, it builds on their earlier work in which they propose a theoretical model of interaction complexity (Janlert & Stolterman, 2010). They argue that the design of interactivity is to some degree about the distribution of complexity and control, mediating the relationship between the artefact and user. By proposing internal, external, mediated and interaction complexity (Janlert & Stolterman, 2010; 2015), they implicitly reserve roles for functionality, the interface, and context. This is similar to what I frame as the role of *artefact capabilities, synergetic capabilities*, and *contextuality* that are paramount characteristics for designing reciprocal engagement with the respectful embodied interaction designs.

Departing from the idea that meaning emerges *in* interaction and that a phenomenology and ecological psychology-informed perspective points to a focus on the in-between (Stienstra, 2016) and *here-and-now*, my research provides exemplary designs in support to the emerging thought style faceless interaction. As such the insights of this work on required design skills address some implications for design. Nonetheless, I wish to hold on to the idea that respectful embodied interactions could direct a thought style branch of its own. I consider it worthwhile to nuance constituents for different theoretical perspectives. For example, phenomenology emphasizes that meaning reveals itself in-between people and their surrounding, i.e., *in* interaction. This slightly diverts from activity theory that places this focus for interaction design on the user. A more elaborate comparison of theoretical strand, however, is not explicitly addressed in this work.

Aesthetics of Interaction

According to Hallnäs and Redström (2002) “function resides in the expression of things”, the aesthetics and the expression of interaction are constantly redefined in terms of meaningful, foundational elements, linking form and function (Hallnäs, 2011). This centralization of interaction aesthetics in how people perceive artefacts is widely acknowledged in the fields of human-computer interaction and product design (Buxton, 1994; Janlert & Stolterman, 1997; Djajadiningrat, Overbeeke & Wensveen, 2000; Hallnäs & Redström, 2002; Löwgren & Stolterman, 2004; Hassenzahl, 2007; Dalsgaard & Hansen, 2008; Lenz, Diefenbach & Hassenzahl, 2013 to name a few).

Bakker (Bakker, van den Hoven & Eggen, 2015) expounds the role of periphery in interaction. Her work on ubiquitous computing and ambient intelligence gives designers handles to utilize the *background-relation* (Ihde, 1998) by appealing to the *cognitive skills* rather than those emphasized in this dissertation.

In his attempt to flesh out key aspects of aesthetics in (digital) interaction design, Löwgren (2002; 2009) developed twenty themes. Respectful embodied interactions have close links to many of these themes. A few nuances in relation to Löwgren’s take on *fluency,* and *pliability* are in order. To Löwgren (2007[a]) *fluency* has to do with how *graceful* one engagement follows the other. The ‘fluency’ aimed for within this dissertation has more to do with how interactions follow each other in an *appropriate*–skill and context dependent–manner. *Pliability* (Löwgren, 2007[b]) refers to the responsiveness of artefacts. Responsiveness and being wound up *in* interaction is at the core of *interactive materiality.* Interactive materiality attempts to deal with tangible (direct) engagement whereas *pliability* seeks to transfer these characteristics to the engagement with digital artefacts (i.e., artefacts that rely on a sign character). Similarly, Vallgårda (Vallgårda & Sokoler, 2010; Vallgårda, 2014) expounds physical form, temporal form, and the interactive gestalt as three key elements at stake when people interact with interactive product and systems. As such she aims to utilize the tangible characteristics of computing (Wiberg & Robles 2010).

Different Types of Feedback

The Augmented Speed-skate Experience can be compared to biofeedback mechanisms. In essence, they share the following characteristics; behavior is translated and adopted in the behavior in a direct manner; and as elaborated, feedback opens up for self-reflection. However, where bio-feedback mechanisms and quantified self in general take bodily or behavioral signals in a direct feedback loop, the form of feedback is often disembodied and decontextualized (i.e., the feedback does not fit in a previously existing flow of use, rather it creates a new somewhat disengaged one). For instance, respiration biofeedback methods attempt to control respiration subconsciously through peripheral paced respiration (Moraveji, Olson, Nguyen, Saadat, Khalighi, Pea & Heer, 2011) while other methods subject breathing to external stimulus such as visual animation–using discrete light representations (that is, on or off), ambient light or sound animations (Yu, Hu & Feijs, 2014; Feijs, Funk & Yu, 2014). The approaches try to provide feedback as instructions to be followed by the patients. Such systems require an effort from the user to adapt their breathing patterns.

In contrast to this approach, *interactive materiality*, e.g. in the way it is used in the Augmented Speed-skate Experience, aims at feedforward that is non-obtrusive and embodied (Fishkin, 2004) as its form fits the context of use (i.e., it utilizes bodily skills rather than that it enforces a speed-skater to contemplate)

Design for Naturalizing Interaction

"Natural" and "intuitive" interaction or mapping are often referred to as design objectives (Norman, 1988; Rauterberg & Steiger, 1996; , 1999; Aarts & Marzano, 2003; Djajadiningrat, Wensveen, Frens & Overbeeke, 2004; Rauterberg, 2014). These objectives somehow hold the promise that designers are able to design things, i.e., artefacts, systems and services, that feel natural and require limited human effort to be used. Intuitive interaction claims to address one's skills in a way that they do not need to be developed any further. In other words, products and services can be used after limited learning effort or by capitalizing on previous experiences and skills acquired in similar circumstances. I empathize with this perspective and its ambitions because it fits with the phenomenology-informed objective to design for respectful interactions. It offers an opportunity to design for interactions that address the underused and pre-attuned *perceptual-motor* and *emotional skills*, instead of *cognitive skills*.

Even though it is often used, the word 'natural' almost always appears in between quotation marks. From a phenomenological perspective, as Svanæs (2001) points out, and an ecological psychological perspective, the naturalness of perception only holds value when considering the relation of the unique bodily and embodied capabilities with the world. In other words, natural interaction is highly dependent on the unique skills of people in a dynamic world. However, this view underlines how difficult it is to design for natural interaction, as it requires the designer to take into account a complex orchestration of one's embodied, social, and culturally developed skills.

In light of the aim to design for respectful embodied interactions, designing for natural interaction seems to merit fruitful insights. Yet,for the theoretical perspective, natural interaction needs to be addressed from the notion that 'natural' is not a static given. In effect, I aim at designing for interactions that utilize one's already naturalized skills or those that are easily *naturalized*[38]. Instead of focusing my work on the diverse cultural and socially embodied paradigms, i.e., the skills that have been acquired to deal with the social, cultural, and symbolic conventions sometimes referred to as social or *cultural affordances*, I depart from the embodied skills that (pre-reflectively) deal with the inherent earthly paradigms, such as tangibility, gravitation, and friction, and build forth from this.

[38] I use naturalized instead of learned to emphasize the embodied aspect of acquiring skill.

Certainly, people need to learn and acquire skills to deal with the tangible world (Gibson & Pick, 2000; Dreyfus, 2014) However, the bodies of people (i.e., the embodied skillset of making sense *in* interaction with the world in an attuning manner) and the inherent qualities of the (tangible) world are subject to less change than, for instance, man-made symbols, language, conventions, and other such paradigms. From birth, people develop (embodied) skills to cope with the natural world; it is what they are naturalized to by being-in-the-world.

Designing for natural interaction is aimed at designing for interactions that utilize the skills people have developed and naturalized throughout their engagement with their world. My approach is primarily bodily-driven and thus clearly deviates from, for example, Norman's (1988; 2013) wider approach to natural interaction, which incorporates cultural and symbolic conventions that inherently, although in a limited way when naturalized, demand contemplation and thinking processes. I suggest that this difference is rooted in the fact that Norman departs from a cognitive perspective rather than an ecological one. Designing for natural interaction in my work is about addressing skills in such a way that perception and action develops skills of *knowing* rather than *having knowledge*.

Addressing Skills

Within the scope of this work, I aim to re-balance how human skills are addressed within product design. I do so by addressing people holistically and respectfully.

My designs depart from the observation that in the discrete, generalizing, and hierarchical products and systems that currently dominate the world, the *cognitive skill* is over-addressed compared to our *perceptual-motor, emotional,* and *social skills.*

Human capabilities such as the *perceptual-motor, emotional, cognitive,* and *social skills* develop over time in a highly intertwined manner. However, the primacy of action suggests a certain order in which they are rooted and develop. Following Eleanor Gibson (Gibson & Pick, 2000) and Maurice Merleau-Ponty (Abram, 1996), it is the bodily–experiential–engagement with the world that enables meaning to emerge. To them, the bodily and experiential engagement is the root for this, even if meaning emerges on more cultural or social levels (De Jaegher & Di Paulo, 2007; De Jaegher, 2009).

People's perception and action-possibilities (*effectivities*) are constitutive of how they can possess higher order meaning. In the words of Polanyi (1983 p. 144), "While tacit knowledge can be possessed by itself, explicit knowledge must rely on being tacitly understood and applied. Hence all knowledge is either tacit or rooted in tacit knowledge. A wholly explicit knowledge is unthinkable". As such, I choose to use the phenomenological order of *perceptual-motor, emotional,* and *cognitive skills*. *Social skills*, as elaborated before, are difficult to place with the three other skills, as they utilize the other skills in relation to other people, beings, and perhaps artefacts. For more detail, from an ecological psychology perspective, on how people as infants get to grips with their world as their capabilities grow, see Gibson and Pick (2000).

For each different design situation, it is up to the designer to define which of the skillsets is most relevant to be addressed. While the *perceptual-motor*, *emotional*, and *cognitive skills* can be utilized in designing for interactions between a person and artefact, I consider *social skills* to be particularly valuable for designing for interactions in which the artefact has its own intentionality as well, i.e., it does not purely 'do' what is 'asked' of it. In what follows, I discuss in more detail why it is beneficial to address *social skills* in design and how to do so.

Designing for Social Skills

I believe that, in order to design artefacts that address the *social skills* of people, we, as designers, should empower the designed with similar capabilities. To give the designed a social intelligence is to empower it with the ability to affirm, appreciate, or understand when to become an acting entity and how to do so appropriately. As such, if we are to incorporate *social skills* into computational artefacts, we need to develop learning algorithms that are so flexible that they continuously challenge users' default states and previous learnings (*attuning* and *habituation* in respectively Gibsonian and Merleau-Pontian terms)[39].

[39] In order to avoid the symbol grounding problem expounded by Searle (1980), it would be fruitful if technology would be able to make an estimation of any situation without having to resort to context archetypes. Steels (2008) points out that a symbol grounding problem would not be problematic if learning would be approached in a non-representational (Brooks, 1991) and embodied manner. In other words, computation should be directive by intentionality and knowing instead of relying on having knowledge (see Michaels & Carello, 1981).

One reason as to why our *social skills* are underappreciated in interaction design is the ambiguity of appropriateness (Stienstra, Hengeveld & Koskinen, Forthcoming). What is appropriate? Inhibition, invitation, or reflection (Tromp, Hekkert & Verbeek, 2011)? If I adhere to the starting points stated in the previous sections, it becomes clear that appropriateness cannot be statically modeled. Also, we should not forget that appropriateness is inextricably linked to ethics. From Merleau-Ponty, Schütz, and Gibson I have learned that meaning emerges *in* interaction and does so in a reciprocal manner. The Gibsonian thought on appropriateness, based on the merging of the desired goals of the people/artefacts involved and the reciprocal character of the theory's unification of object and subject, goes hand in hand with Schütz's and Merleau-Ponty's view that *appropriateness* is related to the unification of shared or respected intentions, objectives, and goals that go beyond the action itself, and incorporate *contextuality*. In short, appropriateness is situated and should be played out reciprocally between people and their (interactive) environment while considering intentions and capabilities on both ends.

It takes two to reciprocate

Since the examples of utilizing *social skills* as well as most phenomenology-derived insights are somewhat given from a first-person point of view, it is easy to overlook that these examples build upon a reciprocal relationship in accordance with the later work of Merleau-Ponty (1968). Both, or in some cases multiple, actors are immersed in an interplay that utilizes their *social skills* and leads to a shared engagement.

When designing for *social skills*, I advocate for addressing people respectfully in terms of their *unique* skillset (that are mostly of continuous, holistic, and ever-changing nature contrary to the discrete, reductive, predefined nature of most artefacts and systems). Key to this is involving the skills *in* interaction (e.g., *perceptual-motor, emotional,* and *cognitive*) in order to empower people to affirm, appreciate, and acknowledge the skills in other beings or artefacts so they have grounds to act appropriately.

When designing artefacts or systems with social capabilities, it is important to empower them with the means to affirm, appreciate, and acknowledge people in their turn through interaction.

I place emphasis on utilizing the embodied *perceptual-motor* and *emotional skills* by designing interaction as continuous and of a rich expressive nature, as *perceptual-motor* and *emotional skills* are one's primary access to the world (primacy of action). Moreover, these skills seem under-addressed in current design. Allowing for rich expressive interaction could enable an artefact to learn more about the person, and respectfully address the inherently continuous and expressive skills.

Designing for *social skills* concerns the enablement of synergy, empowering one another (whether it is between people or artefacts) to fulfill intentions that cannot be met when a 'problem' is addressed singularly. In this respect, almost any function provided by an artefact can be considered social (e.g., the coffee machine is social as it empowers people to make coffee, or the telephone is social as it enables two people to engage in a conversation). However, these artefacts mainly require people to initiate and even control them. What I propose is for the artefacts to be actively engaged with the flow of everyday life (e.g., the machine makes coffee when desired, or the phone ensures that the person on the other end of the line can only be disturbed in the utmost urgency).

For interaction design, I see two types of products and systems that can fruitfully address *social skills* in a meaningful manner: Firstly, there are products and systems that express social behavior (have social capabilities) in their relation to the user(s), and secondly, there are products and systems that mediate the social interaction between people.

In my work, I seek to design for a synergy in which people and artefacts unite and come to affirm, appreciate, and acknowledge appropriate action. Designing for a synergy and appropriate behavior depends on three factors: (a) the actor(s) and its(their) skills and objectives, (b) the context in which the interplay is holistically rooted, and (c) the artefact of interaction, which can be both actor and context. The idea that artefacts can be both actor and context follows from the notion that social situations do not always benefit from an active *here-and-now* attitude by an artefact. It is not always socially appropriate to engage *in* interaction. Therefore, I propose that artefacts not only have a certain behavior, but also adapt to the context, affirming the context (not merely the human–artefact interaction) in which appropriate action results in being engaged, facilitating, delivering, merging, or mediating at the right time.

This dissertation explicitly elaborated the *social skills* for interaction design in relation to the *perceptual-motor, emotional,* and *cognitive skills* respectfully designed for. Even though a foundation has been established, I urge other design researchers to further explore this design approach in applications that aim not only to address the *social skills* of people, but also to seduce people to utilize their *social skills* more often beyond the direct engagements with the products within which the theory is embedded. In other words, I wish to explore whether it is possible to design for long-lasting influential interactions that carry on into other engagements. This is in line with the work of Philip Ross (2008) who explored the notion that products can carry (on) ethical values. In the context of my proposed research agenda, this ethical value concerns the 'utilization of the *social skills* from a phenomenological perspective' or 'respectful embodied interaction' in order to counter the disrespectful interactions dominating our being-in-the-world.

It seems worthwhile to further my research to understand how human capabilities and the capabilities embodied in technologies and the world can unify. In line with this work, it would not be about seeking discrete capabilities that are inherited from mainstream approaches, rather, I suggest to proceed with identifying capabilities that are easily overlooked yet inherently present in the (interactive) materiality of technologies.

Forms of Mediation

The Augmented Speed-Skate Experience clearly exemplified how mediating technology can be used to extend the body in an embodied manner. The seeing-through-the-eyes function of the robot enabled a person to see what the robot could see but also what it could not. To a certain extent, the overlaid expressive mask provided further insight into the 'mood' of the robot, and the action-possibilities provided insight into what the robot could actually do for the person at a given time (Marti & Stienstra, 2013[b]). Even though mediated through the use of (reductive) labels that allowed the robot to act, it is fair to say that these additions – embodied in the mediating user interface – helped people to grasp the opportunities and limitations of the robot and allowed the robot to function as an extension of the user.

From Seeing-Through to Engaging-Through

In designing the user interface's function to not only see-through-the-eyes of the robot but also to navigate the robot in its remote environment, the attempt to engage-through-the-eyes raised fundamental mapping questions. The idea was that by swiping the hand over the user interface, the robot would move. In practice, this meant that when the finger moved in a certain direction, the robot would turn accordingly. This mechanism would have worked out just fine, much like the not-'natural scroll direction' of the trackpad in MacOS or the inversed joystick, if the robot had been able to directly and continuously respond. In such a situation, through the continuous feedforward loop, the interactant would have been enabled to grasp the functionality (action-reaction paradigm) rapidly.

However, a fundamental question arose in the design process because the robot actually moved with a delay, thereby breaking the feedforward loop. It felt wrong to slide one's finger in a certain direction and have the robot reorient itself accordingly, e.g., when the finger moved to the right over the robot's view of the user interface, the robot would turn to the right.

I do not witness his turning,
but I can see that the robot's perspective on the world changes.
He can now do different things for me.
Again, I swipe over the touchscreen, the robot moves but there is something off.
My movements are detached from his.
I am detached from the robot.

Based on this felt discrepancy, a minor adjustment was made to the mapping; when a swipe was made in a certain direction over the user interface showing the current view of the robot, the robot would turn in the opposite direction.

Because of this minor adjustment the user could navigate the robot in its remote location instead of engaging with what was on the screen. By moving over the screen and "holding" what the robot reoriented (i.e., holding on to the furniture or artefact seen from the robot's perspective), an engaging-through-the-screen was enabled: one could engage with the environment the robot was engaged with. The robot view on the user interface enabled the robot to function as an extension of the body in the remote environment. A similar question is thus at stake when using the 'natural scroll direction' on a computer screen; do I engage with what is on the screen via the trackpad, or do I engage with the trackpad?

Behaviored Interaction

The Squeeze Me's *moody interaction* and the Sensible Door differed from the Augmented Speed-Skate Experience and the Sensible Alternative in the sense that they were behaviored. In other words, they did not have a direct mapping against which a consistent background emerged. They used the expressive input of the person and took it as part of (informer) of their behavior. The mapping then adjusted itself based on the behavior of the actors.

This idea of *moody interaction* (Stienstra & Marti, 2012) emerged during the development of the Squeeze Me interaction. Elderly people quickly got the idea that the harder the device was squeezed, the more quickly the Care-O-Bot would come to serve. With this knowledge, users started to 'misuse' this connection, always squeezing firmly to make the robot come quickly. As a countermeasure, we introduced moody interaction – a dynamic mapping that was informed through use. As a point of departure, the mapping started with a direct mapping, but when the device was squeezed more firmly than expected, it started to remember the user's behavior[40]. Each time this happened, the robot became more agitated and dynamically shifted its direct mapping. When the robot was fed up with the behavior of the elderly person, it would begin to ignore the user's attempts to squeeze hard, as if it were saying "Do it yourself!" Nonetheless, the user would discover that by gently squeezing the device, it was still possible to make the robot come.

[40] For practical reasons, a fixed bandwidth of acceptable pressure was used as opposed to incorporating *contextuality*.

The type of feedback to influence a person's behavior can also be non-user-created 'about-content', as was done in the case of the Sensible Door. For example, the level of occupation of people based on the calendar was used to make the door open more heavily. The result was that not only the behaviors of the door became embodied (i.e., taken up in bodily engagements in a ready-to-hand manner), but also people got a certain feeling that the space had impact. In these contexts, the technology served as a mediator of the 'about-content' of the environment and the 'intentionality of the artefacts themselves'.

What was witnessed with the Sensible Interface was that the person started to understand what the robot was capable of and that it tuned itself to what the person desired. In a way, both actors (i.e., robot and person) started to take care of each other. This was even more evident with the *moody interaction*, when a user figured out that they were being too rude and needed to change their behavior. In effect, the robot changed its behavior because of the user and *vice versa*. The *moody interaction* somewhat paradigm levels the behaviors of the actors. Practically, a moody behavior can be built on the basis of a direct mapping that is dynamically influenced by a history that develops – over time.

Negotiated Behavior

The Squeeze Me's *moody interaction*, the Sensible Interface, and the Sensible Door were all responsive designs. By that I mean that the behaviors of the robot and door followed directly what was given as input. Even if it involved external 'about-content' informers and a dynamic mapping design, the response was somewhat 'predictable'. The reciprocal engagement of the Move Me exemplar pushed this responsiveness slightly further. Whereas the Sensible Interface adjusted itself to the dynamics of *contextuality*, the Move Me exemplar attempted to *negotiate contextuality*.

Its *reciprocal engagement* was not a synchronization whereby the robot would simply follow the user. The robot allowed users to anticipate what it intended to do. Occasionally, the robot was capable of picking up the right signals as well. The form of mediation we aspired for the technology was not that of a mediator, but the actual artefact with which the person engaged. That is, the interaction aims at balancing present-at-hand and ready-to-hand engagements, initiating an active process of figuring out what the robot intends to do (as well as what the user intends).

Design for Contextuality

Context-aware computing (Schmidt, 2000), used in human interface design and ubiquitous computing, enables intelligent products, systems, and related services to provide the user with specifically optimized solutions for a range of contexts. Through the use of sensors that perceive the context, the user interface can, for example, adapt itself to the situation of use by providing functions that are relevant to that specific situation. Through the advancements in context-aware computing, graphical user interface design has opened up to proactive applications, function triggers, and adaptive applications.

Context-aware computing, in most cases, addresses *contextuality* by gathering information in a world model on top of which functions and appropriate services are built. For both the definition of context and what is done with this information, the field takes different approaches (Schilit, Adams & Want, 1994). In addition to determining people's context by offering them a set of selected/predefined situations (e.g., photoshop and indesign offer different workspaces for different stages of editing), context-aware computing seeks to ensure the *contextuality* of data for activities and events in the real world without the active intervention of people. It searches for features in the conditions of the physical environment such as the light, temperature, and so forth, to reveal possibilities for action.

The use of location-awareness (e.g., the garage door opens when you approach with your car or your phone enters into silent mode when you enter a meeting space) and someone's history of use (e.g., advertisements based on previous search queries) or that of peers with similar interests (e.g., book suggestions on the basis of what others have bought) are principles that involve the active participation of the user. Moreover, these context-aware computing principles seek ways to grasp *contextuality* from action.

Despite these efforts, it has been discovered that the context is hardly determinable on the basis of a limited amount of sensors (Dey, 2001; Dey, Abowd & Salber, 2001). We all have experienced our phone wrongly assuming that it is rotated and setting itself from a portrait to a landscape orientation. An urgent call missed because of an unfortunate location assessment (i.e., the phone was silent because it (mis-) understood that you were in a meeting room having a meeting) will make you turn off that particular functionality. In other words, context-dependent functions seem acceptable only when they actually work.

Coming to interaction design from the phenomenological perspective, I empathize with Suchman (1987)[41] who argues that a technology-oriented starting point for human–computer interaction does not properly address the full richness of the socio-cultural, emotional, and situated components of a context. Moreover, she argues that human action is constantly constructed and reconstructed within dynamic interactions with the world. To me, this means that, contrary to Ambient Intelligence (Aarts & Marzano, 2003) (i.e., technology as director of functions toward people in dealing with context) or Augmented Reality (i.e., technology as suggestor of functionalities toward people in dealing with their surrounding), there lies an opportunity for technology that dynamically negotiates with people *in* interaction[42].

[41] Suchman drew on Garfinkel's (1967) ethnomethodology, an analytical approach to social action as critique of the formal planning models present in Artificial Intelligence.

[42] Continuous and dynamic negotiation between people and their artefacts (and possibly between artefacts and artefacts as well) is most likely to result in undesirable situations in which 'the world won't shut up'. Nonetheless, I seek for nuanced product behaviors that do consider appropriateness of acting, i.e., products, systems and product ecologies that possess '*social skills*'.

Location-aware and context-aware models have been proposed to tailor interfaces, refine application-relevant data, and so forth (Schmidt, Beigl & Gellersen, 1998). However, I believe that such models are primarily utilized in a predefined and non-dynamic manner. For example, with the current context- and location-aware models, situations are detected and classified. Events are actuated when conditions are met. Therefore, they are highly dependent on the selection and definition of conditions. This turns out to be a difficult exercise due to the non-deterministic nature of our being-in-the-world (Chalmers, 2004; Dourish, 2004).

Informed by phenomenology, Dourish (2004) points out that *contextuality* is to be addressed as an interactional problem, not as a representational problem. In effect, it should be considered to be a relational property held between the actors in the world, who define themselves dynamically *in* interaction; it attunes itself to the particularities of the environment, and *contextuality* arises from within activity.

Instead of addressing contextuality as static, predefined, event-driven, and deterministic, I argue that designing for *contextuality* is about dynamic, attuning, and activity-driven mechanisms. This means avoiding preferences and presets, and approaching *contextuality* as dynamically emergent and dialogue-natured.

Instead of addressing *contextuality* as static, predefined, and event-driven, and highly susceptible to deterministic choices that profoundly contradict the rich nature of people in the world (i.e., the unique richness of the bodily skills of people in a complex (social) world will be reduced if deterministic choices are made), I argue that designing for *contextuality* is about dynamic, attuning, and activity-driven mechanisms. This means avoiding preferences and other kinds of static pre-definitions, and utilizing the emergence of meaning *in* interaction instead. Instead of approaching *contextuality* as a cause and effect mechanism (either initiated by people or systems), I believe that from a phenomenological perspective *contextuality* should be approached as dynamically emergent and dialogue-natured.

Interactive artefacts that embody adapting qualities require designers to anticipate a transition from closed (controllable and predictive) to open systems (use-centric and as such unpredictable). This suggests that design challenges of ambiguity, timelessness, control and transparency need to be addressed (Ahn, Barakova, Feijs, Funk, Hu & Rauterberg, 2015). A phenomenology-informed design perspective, and in particular my design explorations of the Sensible Door and Sensible Interface, suggest that ambiguity is a characteristic that resolves itself when people engage with adaptive systems, i.e. *in* interaction. Our bodily skills seek and find a maximum grip to deal with ambiguity. Yet, inherent to adaptive systems, those interactive artefacts change as well, potentially making it more difficult for people to find fit. Transparency about the changing behavior of artefacts deems fruitful, i.e., people understand things better if they can grasp the rationale or intentionalities of the other (thing).

Control, as stipulated before, is not something that is in either the human or system but could well dwell in-between and emerge in dialogue. To abate the anticipated issues ascribed to adaptive environments (Gorbunov, Barakova & Rauterberg, 2011; Ahn, Barakova, Feijs, Funk, Hu & Rauterberg, 2015), the human-centric design approach suggests that adaptive products can be equipped with *social skills* that address *social skills* of people (i.e., products that understand intentions of people and act upon them appropriately as well as that they enable people to do the same). Not unlike Brooks' (1986) approach, artefactual *social skills* do not necessarily need to rely on formalized categorization and script, rather, *social skill* can remain to dwell in a '*pathic*' realm and merely utilize a direct interaction mapping that becomes meaningful *in* interaction.

Contextualized Interaction[43]

[43] This section consists of parts taken from Stienstra, J.T., Marti, P. & Hummels, C.C.M. (Forthcoming). Sensible Interfacing: Action-Possibility Driven System Design. *Submitted to International Journal of Design.*

In the direct engagement between people and artefacts it is useful to consider designing for continuous and expressive-rich interaction as pointed out earlier. In doing so, the fit between bodily capabilities and artefact capabilities is enabled. In other words, by mapping the discrete functionalities of computing to the continuous qualities of a human being in a continuous manner, there is ground for respectful embodied interaction. However, as indicated in Part I of this work, the context of use is essential when aiming for engagements that address human skills in a respectful manner. From a phenomenological perspective, context is not a given but a dynamic. Not all functionalities of products and systems are needed at any given time. Rather, it is the notion of *contextuality* that guides or constrains those functionalities to be offered in relevant situations. I propose that the dynamic and active character of *contextuality* be utilized to constitute the action-possibilities, i.e., the actual opportunities for action in a Gibsonian way as illustrated in the Sensible Interface.

In what follows, I discuss the ways in which situatedness or *contextuality* played a role in the design of the exemplars. Consequently, I expose how I gave rise to the dynamic qualities of *contextuality* through the dynamic application of action-possibilities. In the context of the Sensible Alternative, Sensible Interface, and Sensible Door, I show how relevancy played out through the introduction of likelihoods as a practical way of dealing with this dynamic, lived-in *contextuality*. This section closes by elaborating on three different kinds of contextual-informers and how the outcomes – the dynamic action-possibilities – function as constraints.

Contextuality, or situatedness, has always played a role in my design decisions. The Augmented Speed-Skate Experience device was light so as to not interfere with the actual act of speed-skating. The Sensible Door was placed in context so that I could get a grip on the elements at play. In the Sensible Alternative, the navigation between applications was guided by content-type similarities. *Contextuality* was made up of these content-type similarities, speculating on the idea that a user might desire to use an application that could actually do something with the data available in the open application. For the Sensible Interface, the robot's available action-possibilities emerged out of a combination of what the robot could actually do in the given environment and what the elderly person desired or needed. Here, *contextuality* was highly informed by the *affordance* of the robot with the environment when attempting to be of help to the person.

Relevancy

The notion of relevancy emerged in the designed-for interactions. In effect, some functionalities or desires a product or system responded to were more relevant than others. In the case of the Sensible Alternative, dozens of application suggestions could have be pushed-in if the number of application icons had not been limited to those that were relevant. If the Sensible Interface had treated each and every action-possibility as equally relevant, there would not have be enough surface area on which to display the action-possibilities. As hinted at before, the action-possibilities were displayed on the basis of relevancy. If they were relevant, they appeared big and accessible in contrast to the less relevant action-possibilities, which were depicted as small or not at all.

Likelihoods

In practice, we introduced 'likelihoods' to function as a representation of whether something was more or less relevant. A likelihood is a calculated relevancy based on ongoing desires, feasibilities, and past use. I roughly differentiate three types of likelihood informers: interaction-informer, environment-informer, and artefact self-informer. Even though the likelihoods of action-possibilities can contain subclasses and complicated structures that must cope with a complex set of intertwined relations, for explanation I describe the types and their qualities separately and in relation to the Sensible Interface and Sensible Door exemplars.

Interaction-informer Likelihood Type

The first type, interaction-informer, takes preliminary information about the person in its definition of the likelihood. In the context of the Sensible Interface, this involved assessing the current condition of the person, i.e., whether he or she was likely to be hungry, tired, in need of calm music, etc. The interaction-informer type also includes the learning of preferences through the use of action-possibilities, as described later. For example, the Sensible Interface attuned its likelihood to the user's desire to drink coffee with sugar rather than without.

Environment-informer Likelihood Type

The second type of likelihood informer, environment-informer, takes the status of the environment and its products as its main informer. With regard to the Sensible Interface's action-possibility of cleaning a coffee cup, the likelihood was thus conditioned by the cup of coffee; its location in relation to other perhaps more easily reachable cups; its dirtiness, fullness, and current temperature; and so forth (i.e., it was conditioned by the state of the smart environment and its connected devices, not the person *per se*).

Artefact Self-informer Likelihood Type

The third type of likelihood informer, the artefact self-informer, utilizes the current condition of the artefact, e.g., in the Sensible Interface, whether the robot had enough power to execute a task, whether it could access the location where it was supposed to perform a task, whether it needed to preheat its motors, or simply whether the robot was grumpy or cheerful. In other words, the artefact self-informer type conditions the likelihood on an *affordance* level (i.e., in terms of the robot's bodily capabilities in its environment).

One could imagine that the likelihood of the action-possibility of offering a cup of coffee would depend on a variety of aspects: interaction-informer (whether the person was thirsty or not), environment-informer (whether there was a clean cup and coffee available), and artefact self-informer (whether the robot was capable of grasping the cup based on its power levels).

As indicated, in order for the action-possibilities to function in a relevant and meaningful manner, the structure of the likelihoods must reach beyond the 'if-then' paradigm. In the Sensible Interface, this meant that the connected devices in the smart environment were surveyed at all times as they changed. The parameters were continuously updated, providing a dynamic character when engaging *in* interaction with the robot and the environment through the interface.

Similar informers were used in the Sensible Door exemplar. For instance, the sunlight was taken as 'environment informer' in the behavior of the door's resistance; the stability of the sensors acted as 'self-informer', and the approach speed and pressure exerted were 'interaction-informers'. By 'stability of the sensors' I mean that I incorporated the design feature that when a specific sensor picked up a lot of noise, it would become less influential on the door's behavior.

In the Sensible Door exemplar, several contextual factors were explored, all of them building on an activity-driven approach, rather than an event-driven one. My focus lay primarily on the human-driven *contextuality* of the door's entering (i.e., visitor to a space) and receiving aspects (i.e., inhabitant of the space). I took human-driven *contextuality* as rooted in human behaviors, such as mood, need-for-entering (entering side of the door), or need-for-disturbance (receiving side of the door). With the design of the Sensible Door, I aimed to find connections between the door and the environment that made sense. For instance, the Sensible Door started as a way to indicate the occupation of the person behind the door. If the person's calendar said that the person was likely to be busy, the door would be difficult to open in contrast to when the person was simply engaged in a colloquial coffee conversation. Furthermore, I attempted to connect the sunlight to the door. This in itself did not make much sense, which led me to decide that the light sensor would not have much effect on the behavior of the door as an 'environment-informer'.

Phenomenology of perception and ecological psychology have shown to be of value for designing engaging experiences. I see an opportunity to broaden the theoretical potency of these approaches if they are opened up to engagements that utilize the advantages of computing found in dealing with distance and time. As such, it is recommended that other philosophical strands that focus on other qualities of experience be incorporated, i.e., theories that are better suited to dealing with the there and later in addition to the *here-and-now* focus of phenomenology and direct perception theories.

A design approach inspired by phenomenology requires new kinds of support: frameworks, methods, processes, techniques, and tools that support embodiment and open up to one's skills, that enable the sensorial/intuitive to connect the abstract/analytical, that stimulate making next to thinking, that facilitate reflection in and on action, and that support designing opportunities through which a person can create meaning in a specific sociocultural context. **– Caroline Hummels and Pierre Lévy** (2013 p. 46)

Supportive Design Approach & Tools

This chapter is concerned with the question of how to design for respectful embodied interaction, with a particular focus on the design frameworks and supporting methods and tools. As explained in the first chapter of Part III, the design process benefits from an iterative design process in which the physical hypothesis, i.e., the design, shapes itself in context and use. For this I used and adapted the reflective transformative design process (Hummels and Frens, 2011), which is elaborately discussed in chapter I of Part III and which won't be addressed in this chapter. Here, I will focus on the specifics of frameworks, methods and tools, starting with *naturalized interaction* in relation to the Interaction Frogger Framework and related theories. Moreover, as shown in the previous chapter, phenomenology-informed design is better equipped if its units and tools consider the qualities of the interaction for which it is designed. That is, in order to design for experiences that are of a continuous nature, the design tools and materials benefit from similar qualities. I specifically address how to make the discrete continuous. In addition, I discuss how the Interaction Frogger Framework suggested earlier can be used as a generative tool in this 'dimension' approach. Designerly Handles is proposed as intermediate design enabler that support interaction designers in utilizing their *pathic skills* when crafting digital artefacts that are physically engaged with. As such, I introduce dynamic and contextualized enablers as the means for interaction designers to work with digital qualities in a designerly manner. The chapter concludes with four high-over suggestions on how units of measure, design tools, workspace, and complexity should be re-addressed when designing for respectful embodied interactions.

(Re-)Designing for Naturalizing Interactions

When aiming for naturalized interaction, the Interaction Frogger framework (Wensveen, Djajadiningrat & Overbeeke, 2004; Wensveen, 2005; Stienstra, Bruns Alonso, Wensveen & Kuenen, 2012) is a valuable tool for reflecting on the designed-for interaction, as it points out that function and action are often mediated through feedforward and feedback mechanisms[44]. This framework was developed based on the theoretical notions of Gibson's ecological psychology and embodied interaction, and inspired, although not explicitly, by phenomenology and pragmatism. The reason for its development was to apply philosophy and theory to a more practical way for designers to use these notions to explore and create intuitive and aesthetic interaction. From a practical angle, this framework tries to exemplify the relations between the notions of feedback, visibility, mapping, and *affordances* as put forward by Norman (1988), and combine them with the notion of feedforward as introduced to the interaction design community by Djajadiningrat, Overbeeke, and Wensveen (2002).

[44] Simply, feedback says something about what you did, while feedforward indicates something about what will happen if you do something.

Interaction Frogger Framework

For me, the first design-practical value of the Interaction Frogger framework lies in its six aspects of natural coupling. These six practical aspects, i.e., *time, location, direction, dynamics, modality,* and *expression,* are used to describe the relations between a person's action and his or her perception of the product's reaction, i.e., between action and accessed functionality. Even though the method behind the framework was designed to make the designer aware of these aspects and consequently to allow the designer to explore the available richness, I understand the framework to be of further use in designing for naturalized interaction. By rule of thumb, the framework argues that the shorter the mapped relations between action and reaction for the six aspects[45], the more 'natural' the interactions become. Wensveen, Djajadiningrat, and Overbeeke (2004) use the example of scissors to show how time, location, direction, dynamics, modality, and expression are closely mapped in this mechanical device and sometimes even coupled. The cutting action is immediate and takes place just ahead of one's hand. Moving the fingers closer together translates into a forward motion over the paper, while the cut line follows both the dynamics and expression exerted by the haptic use of the user. In mechanical products, action and function are often inherently coupled. Electronic products, on the other hand, often rely on uncoupled action and function due to the transition from the tangible domain of use to the digital domain. The Interaction Frogger framework enables designers to assess the relations between input and output, action and reaction, and action and accessed functionality, but also encourages them to re-establish the relations in such a way that the user experiences the interaction as something more natural.

[45] I speak of a (direct) coupling when the mapping concerns a one-to-one relation between the action and reaction of an aspect.

Interaction Frogger Framework in Practice

In the following sections, I elaborate on the six aspects of this framework. First and foremost, I demonstrate how a product can be (re-)designed to be experienced as more natural, i.e., as utilizing one's perceptual-motor and *emotional skills* developed in our everyday engagement with the more-than-digital world. To do so, I point out the qualities of a designed physical–digital interface, the touchscreen, as a functional redesign of the computer mouse.

Even though the six aspects are intertwined, thinking about them separately offers design-practical insights for analyzing human interaction with products. A quick Interaction Frogger analysis of the computer mouse shows that the actuation of the functions of (a) moving and (b) accessing other functions (i.e., clicking) is mapped in a fairly direct manner. I briefly discuss the first functions separately in order to show how, with the use of the Interaction Frogger framework, the designed-for interaction can be improved with minor adjustments to the mapping.

Time When considering the movement of the mouse, the cursor's movement is directly mapped in terms of time (i.e., the cursor on the screen moves when the mouse is moved); the location takes place through a translation (i.e., the mouse moves over a horizontal surface, while the cursor on the screen moves along a perpendicular plane). Despite the planar translation and scaling factor (i.e., the distance covered by the mouse relates to that of the cursor), the direction is mapped in such a way that an upward movement of the mouse results in an upward movement of the cursor on the plane of the screen. Through the directly and continuously mapped movement, the dynamics of movement are sustained. The movement of the hand's modality translates into the movement of the representative cursor, in that, the expressions exerted on the mouse are reflected in the movement of the cursor (e.g., the specific character of acceleration).

Location The not directly mapped aspect that stands out here is the location, i.e., the actuated mouse and reactive cursor follow a mapped translation over a perpendicular plane. An existing solution dissolves this discrepancy and shortens the relation between action and reaction that coincides with the movement of the mouse and cursor in terms of location. The touchscreen enables people to manipulate what is on the screen, where it is on the screen. Thus, this designed solution transforms scaled mapping into a coupling. Interacting with touchscreens is generally experienced as natural as it is comparable to how people move in the tangible world, to how they leave ink traces on paper when writing, or to how they move things under the tips of their fingers.

Under my fingertips, the picture can be moved.
Under the spell of my finger's movements.
I control the position, size, and orientation of the image.
The touchscreen allows me to be in direct control of what is going on.

Early implementations of touchscreens faced several issues due to a lack of computational power or other technological inaccuracies. For example, the reaction following an action was subject to a delay in terms of time, or where one pressed one's finger and the location of the cursor did not fully coincide. When the time aspect was not directly mapped, the touchscreen was experienced as unnatural. This discrepancy was only naturalized once the body found a way to deal with it, i.e., anticipate the discrepancy. When a designed mapping is close to being coupled with respect to the six aspects but not quite there yet, people's bodies utilize the learned interactions acquired from their everyday engagement with the tangible world to find ways to cope with the discrepancies.

I catch myself rubbing the paper.
It doesn't move; the words keep hanging on the page.
Did the application stall?
Once again, I flick my finger alongside the text, hoping that I am able to read further.
This paper won't listen.
It needs to be turned.

Designed mappings that speak to one's already developed *perceptual-motor* and *emotional skills* are picked up more rapidly in comparison to those that require to be internalized (Rauterberg & Steiger, 1996). Man-made (electronic) conventions are learned and can become embodied as well. At times, they may severely conflict with the paradigms people have grown accustomed to. For example, a display interface with a page flip metaphor does not always work out. In order to prevent clashes in the interaction paradigm, interaction designers could give interactions their own character (Djajadiningrat, Overbeeke & Wensveen, 2000) instead of borrowing, and mixing up metaphors.

Making the Discrete Continuous

People engage in a continuous manner. Computers, on the other hand, are often more discrete in nature. In order for people to engage more effectively with these abstracted zeros and ones, it is common to provide an interface. In what follows, I point to several practical approaches that enabled me to map the *continuous of being* to the *discrete of computing*. My approaches and insight are in line with existing literature, e.g. in robotics, mechatronics, human-computer interaction and product semantics, and as such maybe not new for the audience. However, I do want to reflect on them from a design research, and specifically from a phenomenology and ecological psychology-informed perspective, and indicate that it fits with designing for respectful embodied interactions.

Sensors and Actuators

Use of Analog Sensors

The first approach to achieving continuous interaction is simply to use analog sensors instead of digital ones. I have used their sense data raw, or at the most slightly gauged, when mapping the sensors to an (again) analog actuator. But, digital sensors are often more reliable, even though they are not prepared for providing continuous and instantaneous flows of data. The trick is to tune them to the best of people's abilities, that is, to consider the limitations of perception. For instance, an RFID sensor is normally tuned to return an event with the identifier and strength of the chip, when the chip is held in front of the sensor. By increasing the frame rate of polling, it is possible to also know when the chip is removed and even its distance in front of the sensor. However, depending on the design context, an analog distance sensor might be more useful.

Use of Analog Actuators

The same goes for actuators. Even though they can consider continuous flows of data, it does not mean that they are capable of acting on that data. For instance, a (vibration) motor can turn when low or high voltages are provided. The higher the voltage, the faster the motor rotates. The issue here is that, if the aim is to make the motor turn very slowly, little voltage is needed. The consequence is that the motor does not spin even though it just worked some minutes ago with a higher voltage. Increasing the voltage slowly makes the motor spin suddenly, and increasing the voltage further makes the motor go even faster. So what happened to the subtle start that I thought I could have based on linearity principle? It turns out that the motor is blocked by friction, by its own mass. Basically, this physical property prohibits designers from creating any subtle movement from nothing. The practical solution to this issue is to give the motor a tiny kick start, a peak that is just enough to make the motor turn, so the low voltage will be enough to maintain the slow speed. This method works, but requires the designer to develop an in-between solution, placed after the input and before the motor, to deal with this kick start.

Sensing Actuators

The act of accurately placing a sensor is a crucial part of designing for continuous interaction. Sensors are required to capture what needs to be captured. In the case of the Augmented Speed-Skate Experience, force-sensing resistors were located between the shoe and the bridge of the skate so as to capture the transfer of energy from the speed-skate to the ice (in that exact direction). The Sensible Alternative and Squeeze Me designs benefited from an easily accessible pressure spot.

For the Sensible Door exemplar, the intention was to capture the movement of people stepping aside or going in. For the Sensible Door, these sensors were located on the moving part of the door, which made them move with the surface and thus change sight lines. This also meant that the centralized sensors maintained focus on the person once he or she was engaged *in* interaction with the door. In addition to distance sensors that grasped information about incoming movement from the horizontal landscape perspective of the door, overhead cameras were used to obtain similar data about incoming people. The real-time data processing here focused on the speed of movement and the directedness of people (i.e., the positioning of their shoulders) in relation to the door and other people.

For the Move Me design (Marti, Iacono, Stienstra & Tittarelli, 2014), the robot's movement was enabled by utilizing a series of distance sensors as an array, i.e., as a single sensor as opposed to separate ones. This array captured where a person was moving in relation to the robot's own position. In turn, the position of the person was mapped to the movement of the robot itself. If the person increased pace, the robot's sensor array would notice that the person had moved ahead, and the robot would thus decide to increase its own pace to keep up.

By enabling sensors to incorporate movement in their act of making sense, sensors (and thus acting bodies) can become *inherently* anticipative.

In retrospect, this useful strategy resonates with the ecological psychology-informed idea to give the perceptual system an active participatory role (Michaels & Carello, 1981; Brooks, 1991).

Bypassing Planning

In order to make the Care-O-Bot act promptly and move continuously, two proposals were put forward to overcome technical issues. The first issue was that the robot had a control mechanism that was dependent on planning. In practice, this meant that if an action-possibility was addressed on the Sensible Interface, the robot would start to calculate its path considering any obstacles. Eventually, it would start to move accordingly. This waiting time was unacceptable for the proposed Squeeze Me interaction. Even if the design did not require continuous feedforward, any user would not be willing to wait that long. In order to perceptually bypass this planning procedure, one might better enable the robot to be prepared for movement and make calculations along the way. This means that the robot should be prepared to move at all times in any direction that is known to be free and able to adjust its path once a more accurate path is constructed. Although the robot still depends on planning, its response could feel more instantaneous and spontaneous.

Another example of bypassing planning could relate to the see-through mask. In the current version, the robot turns too late to create a sense of continuous interaction or even control, when the person changes the direction of the robot. To solve this issue, the camera view of the mask could move immediately. By mapping the camera view to the steering on the controller, the movement delay of the robot itself could be overcome. In a sense, we would use an illusion to create the sense of promptness and fluidity.

Limits of Perception

When designing for the senses in a respectful manner, it is beneficial to understand how the senses work, how people make sense of the world, and their limitations and opportunities. As described in the previous section, it is important to map the appropriate sense modalities to the engagement with the artefact. When choosing an appropriate channel, it is worth investigating the limitations and opportunities of perception and modalities. The human perceptual system is very good at compensating what is not perceived (Noë, 2004), and it is up to the designer to make use of this. In my designed exemplars, the usage of compensation mainly played out in the Augmented Speed-Skate Experience in which the continuous feedforward loop was crucial for the design's functioning. I aimed to develop a feedforward loop in which there would be no delay whatsoever, i.e., with the sound being generated simultaneously as the athlete moved. A known signal processing issue kicked in. That is, a direct loop without delay was not possible to achieve. The movement data, i.e., the pressure exerted, had to be captured, sent to the main computing device, mapped into a coherent soundscape, and sent back to the athlete causing a delay.

Fortunately, the body has ways of coping with this time lag caused by technologies. For achieving continuous interaction loops, two aspects that influence people's integrative capabilities can be addressed with known tactics borrowed from bio-robotics, mechatronics and other engineering disciplines that deal with time critical signal processing.

Latency The first is latency, the delay between action and reaction. In the case of the speed-skate design, I utilized the integrative capacity of transmodal senses through which the body is capable of resolving a delay below 100ms (Stienstra, 2009). People's synaesthetic capabilities are able to merge one sense with another. When a movement is made and a sound follows, the body is capable of matching these two sense modalities and perceiving them as one, even if there is a slight delay between them. For design, this means that delay does not have to be an obstacle. This idea was further utilized in the Squeeze Me exemplar in which the delay between the user's squeeze and the robot's movement could not be resolved. To compensate for the delay, We designed an in-between solution, introducing a corresponding mask that was able to respond within a reasonable time frame, i.e., quicker than the robot's movement and instantaneous to be perceived as direct. In addition, the design was able to achieve a coherent experience through the development of a squeezable cover (Marti, Tittarelli, Sirizzotti & Stienstra, 2014); through its material feedback, the cover offered a mechanism through which the user's integrative capabilities could work. For multimodal interaction design to support our synaesthetic capabilities, it is commonly recommended to have the separate channels to respond coincidal, i.e., within the range of our integrative capabilities to make sense of it as one (Dozza, Horak & Chiari, 2007)

Resolution The second dimension is resolution – the frame-rate at which 'movement' is perceived as a continuum. A clear example of technology that makes use of this capability of perception is the mp3 music format. Other formats are likely to have a higher level of resolution, including more data. Mp3, however, merely keeps what can actually be perceived and dismisses the rest, resulting in smaller file sizes. In signal processing, the reduction of a continuous signal to a discrete signal is called sampling.

I applied this idea in attempting to make people's engagements with the exemplars perceived as continuous. In the Augmented Speed-Skate Experience, it would not have worked to give feedback to the athlete once every second. In such a case, the 'about-content' would have been unsuited and unrelated to the continuous behavior of the athlete. In short, even if the athlete heard a beep of a certain quality, he or she would not have been able to relate this back to the movement. On the other hand, capturing movement data at a high rate would have overloaded the technology beyond its capacity. In the end, my resolution was to capture movement data that the technology was capable of handling and transform it into a coherent soundscape that the person would perceive as continuous. The same idea was applied to the modality of light with the Sensible Door, where I mapped the opening of the door to the brightness of a lamp. The lamps used for this function were not enabled to act continuously, i.e., they were subject to discrete state changes. However, by increasing the flow of the lamp's discrete state changes it was possible to perceive the changes as continuous transitions without overloading the lamp. This shows one of the, for designers, useful qualities of our perception: it is capable of filling in some of the gaps. This means that designers have some space to play with the resolution of that which is perceived. I believe it is crucial for designers to understand senses and their sensitivities when they wish to utilize this quality.

Artificial Constraints

When I designed the mapping of the push-in button to the appearance of the icons of the Sensible Alternative, I ran into the following issue. I started off with the base mapping that the more the application icon was pushed-in from behind, the more the application icon would come through the screen, i.e., it would become bigger when pushed harder. However, the consequence was that people started to understand this relation quite quickly and thus tended to push harder just to get the icons to grow bigger. This was problematic, as the sensor was not capable of sensing high pressure; it was capable of being relatively linear within a limited range of pressure. Users would press out of measurable reach and perhaps damage the smartphone. Furthermore, people tended to not 'feel' that they had reached their own maximum pressure. When pushing the pressure-sensitive spot, the icon would grow bigger, but not as big as users expected it to, persuading them to try pressing harder.

As people are enabled to 'self-reflect', on a conscious (cognitively) and unconscious (bodily) level, when expression-rich interaction is enabled, the mapping design can *constrain the behavior*.

My solution to this was to build a constraint (Norman, 1999). To be more specific, I developed an artificial constraint. Instead of mapping the push and icon-emergence linearly, I diverted the mapping at the point where the person was pushing hard enough to break the screen. This led users to push the icon in, but once they figured out *in* interaction that it did not help to push even harder, they were inherently coerced to not over-push. To develop similar interactive constraints, I believe that designers should pay attention to the synaesthetic qualities of perception.

Sense-Modalities

Designing for respectful embodied interactions requires the sensible use of the different modalities. When people are already over-engaged visually, it might be useful to provide additional 'about-content' through a different sense modality so as to not overload or distract them from their task. For the Augmented Speed-Skate Experience, I explicitly chose to provide the feedforward loop over the auditory sense modality. The athletes were already overwhelmed with visual information (i.e., constantly anticipating their movements for the upcoming turns and lane transitions), but their auditory sense was under-used. The advantage of selecting the auditory sense modality was that it offered integrative and multidimensional capabilities. It could be used to reveal many layers of 'about-content'. For example, when we hear a door close, we inherently hear and grasp qualities about the material of the door, the user's mood, and so forth. In the Augmented Speed-Skate Experience, both the integrative capacity of the auditory sense and its multidimensionality were utilized in the mappings. Alternatively, the Augmented Speed-Skate Experience could have utilized vibration motors to embody the 'about-content' of the extra senses, as achieved by Bach-Y-Rita (1972) in making blind people feel and taste their surroundings. Sound, however, offered a multiplicity of depths as opposed to the more or less 'on'/ 'off' and delayed capabilities of vibration motors. Addressing the haptic sense is known to be difficult (Buxton, 2007; Mousette, 2012).

One of the more thoroughly explored mappings of the Augmented Speed-Skate Experience exemplar (Stienstra, 2009) was a multi-layered one in which the earlier described mapping was extended through an additional sound layer. The acceleration meter's movement data was translated into a pitch that could be heard over both earphones, separate from the other mapping. Using this layered mapping, the speed-skater was capable of understanding and utilizing both mappings. In practice, it turned out that the mapping of acceleration to sound was not functional for the athlete, and therefore it was removed from the sound-scape. Nevertheless, this multi-layered mapping demonstrated the opportunities of the auditory channel (Stienstra, 2009; Kramer, 1994). In the case of the Sensible Door, sound was not chosen as the primary channel for communicating 'about-content'. Here, it was movement that fit with the ongoing engagement, i.e., moving through a door is mainly about moving, not about listening.

The Squeeze Me exemplar utilized the movement of the robot instead of other modalities, such as the visual, as the purpose of the exemplar was to address the *emotional skills* of people. In this context, the characteristics of movement were shown to be more touching than the endeavors with lights on the robot, which were hardly visible. The Call Me approach (Stienstra & Marti, 2012) of mapping one's expression captured through audio to that of the robot's movements was rejected by us because it could create falls expectations of a robot capable of understanding natural language, which wouldn't be the case when using tangible interaction. Moreover, one could wonder if voice input is better suited to the dimension of expression in comparison with the user's squeezing behavior. The microphone can capture sound and its loudness, but it is more difficult to capture expressiveness in terms of urgency or care with a microphone in comparison to the Squeeze Me.

When choosing sensors and actuators for an expression-rich interaction, it is important to chose them fitting with the intended purpose. For instance, if a bread toaster interface is about the control of the 'crispiness' of the toast, the sensors should allow for people to express 'crispiness' (Stienstra, Pul & Bruns Alonso, 2016). In case a music player is designed, this perspective would emphasize the expressiveness of the music, i.e., mood or genre, which in turn could be mapped to the expressive interaction with the controller (Mailvaganam & Bruns Alonso, 2015). In case a coffee machine is about making coffee and making a certain 'flavour', the machine should allow people to express this 'flavour' (e.g., strength and/or roundness).

Body Orientation, Expression Orientation

[46] The book *Body and World* was written as a doctoral dissertation at Harvard in 1963 and first published in 1990 under the title *The Human Body as Material Subject of the World*.

Samuel Todes (2001)[46] goes beyond Merleau-Ponty with respect to the role of the body in the emergence of meaning *in* interaction. He develops in detail how the structure of the (active) body is constitutive of the unified experience of time and space.

From these phenomenological insights, I sketch a few basic implications for the design for interaction. Accepting the horizontal field as one that offers the person a variety of action-possibilities and the vertical field as one that offers approachability and opportunities to gain depth within an engagement guides me to the following perhaps insight: (a) that options for interaction should appear in an horizontal layout, and (b) that particularities should appear in a vertical layout, much like the stocking of supermarket shelves. This would place, for example, dropboxes with a variety of options in the horizontal and dropboxes with options concerning particularities in the vertical orientation. While this makes sense to me, when I actually move my body, it is arguable that this arrangement does not apply to, for example, screen-based interactions in which the body–product relation does not require the body to rotate (i.e., shift or explore within the horizontal field).

The Augmented Speed-Skate Experience, the Sensible Alternative, the Squeeze Me, and the Sensible Door all had one thing in common that I would like to relate to Todes's insights: the utilization of force as a means of expression. For example, the movement of pushing away implies a certain 'disgust' or will to set free, while the movement of pushing inward implies an embrace or caress. Therefore, I propose to extend Todes's insights to consider the directedness of action (Stienstra, Hengeveld & Hummels, 2015). To me, this relation highlights that expression and pressure are strongly related and that its orientation should be considered when designing for interaction in which certain *emotional skills* are addressed.

When designing for addressing *emotional skills,* it is useful to consider expression. Consequently, I believe it is valuable to consider *direction of expression* in relation to the body as well.

Dynamics Overrule

Following the insights of the Interaction Frogger Framework, it is crucial to map the six aspects of natural coupling as tightly as possible in order to utilize naturalized ways of engaging. That is, if aspects are uncoupled, the interaction is most likely to feel unnatural. Strictly following this idea would mean that, in the interaction design of the Sensible Alternative, the application icons would need to appear at the time of pushing, at the location of pushing, in the direction of pushing, and with the dynamics and expression of pushing. The tangible push would transfer over the visual modality. Even though the *dynamics, direction,* and *expression* aspects were not fully coupled in the design, i.e., they were mapped in a coherent manner in which the expression of pushing would transfer, the most uncoupled aspect was the location aspect. The *location* was coupled in the most minimal way, in that, there was only one push area on the back that was used to bring in application icons all over the screen. Theoretically, icons should have appeared at the exact location that the smartphone was pushed, but that would have required a touch-sensitive area all over the back of the phone.

Nonetheless, the uncoupled location was not perceived as such by the eighteen experts consulted in the walkthroughs (Stienstra, 2010). In other words, despite the discrepancy, the interaction did not feel unnatural. I see two reasons for this. First, *location* was not uncoupled to a great degree. The interaction took place in the hand; when the user pushed, things happened. So, even though strictly following a tight mapping is recommended, there is a little flexibility in terms of scale. As an interaction designer, it is worth considering this flexibility. In the context of the Sensible Alternative, it was sufficient to consider the hand as the means to reveal application icons, instead of the fingertip that would point to a higher resolution. Second, the mapping of the dynamic and expressive aspects overruled the discrepancy in location. The icons' emergence felt so direct and nuanced yet expressive that the user's attention was drawn to this aspect. This insight was observed when I accidently applied less expressive and direct mappings. In those situations, the location discrepancy stood out.

What happened here could be explained by the perceptual sensitivity to movement, a quality of human perception that helps people to perceive dangerous situations. In a more profound way, this perceptual sensitivity provides a basis for action, as people are more capable of perceiving change than they are at perceiving stability. The more things move, the more they stand out against a background. For example, the noise of a fridge is only witnessed when it stops and clothing only felt when it moves over the skin. In turn, people can only see because their eyes constantly move and can only feel when they move over a surface or are being moved by touch.

Dynamics and expression are strong means to draw attention, they can be utilized in design for an artefact to stand out or to suppress discrepancies of other interaction mapping aspects.

In the context of the Squeeze Me exemplar, we exploited the idea of covering up discrepancies by emphasizing the *dynamic* and *expressive* character of the robot's movements, and interface dynamics. When the user squeezed the tablet, the robot responded by moving toward the elderly person. The discrepancy here was one that concerned *time*. Despite efforts to make the robot respond as promptly as possible, it could not move until after the person squeezed the controller. This caused severe uncertainty for the users, because the delayed feedback left them unaware of what was done. To overcome this time lag, the mask on the tablet was incorporated into the design. When the tablet was squeezed to get attention from the robot, the expression of squeezing was directly mapped to the opening of the eyes of the mask, i.e., the *dynamics* and *expression* transferred to the tablet covered the delay in the robot's movement.

In terms of the Interaction Frogger Framework, the *dynamics* and *expression* aspects can be used to overrule or mask discrepancies of other aspects such as *time*, *location*.

Systemic Implementation

Both autonomous artefacts and those that are networked need to be interfaced with the world and engage with people. Behind the interface that serves as mediator between person and functionality there often lies a system architecture. So far, I have shown from a theoretical perspective how artefacts might be designed in such a way as to meet the continuous nature of human perception. Although I am not a specialist in this area, I would like to reflect on my experience as a designer in programming experienceable prototypes and my attempts to implement this continuity beyond the surface of engagement in a designerly manner.

Would it be possible in system architectures to bypass or tackle the discreteness of computing differently in or to fit the continuous of people? Because, mapping the continuous to the discrete and then back to the continuous in a feedback loop means that the richness is often reduced. That is, the expression is carried on but depreciating; it is then translated into bits and bytes and unpacked in a way that enables people to reuse it. In this process, a lot of value is lost. Moreover, it is common for the discrete of computing to generalize, categorize, and so forth; values have to be expressed in defined dimensions. From a phenomenological stance that respects the bodily skills to their full capacity, this is undesirable. Since I am doing research through experienceable prototypes, I was also confronted with the question how to push the continuity of engagement further (back) into system architectures that are mostly discrete. Being a design researcher, I am aware of my immaturity regarding system architecture, and I acknowledge the depth of the work of e.g. Brooks (1991) and Varela (1991), and their struggles in facing these issues. So, in this section I mainly reflect on my own experience during the development of the exemplars, and discuss the relation between system architecture and taking a phenomenology and ecological psychology-informed perspective.

Focus and Handling Noise

As Deckers (2013, pp. 96-97) highlights, *focus* is an essential part of achieving a perceptual crossing between designed artefacts and engaging people. Even though it is not explicitly mentioned, I observe that her approach relates to Merleau-Ponty's insight that focus is needed to distinguish other intentionalities (Abram, 1996). Moreover, focus is achieved through the dynamic sensitivity of the senses and an active approach to action-perception (i.e., if the body moves itself, it is more likely to observe other bodies standing out against a background) (Lenay, 2010). For artefacts to be able to affirm the expressive behavior of people, e.g., expressive touch or directed movement, it is relevant to apply focus. Focus is a mechanism to identify and to retain a grip on something that stands out. That is, in order to consider the person as being part of the engagement, the person needs to stand out against a background; the person needs to be recognized. In most cases, it is obvious that the person is engaging. If a button is pressed, it is most likely pressed by a person. Here, the limited action-ability constraints and allows for this recognition. This was also the case for the Sensible Alternative and Squeeze Me exemplars. In these exemplars, the action-ability of pressing or squeezing identified both the action and the interactant.

In the case of the Move Me and Sensible Door exemplars, distinguishing the person as an engaging entity had to be tackled in a different manner. With these, the sensor (arrays) considered the space and was able to distinguish a moving entity by witnessing change.

This approach was taken in the reciprocal engagements of the Move Me and the Sensible Door. In those contexts, the movements of the robot and door, respectively, gave rise to the perception of the moving person as another nexus of experience informing the artefact. The noise sensed by sensors can become meaningful when reflected in actuation. For example, the Sensible Door would open slightly when light conditions troubled the distance sensors and it wrongly perceived the presence of a person. This brought about a behavior of the door that embraced the context beyond its direct interaction with the user. In effect, this made participants feel as if they were part of a larger environment. In the context of perceptual crossing, Deckers (2013) recognizes similar effects. Positioning contextual noise as an essential element, Deckers notes, *"Contextual noise can be reflected in the perceptive activity of the artefact to create behavior that is not anticipated, but is a natural result of the context"* (p. 100). In my designed exemplars, contextual noise allowed for meaning to emerge beyond the direct engagement. Yet, in most of my endeavors, in practice, this contextual noise resulted in unpredictable behavior that swept away the user's feeling of control. Based on these experiences, I consider it relevant to promptly inform behavior with the three types of context-informers (i.e., interactivity, environment and artefact-self). Contextual noise can, however, be considered as environment/background-informer, but it is preferable to not employ it as an artefact- or interactivity-informer.

Affordance and Likelihood

In developing the Sensible Alternative and the Sensible Interface, I was challenged to develop a systemic back-bone from scratch based on continuity. The designed exemplars dealt with 'about-content' that had to be managed and connected before its meaning could be accessed. For instance, in the case of the Sensible Alternative, the applications were connected on the basis of content-types (e.g., location, time-frame, people, and so forth). The applications further developed likelihoods through use. In the case of the Sensible Interface, action-possibilities were developed out of a complex network of context-informers that revealed the likelihood of use and the relevant Gibsonian action-fit of the robot with the manipulable artefacts. In my opinion, a database in the traditional sense would not have sufficed here, as phenomenology points to relation-descriptions that are highly dynamic.

Therefore, when designing these relations, the consortium did not develop a database that would contain all relations, as could be achieved with a triplet-structured database, i.e., a database that stores relations rather than 'static values'. Instead, mathematical constructs, i.e., *likelihood* descriptors, that subscribed to context-informers were developed. These context-informers were stored as raw captured data and updated continuously, as described in the previous section. In terms of the radio-analogy Gibson makes (1966), a functionality tunes in to flows of data that are relevant. The likelihoods do not contain knowledge; they are knowing entities. Phenomenologically speaking, the structure of a likelihood attunes to the desired maximum grip, in Merleau-Pontian terms. In the context of the Sensible Alternative, the *likelihood* of a functionality was defined by the appropriateness of available and manipulable 'about-content', i.e., the content-type relation, multiplied by a weight that was informed by previous encounters. Here, the likelihood thus utilized a person's previous use patterns, yet the likelihood itself was not restructured, i.e., did not learn.

Learning Artefacts

From a phenomenological and ecological psychology perspective, learning is about attuning bodily capabilities to come to terms with what the body engages with. As illustrated in the bicycling example, cyclists adapt their skills to what is needed to keep moving and staying upright. A lot of this learning takes place in the body and is empowered by an active-perception loop. Through continuous engagement with the ground through the bike, people learn what and what not to do in order to move forward. In this process, it is not just the thinking capabilities that inform the body of what to do next. It involves an essential bodily process in which the senses and actuators tune to what is necessary. The eyes enable the cyclist to pay attention to certain qualities of the terrain; through the pedals and steering wheel, the cyclist becomes sensitive to other qualities. At the same time, the body learns on a muscular level what to do, and the cyclist learns to grasp and anticipate the *contextuality* and act upon it appropriately.

I believe that artefacts or systems can benefit from a similar structure and approach when they need to adapt to and anticipate certain behaviors by the engaging people. In what follows, I reflect on how learning on a system architectural level was incorporated into the Augmented Speed-Skate Experience, the Sensible Alternative, and the Sensible Interface, and speculate on the outcomes of a more thorough interpretation of the phenomenological insight, as explored in the Sensible Door.

Distributed Learning

In the context of the Augmented Speed-Skate Experience, learning was transferred to the athlete. It was not the system that learned from the speed-skater; it was the speed-skater who learned more about his or her own technique as unfelt 'about-content' reflected over an auditory stream, i.e., what was normally unfelt was heard and embodied in the holistic experience of the technique. The essential quality of the auditory interface was the consistency of the measurements to the auditory quality. It did not matter that the sensed pressures were not linear or even exponential (in fact, the measured values did not correspond with the actual weight on the skates, even after gauging). As long as for each value or transition the same auditory soundscape emerged, the body took care of the mapping and emergence of meaning. It is, however, useful to highlight that, in addition to a consistency of measuring (not accuracy), it is crucial to attend to the sensitivity to values of pressure that are effective in use. For example, in the Augmented Speed-Skate Experience, pressure never exceeded a certain value. It was not relevant to enable excessive amounts of pressure to take part in the mapping. Rather, the speed-skaters only exerted pressure between two values, and so it was worthwhile to give higher resolution to that sense area.

The difficulty with learning systems that intend to build behaviors based on likelihoods and related context-informers from scratch *in* interaction with people is like raising babies — so I've been told. From a theoretical perspective, this challenge might be feasible and perhaps even desired, as it would attune the system to the *unique* qualities of the engaging people. Yet, practically, it would take too much time and effort. For this reason, both the Sensible Alternative and the Sensible Interface grew out of two theoretical principles: *content-type similarities* and Gibsonian *affordance* from a robot's perspective, as elaborated in the following section.

Content-type Similarities

With the Sensible Alternative, I took a more traditional approach to learning. That is, the content-type relations functioned as the initial weight of the likelihood that application suggestions would be relevant. For instance, the Map application was easily accessible from the Weather application, as the content-type 'location' could be used, i.e., the *effectivities* of the application had an *affordance* with the 'about-content'. The weights of these likelihoods developed over time through use. If the weather application was often accessed from within the maps application, its likelihood would rise and *vice versa*. Consequently, the weather application could be accessed more easily when pressure was exerted on the touch-sensitive spot. This learning through engagement turned out to be practical, despite the fact that this dynamic was undermined by the widget-like icons that showed data beforehand. Paramount to the success of this technique was that the context-informer or 'about-content' in this case was part of the engagement. In other words, the activity that directed the increase and decrease of a likelihood, i.e., the relevancy and thus accessibility of the application, was part of the user's direct engagement with the smartphone.

Affordance based Context-informers

For the Sensible Interface, I aimed to tackle learning in a different manner. In accordance with the theoretical stance, I aimed for the action-possibilities to emerge *in* interaction. Based on the actionability of the Care-O-Bot and the artefacts in the smart environment the robot would 'figure out' whether an action was feasible and desirable. Ultimately, the Care-O-Bot would have been able to grasp this kind of *contextuality* and attune to the weight and influence of the context-informers *in* interaction. This approach was not feasible for this project, and instead the action-possibilities, their likelihoods, and the influencing context-informers were programmed statically.

A possible approach to establishing the relevancy of certain context-informers would be to take a look at the (development of) states of artefacts in the smart environment or the activity of the user. If a person would always use the Care-O-Bot to make coffee while reading a newspaper, for example, this would develop as an informer. In practice, however, such an approach would be highly problematic, as the states of some artefacts that grow to become informers may simply be irrelevant, i.e., not part of the *contextuality*. An alternative approach would be to build new action-possibilities on the basis of related action-possibilities, taking their likelihood structures as the base before the system starts to tune. Due to the limited capabilities of the Care-O-Bot the number of feasible action-possibilities was also limited. Therefore, the most effective method in the Accompany project was to develop the *likelihood* constructs by hand. The constructs of the *likelihoods* should be critically analyzed once more after they have been developed and shown to be successful.

My senses connect up with each other in the thing I perceive, or rather each perceived thing gathers my senses together in a coherent way, and it is this that enables me to experience the thing itself as a center of forces, as another nexus of experience, as an Other. **– David Abram** (1996 p. 62)

Systems Grow From a phenomenological perspective, *contextuality* is not a given, nor are the solutions that result from the phenomenological approach. Interactive and connected systems are most likely to gain functionalities, have parts replaced, learn, and so forth. In short, systems are likely to grow. This given has a multitude of consequences, as previously expressed by Frens and Overbeeke (2009). In what follows, I turn back to what I found useful when developing the designed exemplars, particularly the Sensible Door and the Sensible Interface, both of which started with the idea of infinite opportunities for action that needed to be constrained.

What is pertinent to the development of the exemplars is that I attempted to avoid predefined variables, values, properties, and so forth. In practice, this was not always possible, i.e., some variables needed to be defined in order for artefacts or hardware to communicate. Nevertheless, the exemplars contained possibilities that opened up systems for growth. In the most elementary way, I preferred to utilize globals that described qualities of a certain character (e.g., the openness of the door) to be accessed by functionalities (e.g., the opening swing of the Sensible Door) that could make use of that quality. The properties of these variables were expressed in 'floats' that would connect to the continuous and expressive-rich nature of engagement. For instance, the Sensible Door incorporated the 'crowdedness of the space' in its movement behavior[47]. The Augmented Speed-Skate Experience's auditory feedforward used the 'downward pressure' in the loudness of the soundscape. The Sensible Interface's action-possibility took certain context-informers to constitute likelihoods. What is difficult to conceptualize is that, as a designer, I am not interested in labeling the characteristics. Rather, I take the dimensions of exploration and directly use them without semantically knowing what they represent. For example, even though I was aware that I was measuring downward pressure on the speed-skate, I was unaware of what this meant from the perspective of the athlete, i.e., how to move accordingly. Once again, phenomenology embraces the rich qualities of *being-in-the-world* in a bodily manner next to a cognitive manner. It is not about categorization and acting accordingly in a scripted kind of way.

[47] The microphone would pick up noise (sound) and transmit that information to the 'resistance for opening' function. With too much or too little noise it would be difficult to enter the space and easy to leave, i.e., the noise level indicated that the space was already full enough or perfect for working in silence. An in-between sound level would make it easier for people to enter.

To me, utilizing streams of data is about taking them out of the world (choosing wisely in the dimension of action) and giving them back in such a way (continuous) that meaning can emerge *in* between person and artefact, as opposed to being defined by the artefact and perhaps misinterpreted.

Design Process Foci[48]

[48] This section is based on Stienstra, J.T., Bruns Alonso, M., Wensveen, S.A.G. & Kuenen, C.D. (2012). How to Design for Transformation of Behavior through Interactive Materiality. In *Proc. of NordiCHI'12 (pp. 21-30).* New York: ACM Press.

Even though I strongly believe in an incremental design process that leads itself from activity to activity through critical reflection, I do wish to offer three foci that support designing for respectful embodied interactions. These foci have proven to be fruitful in my work when the aim was to transform behavior, as with the Augmented Speed-Skate Experience, Squeeze Me, and Sensible Door exemplars.

Designing for the transformation of behavior can benefit from the three foci expressed through practical handles for application embedded in a design process. This approach to design builds upon the Interaction Frogger Framework that was described earlier and that will be further elaborated as a generative tool hereinafter The proposed foci utilize existing tools for understanding *contextuality*, expression, and embodied sensitivity. I here briefly introduce the foci following the two designed exemplars that incorporated two different modalities, i.e., the auditory (Augmented Speed-Skate Experience) and haptic feedforward (Sensible Door), resulting in behavioral transformation.

The first focus concentrates on the analysis of context and opportunity, the second on design mapping, and the third on detailing that mapping with a great emphasis on subtleties. In general, the three foci are applied sequentially and thus can also be seen as steps. However, the nature of design activity means that the presented foci have overlaps and occur iteratively throughout the process. Nevertheless, similar to generally accepted design processes, I separate the process here into three foci.

In the Augmented Speed-Skate Experience, the three foci appeared as followed: (a) I first analyzed the activity of speed-skating; (b) I then synthesized the design mapping between the movement and the audio to provide the athlete with meaning(less) feedforward; and finally (c) I detailed the movement sonification mapping to such an extent that it fit the perceptual-motor (including the auditory) capabilities of the athlete.

First Focus (Analyzing): Affirming and Appreciating the Current Behavior

With the purpose of transforming behavior, I take it as a given that there is a current context and behavior[49]. The first step toward transformation involves an exploration of the context by analyzing the current behavior that is to be transformed. Here, as a designer, it is essential to grasp and feel the context: the space, parameters, and essences. To achieve this, it is useful to consult experts, such as trainers, athletes, patients, physiologists, psychologists, users, and so on, as they can provide insights into the chosen behavior. During walk-throughs or interviews concerning the current behavior, insight is gained into skill levels, i.e., whether certain aspects of behavior address the physical *perceptual-motor skills*, the mental *emotional skills, cognitive skills,* and/or *social skills*.

[49] If there is no context, a designer can create the 'current context' by, for instance, placing an experienceable prototype in a context in order to reveal a new situatedness to be analyzed.

It is worth noting that people's behavior in the given context is of a continuous nature, as the way people act within the world is of a continuous quality *per se*. For this, the designer is required to develop and have a certain sensitivity toward, for example, the haptic or auditory sense.

The description of an ongoing interaction in the context of the current behavior should not be defined as discrete states, but as movements, repetitive patterns, or transitions in terms of expressions and multi-modal sensations.

I further stress the value of first-hand experience, regardless of the skill differential between the designer and the users with respect to that particular activity. It is the differences in skill levels and in points of view that can actually help the designer to identify the essential aspects of a skilled behavior. The Interaction Frogger Framework, as revised during the process of this dissertation (Stienstra, Bruns Alonso, Wensveen & Kuenen, 2012), provides a foundation for describing a continuous interaction between people and products. The framework is a powerful tool that can be used to describe the salient aspects and qualities that can transform the current behavior into a form that opens them up for designing. Therefore, the focus should be on movement, its richness, and expressive freedom.

Second Focus (Synthesis): Design Mapping for Transformation of Behavior

Once the current behavior is understood and described through the six aspects of natural coupling with all its continuity and richness *in* interaction, the designer can move on to the "behavioral transformation" part of the design approach. The designer can start to explore ways to 'color the mapping' in order to achieve the desired transformation by designing the continuous mappings that influence the behavior. Explorative and generative design tools, such as role-playing (Seland, 2006) and design movement as developed by Hummels, Overbeeke, and Klooster (2007), provide appropriate measures through which to invite particular movement.

As described earlier, directly coupling the six aspects of natural coupling exhibits a natural relationship between the input and output of the activities *in* interaction. Actions are then coupled to responses without 'coloring' them. Mapping on the other hand can be used to 'color' a certain activity. Experientially speaking, one can invite or inhibit an activity by means of amplifying or reducing the feedback of the movement (Tromp, Hekkert & Verbeek, 2011), i.e. through 'coloring'. The practical and thus design-technical terms related to this 'coloring' consider modulations of input toward the output, of actions to responses.

Designers can explore timing-related mapping, e.g., delays and anticipations. By delay, I mean that the continuous input of action has a delayed feedback. Anticipation involves the invitation to move faster by anticipating an ongoing behavior; the 'coloring' can here push forward a certain movement where delay works more as a pullback. Mappings can also be explored as scale-related mappings, such as inversions, up- or down-scaling, and other amplifications and reductions of input toward output. In effect, an input is expressed proportionally as bigger or smaller on the linear or exponential dimensions of the output in order to invite or inhibit a certain activity. An inversion, for example, implies that an upward movement input gets returned as downward output. The design exploration of the mappings should lead to a continuous action-perception loop that seems capable of transforming the current behavior into an alternative behavior.

Third Focus (Detailing): Fine-Tuning the Sensitivities in the Materiality

While the Interaction Frogger Framework can be used as a generative tool for designing for interactions that are experienced as 'natural' (Wensveen, Djajadiningrat & Overbeeke, 2004), transforming behavior using the Interaction Frogger Framework as a generative tool requires more attention to the sensitivities within the mapping.

As elaborated earlier, in the context of behavioral transformation, I aim at a ready-to-hand interaction. In order for users to remain in a ready-to-hand immersion with the product, it is essential that their attention not be diverted through disrupted behavior. Disruptions of behavior can be prevented by designing unobtrusive or subliminal mappings. This means that the mapping, as discussed in the second step, should not be noticeable in a way that the interaction becomes *present-at-hand*. To achieve this, the designer must have an in-depth understanding of and sensitivity to the chosen modality and sensorial system being addressed. Musicians and elderly people, for example, have different sensitivities to auditory information, and therefore the uniqueness of their skills and capabilities should be taken into account in the design.

Designing mappings that address people's senses in a ready-to-hand interaction requires a designer to play with subtle nuances of the input–output relation (mappings or couplings) and to pay attention to the uniqueness of users.

Informed by literature and their own sensitivities, designers can explore the subtle mapping of an in- and output that matches the sensitivities of the human *perceptual-motor* and *emotional skills*. They want to find the thresholds where one becomes aware of sensations, and the balance between just-noticeable and just-unnoticeable differences. Designing for transformation requires validation in context as well as a holistic approach. This involves the iterative making of experienceable prototypes (Hengeveld, 2011) and their evaluation in context.

Designing for this kind of subtlety takes time and effort. For the design processes related to the mapping of both the Augmented Speed-Skate Experience and the Sensible Alternative, i.e., respectively between movement and sound, and between the push and the visual appearance of icons, it took over a hundred iterations before I was satisfied as a designer. As the effects of what is aimed for are supposed to not be felt but perceived and used in the engagement of people's behavior, it is fruitful to use real-time data streams to validate the iterative design process.

In the aforementioned exemplars, I was able to develop iterations that focused on the details in the software part of the interaction loop. In the Squeeze Me exemplar, the iterative design process pointed out that the physical qualities of the design had to be addressed as well (Marti, Tittarelli, Sirizzotti & Stienstra, 2014). Subsequent improvements in this regard were managed by engineers in Siena. I highlight this to illustrate that the experienceability of the initial prototype easily convinced the people involved of the potential of the Squeeze Me exemplar, and at the same time encouraged them to make certain improvements to the quality of the experience, i.e., by improving the physical qualities that I had tended to overlook in focusing on the software part of the design. In the Sensible Door exemplar, I required an additional tool to analyze, map, and detail behavior. This is discussed in the section entitled "Designerly Handles".

Designers in action are commonly described as being intuitive or sensitive to a situation – **Erik Stolterman** (2008 p. 61)

Designerly Handles[50]

[50] This section is primarily based in Stienstra, J.T., Bogers, S.J.A. & Frens, J.W. (2015). Designerly Handles: Dynamic Tools for Interaction Designers. In *Proc. of Desform'15,* (pp.86-94).

Following Schön (1983), I see action and reflection as the designer's way of coping with complexity in the real world (Cross, 2006; Hummels & Frens, 2009; Nelson & Stolterman, 2012). I embrace designing as a skillful activity, yet I observe that the design tools and materials have changed, as the discipline faces the challenges of designing for interaction and systems. To cope with the particulars of shaping the dynamic behaviors of connected products in intelligent systems (Löwgren & Stolterman, 2004; Frens & Overbeeke, 2009), design tools and materials from other fields of expertise have been borrowed, e.g., from social sciences and engineering practices such as computer sciences (Rogers, 2004; Stolterman, 2008). However, together with these new tools and materials, the values of those particular fields have been carried over. Although such values have been successful in their own fields, they are not always compatible with those of design (Carroll, 2003; Rogers, 2004; Stolterman, 2008; Stienstra, 2015). Where traditionally the design discipline used design tools and materials that were open for interpretation, that did not prescribe but supported reflection and decision-making, the new ones ask for more definition, rigor, and pre-reflection. Moreover, whereas design acknowledges that no situation is alike and thus the design process benefits from a unique and tailored approach, the new design tools and materials are strongly generic in nature.

In this section, I propose a reconsidered use of the tools borrowed from other disciplines, not by refuting them, but by using the tools themselves as the material for design. In doing so, designers can tailor the tools to the unique needs of specific design challenges and capitalize on the designerly ways (Cross, 2006; Nelson & Stolterman, 2012) of grasping complexity by introducing the openness for interpretation. In what follows, I first introduce the notion of *pathic* understanding in order to grasp the mismatch between the borrowed tools and the needs of design.

I discuss one of my exemplars, the Sensible Door, that presented a new way of understanding the 'tools for interaction design' by seeing those tools as dynamic and contextualized design enablers. These enablers I call *designerly handles*. They are specific customized tools that serve to explore (with) the dimensions of the potential design solution. They are a mix of physical interaction possibilities interwoven with the digital backbone. After elaborating on these designerly handles, I discuss the qualities of these enablers and conclude by tying them back to the designerly take on *pathic* understanding.

Design Values, Designerly Tools

In this section, I investigate the notion of *pathic* understanding in the context of design in order to better grasp the incompatibility of the design tools borrowed from different areas of expertise.

Grasping Complexity Pathically

Designers utilize the process of making to get a grip on the complexity of the design context. They accomplish this through reflection-on-action and reflection-in-action (Schön, 1983; Cross, 2001), where the latter is not necessarily a cognitive process. Designers get in touch with the design material itself in direct interaction and are thus enabled to manipulate the form or interaction qualities without the interference of cognitive reflection; they are able to bypass the cognitive and utilize the tacit, or to be more specific, what van Manen (2007) calls their *pathic* understanding. This term furthers the concept of 'tacit knowledge' coined by Polanyi (1983), which is used to speak of the inarticulable nature of certain forms of personal knowledge. Whereas tacit knowledge has roots in silence, thus residing in an implicit–explicit dimension, *pathic* knowledge is rooted in 'feeling' and thus contrasts with the cognitive and (dia)*gnostic* aspects of bodily knowledge. *Pathic* information is that which resides or resonates in the body, in the relations with others, in the things of the world, and in people's very actions. These cannot necessarily be translated back or captured in conceptualizations and theoretical representations (van Manen, 2007). Where Polanyi describes tacit knowledge as something implicit, van Manen frames *pathic* information as a tacit knowledge to be accessed via bodily skills of doing and feeling as opposed to thinking and reflecting.

Hence, to me, *pathic skills* ***refer to how we, as users and designers, make sense of the world in relational, situational, corporeal, and actional ways as opposed to primarily*** *gnostic*, ***cognitive, intellectual, or technical ways.***

By accepting *pathic knowledge* as a form of knowledge that designers and users are able to grasp and work with *in* interaction, I acknowledge that meaning resides *in* a bodily relationship with the world and not in an abstracted, reflective relationship *per se*.

Instead of turning *pathic knowledge* into a 'determinable' realm, I depart from the idea that *pathic knowledge* and people's skills to deal with it are valuable in themselves. A common method for designers to cope with unknown yet experienced salient qualities is reduction. In other words, to get a grip on the design challenge, designers 'label' the hidden, invisible, originary, and salient aspects of meaning or qualities in the design or the engagement with it, i.e., we name things. These aspects that belong to pre-reflective phenomena are brought into view or proximity through, for example, affinity diagrams, repertory grids, and other determination methods. By reducing the user's experience with products or systems to a set of 'words', a whole realm of nuances can be lost. In other words, designers have a tendency to constrain their *pathic knowledge* through words in order to communicate and perhaps get a 'grip' on the matter. I believe that designers should be capable of transforming, manipulating, exploring, and fiddling with matter (i.e., designing) while staying within the realm of their *pathic skills*.

Mismatched Design Tools

Traditionally, designers use (physical) tools and materials that can be directly manipulated. For example, when sketching or physical modeling, designers utilize their *reflection-on-action* and *reflection-in-action* skills; they engage in a dialogue with the material through their hands. To be more specific, during the act of sketching, a line can easily be reinterpreted and redefined. The ambiguity of the sketch or the design model is a valuable resource for design (Fish & Scrivener, 1990), as it allows the designer to act upon the reflection almost immediately, offering ground for new reflection and redefinition. In other words, it allows the designer to express and to discover the desired form (Sennett, 2008).

When designing for interaction and systems, new design tools and materials for exploration have been introduced into design practice. These have been borrowed from other academic fields and rely heavily on computers and computation. I identify two problems with these tools and materials: (a) they are often abstract, closed, and reductive; and (b) they are mostly directed toward a defined prototype rather than an exploration.

Firstly, I feel the need to briefly clarify my understanding of these computer and computational tools and materials. Over three decades ago, the computer was introduced to design, first as a literal replacement for existing tools, e.g., technical drawings moved from paper to the computer, but later as a new tool for the exploration of, for instance, the interactive behavior of products, e.g., paper prototyping (Rettig, 1994) or augmenting physical models (Avrahami & Hudson, 2002; Frens, Djajadiningrat & Overbeeke, 2003; Greenberg & Fitchett, 2001). More recently, microcontroller platforms, such as Arduino, Gadgeteer, or Raspberry pi, have emerged as successful tools for the exploration of interactivity in product design.

These computers and computation techniques can be regarded not only as new tools, for example in the form of an Arduino microcontroller board, but also as new material, for example computer code as a design material that can be shaped. These new design tools and materials share the characteristics that they require discrete and defined input (Frens & Hengeveld, 2013) and are manipulated indirectly. Thus, they allow for neither ambiguity nor direct experienceable manipulation. In these tools and materials, interactivity is approached through abstraction, resulting in the richness of the physical being filtered through the limitations of the abstract. For example, developing a code to define interactive behavior requires a certain level of abstraction, structuring, and planning that poorly facilitates reflection-in-action. Possible moments of reflection are often shifted to a later stage in the design process. Only then, in being able to feel and experience, the designer's *pathic skills* come into play. All these issues are important drawbacks of those tools, as they poorly encompass the explorative qualities that I seek in design tools and materials.

Secondly, digital tools tend to facilitate the creation of defined results (e.g., prototypes that have a fixed form and implementation). In most cases, a 3D-printed prototype or uploaded programming code can only accommodate limited exploration. Fluid exploration is limited by the fact that it takes time to code, print, and redesign according to predefined measures, and this breaks the flow of designing. This limitation contrasts with the previously mentioned process of sketching and sculpting in which the making and validating take place in the hands of the designer.

These criticisms are partially sidestepped by, for example, Hartman, Abdulla, Mittal, and Klemmer (2007) who developed a programming-by-demonstration environment in which sensor inputs can be authored and mapped immediately, allowing for exploration and reflection-in-action. In this section, I present an approach that marries a similar holistic vision of designing for interaction. My aim is not to create a generic toolkit as such, but to empower the designer to simultaneously explore form and interaction within specific contexts and specific skillsets.

Opportunity I see an opportunity for digital tools to have a closer fit with the designer's idiosyncratic design process in the sense that they could better accommodate the designerly way of reflection-in-action while exploring form and interaction. In response to the criticism outlined above, I propose the development of designerly tools within the process of designing. In order for these custom designerly tools to 'speak' to the *pathic skills*, I argue that designers should capitalize on the rich expressive character of the physical while designing for the digital. For this purpose, I consider it valuable to bring digital qualities into the physical realm where the designerly skills come into play.

Design Tool Example

In order to accommodate my design process when designing intelligent products and systems, I have decided to develop my own tools that would be more suited to the fidelity of the design phase and utilize my designer's skills of feeling and grasping. In this respect, the use of the words 'tool' and 'platform' in my exemplars are slightly misleading. In this work, I do not refer to the tools and platforms as generalizable means to accomplish design activities. Instead, I propose custom enablers with designerly handles developed in context. Designerly handles are the specific customized tools that can be used to fiddle with the dimensions dealt with by the dynamic enablers (e.g., urge, power, flexibility). In the following, I elaborate on two design examples in which I developed these tools and integrated open-endedness. These examples concern the exploration of the movement of the Sensible Door for which different implementations of a trackpad as a designerly handle were investigated. As these designerly handles and modifications were designed in the process of developing the Sensible Door, I follow the descriptions with a reflection on the characteristics of these tools.

Door Movement Behavior In order to design the dynamic movement behavior of the intelligent door (Stienstra, Hengeveld & Lévy, Forthcoming), a trackpad was used to manipulate the characteristics of the movement. The Sensible Door project aimed to bring back nuanced movements that could address people's feelings when they interacted (i.e., walked through) with the door. While most automated doors function to open and close at the appropriate time, the Sensible Door aimed to do so in an appropriate manner as well, meaning that the door needed to embody behaviors of opening and closing. In effect, the door would ideally be capable of swinging gently or graciously, slamming roughly, opening curiously, and closing confidently.

While the behavior of the door had to be mapped to the behavior of interactants and the context, the exploration of the nuances was done through the use of a trackpad. The trackpad was chosen as it allowed for a variety of expressive input manners, i.e., the hand of the designer could be placed and moved in various manners. Furthermore, the software allowed for the use of real-time trackpad data, such as the location, angle, size, and major and minor axes of the fingertips touching the surface (i.e., touch-points). When designing the behavior of the door, the trackpad was utilized in two distinct manners.

The first was the employment of sense data to directly manipulate the movement of the door. In this case, the location of the first finger was mapped to the openness of the door. In an iterative process, I could control, for example, the movement of the door as a person approached the door. The initial mapping that was explored was based on the person's approaching speed: when someone walked up to the door quickly, the door would open quickly; conversely, when someone walked up to the door slowly, the door would open slowly. This easy use of opening and closing the door, and the ability to control the expression, was further used to explore whether it might be possible to persuade people to move in or out of the door by applying simple nudges and gracious swings. As these simple ideas were easily executed, the opportunities of an enriched Sensible Door were explored.

The second application of the trackpad was to combine the sense data of the Sensible Door on top of the direct control of the designer in the dimension of expression. After exploring movement-expression mappings with the direct control, several sensors were used in the mapping. A distance sensor and top-view camera were used to measure the distance and consequently the pace of the person approaching. These data were mapped to the door's speed of opening. Similarly, when a person walked through the door, the door handle could be pushed or pulled by the user. The Sensible Door could also push back or pull the person as he or she went through the door. The mapping of the door's behavior in this case was thus between sensor and actuator, whereas the sensor in the first exploration was replaced by the trackpad. The trackpad was used to manipulate the nuances in the already established mapping between sensor and actuator (i.e., the movement of the person and the movement of the door). For example, the size[51] of the designer's fingertips pressing on the trackpad influenced the resistance or friction in the mapping. When a person approached the door, the door would open easily if the trackpad was pushed gently. This indirect manner of utilizing the trackpad in the iterative design process allowed me, as behavior designer, to explore the nuances in the designed mapping in a more natural way. When a person walked through the door, the characteristics could be adjusted in real-time. This informed me about the qualities of the movement and mapping in the process of designing. It turned out that I did not have full control over the adjustments made to the mapping in the sense that I as designer could consciously predict the effects following a cause. I got a sense of and grip on how the nuanced use of the trackpad influenced the nuanced behaviors of the door through iterations that were carried out in real-time. Without conscious reduction, I was capable of utilizing my *pathic* designerly skills in sensitively attuning the behavior of the door's mappings.

[51] The size of the fingertip somehow served as functional derivative of the pressure exerted on the trackpad.

In this example, I sketched the need for specific, dynamic, and contextualized enablers for interaction design. Dynamic enablers are highly project-specific, tailored design tools and platforms that facilitate *designerly skills* in interaction design. The example focused on dynamic and expressive qualities and revealed designerly handles that utilized the openness and immediacy of exploration.

Reflection and Insights

After outlining the main characteristics of my 'designerly handles' that enable designers to use their *pathic skills* in context when designing for interaction, I elaborate upon the benefits, generalizability, and possible pitfalls of this approach (Stienstra, Bogers & Frens, 2015). Besides characterizing these designerly handles as enablers, I reflect on some particular design skills and attitudes I consider to be valuable for applying such handles.

Tuning in the Moment

A method often used to tweak or define behaviors and other interactive qualities in product and system design is to adjust the model or programming after each confrontation or validation. In other words, qualities are analyzed and adjustments are made to the source code, which will be uploaded to the device to face another confrontation that provides new insights. When we design for the interactive behaviors of products and systems, the design process benefits from the possibility of tuning the behaviors in the moment.

Exploring and Creating Nuance with the Handles

I argue that the design process could benefit from designerly handles that exploit and explore an open-ended space of possibilities. It is up to the designer to design the scope, constraints and dimensions of the exploration, yet to not fall into the trap of definition and temporal reduction. If a design concerns the expression of a product, the designer could, for example, define the landscape for exploration in terms of dimensions such as spontaneity or fluidity. Instead of defining the particular degree of spontaneity, I recommend exploring spontaneity in terms of a certain dimension (i.e., in this case a spontaneity dimension). The designer then attaches a tool to this dimension of exploration, which allows him or her to explore this aspect in context as part of the design process, similar to how the trackpad enabled the exploration of the character of the door's movement.

Arguably the easiest way to explore a dimension in a specific interaction challenge is to add a rotary or linear potentiometer to the prototype. In my view, an expressive handle needs to be as much a designed entity as the prototype under exploration. In other words, the handle needs to be contextualized so that it fits the act and form of the exploration.

Multi-Dimensionality in Handles

So far, I have positioned the dimension of exploration or creating nuance as the sole dimension to be integrated into the design tool. However, what the trackpad example shows is that the 'handles' of dimensions can be approached differently. Instead of tuning, fiddling, or exploring a single reductive dimension, multiple dimensions can be integrated at the same time. Thus, I argue for a more holistic approach in which separate dimensions are explored simultaneously by, for example, stacking or intertwining in the mapping of the dimension to the tool's action-possibilities. This created amalgam does imply ambiguity, as it would be difficult to assess what 'action' influences what dimension. Yet, while the stacked or intertwined dimensions offer the opportunity for the designer to explore over 'surfaces or blobs' instead of 'lines on a continuum', it enables the designer to explore multiple dimensions at once in a holistic manner. Furthermore, it speaks to the *pathic skills* of the designer that develop *in* interaction.

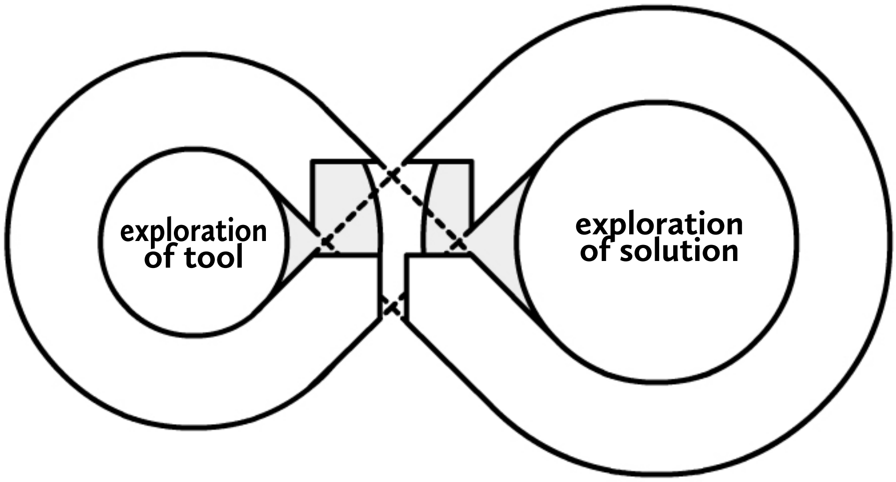


Fig 30. The Double Loop of Exploration.

Double Loop of Exploration

Bringing these points together, I introduce a continuous *double loop of exploration*. In the process that I envision, the designerly handles become part of the process of exploring the design solution, and these two explorations (i.e., the tool and the design solution) influence each other. In fact, this process could be seen as a double loop (or Mobius band) that fluently integrates these two different processes of exploration.

In the process, the understanding of how to solve the design challenge will grow together with the understanding of how to explore it. It is crucial to understand this as a 'looping' process, an iterative process. In this way, designerly handles are always a reflection of the current state of the design process, whether it is early in the design process when broad explorative qualities are needed (e.g., the door movement behavior) or later in the process to fine-tune and explore detailed dynamic qualities. Highly customizable, tailored designerly handles give us, designers, the necessary openness that allows us to explore beyond the limits of the generalized tool.

Benefits for Designing and Generalizability

Whereas current research on design prototyping tools has focused on reusable and generic tools, I propose designing highly customized and tailored explorative handles in order to empower designers to use their *pathic* skills. In the physical process of making, tools enable us, as designers, to shape a design on the fly and have a dialogue with the design matter. By contrast, making in the digital realm is currently dominated by building structured software that is disconnected from the design context. Making benefits from what these handles empower and facilitate.

Through designing highly customized explorative dynamic enablers with designerly handles, designers can regain the explorative freedom and ability to reflect, and act on their skills and design.

A critical note is that, although these custom explorative enablers are specific and therefore not generic enough to be reusable, they are the building blocks of the designerly toolkit. While they might be one-offs, they are not a waste of time. The skill that is involved in making them does carry forward. I envision designers creating their own enablers as part of their practice. A casuistic approach to disseminating these endeavors would be warmly welcomed.

Consequences for Design Skills

A consequence of what we (Stienstra, Bogers & Frens, 2015) are proposing is that designers will create very particular repertoires of tools as a result of their double-loop engagements; in a way, designers will formalize their approach to exploring certain design problems in a sort of 'frame' that carries over to new design problems. This means that not only will the approach and tools selected be quite idiosyncratic, but also there will be an inherent risk of developing blind spots because of the assumptions (e.g., the wrongly chosen dimensions) that crept in during the process of creating these tools. In light of this, picking the 'right' dimensions is a skill that needs to be developed further.

As the developing toolkit is largely individual and designer-specific (i.e., it focuses on what the designer can emphasize and benefit from personally), I see the need for a changing skill repertoire for interaction designers.

One might argue that what I propose is not a very efficient approach to creating tools, as everybody creates their own rather than using pre-made, pre-programmed solutions. I feel that what I propose is a much more effective way of opening up the solution domain of new design challenges. It allows designers to explore very specific and contextualized realms that would otherwise suffocate and be reduced by a generalized approach. As for the lack of efficiency, I feel that this is a necessary tradeoff that values quality over speed. Yet, at the same time, I feel that the tradeoff is less severe than suggested by the need to make a new tool every time a new design challenge surfaces. This is because the skill necessary to create custom exploration tools is carried forward. The approach can be applied in other design processes, and with some appropriation, the design can be prepared for a more finite version on the basis of the designed dynamic enabler and designerly handle.

Expressive Dimensions

My quest for finding 'dimensions' is particular to my work as evidenced in several exemplars. When mapping the *continuous* of being to the *discrete* of computing, I always aim to find a match between the body and the artefact or system. When addressing *perceptual-motor skills,* which is often the case with people's engagement with artefacts, I seek affordances, that is, a match between the effectivities of the body and the physical actionable-fit of the artefacts.

For example, when developing the Sensible Alternative, I used the *effectivities* of applications in how they deal with particular types of data (content-types). The robot was controlled via the *affordances* it had with its world. For the Augmented Speed-Skate Experience, I looked for a way to translate expression into a coherent auditory sound. To do so, I used the dimensions of that expression, such as pressure that transferred into loudness and balance that translated into pitch. For the Squeeze Me exemplar, the 'roughness' dimension of pressing translated into the 'roughness' of the Care-O-Bot's movement. As such, I believe that when designing for respectful embodied interactions, it is not the aim to design people's behaviors or artefacts, or for people or artefacts. Rather, that it is to design for what could emerge amidst, *in* interaction (Stienstra, 2016; Stienstra, Pul & Bruns Alonso, 2016).

Four Implications for the Design Studio[52]

[52] This part contains parts of Stienstra, J.T. (2015). Embodying Phenomenology in Interaction Design Research. *Interactions, 22(1),* 20-21.

Basically, I could 'mind my own business', drift away in poetic and embodied engagements with the artefacts I made, yet throughout the process, I was always challenged to 'come to terms' with myself and my (research) environment. It is not only the thought paradigms that pose problems for phenomenology-inspired design research, but also the available tools. In the process of designing prototypes that functioned as my physical hypotheses, it was often impossible to ignore the consequences of objectified standardization. CAD machines demand millimeters; the weight of products is expressed in grams; animations are constrained by frame rates (Hz), dimensions, and resolution; digital calendars are ruled by hours, minutes, and seconds; a good number of locations are reduced to room numbers or represented by geo locations; people are reduced to user IDs and IP addresses. The majority of sensors and actuators work according to predefined thresholds, gauging, and discretized output. In general, buttons merely accommodate on and off, servos move with predefined speed, databases expect defined objects, and camera systems provide category-recognized identifications.

In and of themselves, these are all valid characteristics of technology (i.e., the calculable properties of units and measures and the predefined, static, and reductive character of computing) used to develop functional and effective engineered solutions. However, from a phenomenological stance, they hold limited value. They are not what I am looking for. These characteristics overlook the *uniqueness of people* and their rich, expressive, and *embodied skills* that are attuned to the open and dynamic character of context. People have different bodies, beliefs, and thus action-possibilities within the world. To me, experience is pivotal, and so measurements in these dimensions are somewhat less relevant.

Whether something is far or close should not be expressed in millimeters. Phenomenologically speaking, its value ought to be expressed by its reachability from the highly subjective perspective of people.

Embodied Units

Digital sensors, as opposed to analog sensors, as well as digital actuators are often designed to function optimally with predefined protocols. Sixty-seven degrees might be the way to describe and reproduce a certain angle, but if this refers to the degree to which a door is open or closed, it is not that important. What is more important is the degree of openness in relation to the body, space, and pace of movement. I prefer to design an embodied calendar that utilizes the rising of the sun, one's hunger, and the opportunities for people to meet – not the disembodied, predefined hours and minutes fixed in timestamps.

Microsoft's Exchange, Apple's iCal, and Google's Calendar, along with paper date books, are all systems that streamline the flow of daily and business activities. But these calendars pay little attention to the notion that time as people experience and use it might actually be slightly more flexible than the predefined blocks of hours and minutes allow. Reconceptualizing hours and minutes (which I here suggest from a phenomenological perspective) has far-reaching consequences beyond the calendar. It involves a radical shift in both our thinking and the system architecture to break with these deeply rooted conventions. However, if we want to build systems that can cope with spontaneous bodily needs (e.g., going to dinner when one is hungry, waking up when one is rested, meeting up with others by chance), it might be more sensible to let people's bodies govern time, instead of the hours on the clock.

To meet the continuous nature of experience, I suggest making 'discrete' sensors 'continuized' as evidenced in several exemplars. Most 'discrete' sensors could be 'continuized' by modifying their method of data acquisition to open up to raw and continuous streams of data. For instance, the Squeeze Me pressure sensor was able to 'grasp' more of the expressive exertions when the force-sensing resistor was polled at a higher frequency compared to merely measuring on impact. However, a second quality of data acquisition that interferes with continuous experience is the common desire to gauge and bend data under some deterministic labels such as metrics. These metrics are often highly disembodied and directive. The Augmented Speed-Skate Experience's pressure measurements were gauged and expressed in kg. Yet, when the values were directly used in the feedback (forward) loop of the movement sonification, they were not used as discrete metrics. As long as the mapping was stable, i.e., for each input value a consistent output was given, the athletes were able to embody the values transposed in auditory feedforward. Moreover, the athlete did not have to worry about or engage with kgs: improving the technique is based on transition in balance.

On the actuation side of a designed artefact, actuators are also often discrete. They can be manipulated so that one perceives them as being continuous. This was accomplished in the Augmented Speed-Skate Experience's use of continuous parameter mapping instead of predefined mp3s. In addition, HUE lamps modified to work at a 20 Hz rate were connected to the Sensible Door, and the Care-O-Bot could move at a variety of paces.

Reconsidering Tools

The motor used in the Sensible Door required a certain amount of voltage to move, and it would preferably move at a suitable speed so as not to overheat. In this respect, I abused this motor by boosting it, sending commands every twenty milliseconds, and giving it power and draining it in unpredictable ways[53]. The point I am trying to raise here is that (a) hardware needs to be prepared for the continuous and expressive demands of respectful embodied interaction designs; and (b) hardware and its control mechanisms could benefit from stepping away from their standard dimensions. In other words, the motor and often the in-between motor controller required certain 'voltage' or 'speed' values that were not always compatible with the 'openness', 'smooth-swing', or 'resistance' values used in the design of the expressive Sensible Door. As such, the inherent qualities of the motor, in which speed of movement and force were highly dependent, made it difficult to directly control the motor within the dimensions of the design (i.e., making the door open slowly with a lot of force or quickly with little force).

[53] Obviously, this was done with the purpose of making users experience the Sensible Door as expressive and moody.

The designed behaviors of the Sensible Door hinged on technological feasibility in addressing an interaction paradigm suited to the continuous nature of people's experience. As noted before, from a phenomenological perspective, openness is not to be considered in terms of angles, but in terms of the degree of openness in relation to the user in order for it to be useful. Nevertheless, it is this discretizing and metric system that is embodied in the language of programming. What the work has shown me is that it is possible to make the discrete of computing perceived and appreciated as continuous. For instance, motors that demand seemingly discrete inputs can be addressed in different ways that allow for expressive swings and push or pull behaviors. As shown with the issue of resonance (Stienstra, Hengeveld & Lévy, Forthcoming), and timing appears to be of the essence in the design of action-perception loops. When designers address *contextuality* from a continuous and dynamic perspective, it is useful to consider the variables in terms of likelihoods, i.e., considering actuation or behavior from a probability perspective, instead of in terms of discrete state changes. Designing with floats instead of numbers in mind is an important step in opening up to the continuous nature of experience, i.e., in designing for behavior that feels more natural than the mere open, closed, and predefined speeds of automated doors.

The key insight here is that designing with action-perception loops does attend to overcoming the discrepancy between computational perceived discreteness and how people perceive continuously.

Designing in Context

Designing for respectful embodied interactions is inherently about people and their behaviors in the world. As such, I found it useful to design in a context where the end-user is present as well, i.e., a workstation in the actual use-context. Being part of the habitat can enable designers to be sensitive to the particularities of use that are easily overlooked from a distant design studio. I consider it key to develop iterative and flexible prototypes in context make the use consequences of the proposed design explicit. This approach acknowledges the complexity of being in the world.

To me, design is about being part of the experiential design landscape (Peeters and Megens, 2014), delivering experienceable interactive products that are used in context. To design in it (with all design tools at hand) enables designers to immediately attend and anticipate the observations that direct the design decisions.

Embracing Complexity

Systems that acknowledge a phenomenological complexity of being in the world are more likely to embrace the complexity, holisticity, and continuity of context and not follow if/then paradigms. The intertwined complexity of being and *contextuality* cannot be captured in discrete states. I believe that people do not deserve to be reduced to a mere element within a fixed chain of procedures. Their embodied capabilities should not be limited by the prescribed on/off functionalities of systems. This approach should permeate most (if not all) layers of technology. In other words, a respectful embodied approach to interaction design can benefit from the reconsideration of objective measures and numeric systems (the discrete) in order to make them compatible with the subtle subjective and ever-changing qualities of life (the continuous).

When addressing context and functionality, technologies need to be open to the spontaneous and dynamic character of being in the world. Such an openness would require sensors, actuators, and computations that do not take over the decision making, but rather allow for meaning to emerge in *continuous interaction.*

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Summary

The world we live and function in is predominantly governed by abstractions, hierarchies, generalizations, and symbolization, as seen in accounting principles, legislation, stock indexes, educational systems, and mechanisms that imply bureaucracy and control. Most of the everyday interactive products and systems we use are developed from a similar perspective that implies actions, rules, discrete representations, sequences, and hierarchies. Ubiquitous computing, connected products, and other advancements facilitate people in many ways, also to increase their efficiency. We seem often occupied with and absorbed by those technologies that are brought forward to make our lives easier and efficient. Next to hierarchical logic and lenient buttons that are found in most interaction designs, technologies seems more and more put forward to autonomously make decisions for us.

Consequently, we, as people, adapt and embody those mechanistic principles in our everyday being and begin to grow estranged from our physical relation with the world and one another. Mainstream advancements tend to overlook that we, people, are skillful beings capable of dealing with ambiguity in complex situations and that we have a rich repertoire of emotions we are able to hold, express, and fruitfully share. This dissertation promotes an alternative design approach and vision that redresses the fundamentally different nature of people and designed interactive artefacts; a movement that embraces (bodily and social) skills that seem to be forgotten in interaction design; a movement that reunites our *being-in-the-social-world* with technological advancements from a humanist stance.

Respectful embodied interactions address an often neglected mismatch between human capabilities and the capabilities of more deterministic technologies, and seeks to provide an alternative approach to designing intelligent and interactive products and systems that is anchored in a human-centric philosophy; an approach that seeks to unite the qualities of computing to the bodily capabilities of our being; an approach that makes space for the inherent and unique qualities of people in a complex social world. As such, this dissertation explores and proposes an alternative design vision that is anchored in a theory that makes the human as a holistic, skillful being its central focus. A design perspective that acknowledges a human that can *do, feel, think,* as well as *synergize with others*. With Respectful Embodied Interactions, this dissertation stages a design perspective that aspires to deliver interactive products and systems that are more appropriate to our *being-in-the-world* and to how we make sense of it; ways that are compliant with the continuous and holistic nature of our skills in their engagement in a more-than-abstracted world.

For this quest, phenomenology of perception and ecological psychology have been put forward as the theoretical anchor; as human-centric philosophies for interaction design. Phenomenology rejects the deterministic and objective approaches that overlook the ordinary, everyday experience of the world around us. Instead, phenomenology embraces the direct experience in open and dynamic environments, emphasizing that life and the world are deeply intertwined. Not unlike ecological psychology, phenomenology places emphasis on the emergence of meaning *in* interaction with a focus on the relationship between the body and the world. In effect, meaning is not something that is defined in a product or a person, moreover, it develops through bodily engagements with the world in a reciprocal manner.

Phenomenology of perception and ecological psychology, contradict with many aspects of the mainstream sciences; they approach the world and the construction of meaning through perception as *subjective, holistic,* and *dynamic* as opposed to objective, hierarchical, and deterministic. In doing so, the phenomenological perspective points to the need for both interaction aesthetics and system-level revolutionary ways of design thinking and design research in its own right. This dissertation explores the consequences of a phenomenology and ecological psychology-informed approach to designing interactive and intelligent products and systems. First, this work investigates how a phenomenology of perception and ecological psychology-informed approach to design could impact the way people engage with the designs. Second, the work illustrates how this can be applied to the design of intelligent, connected and interactive products and systems.

For a phenomenology and ecological psychology-informed design perspective, it is apparent to acknowledge that people engage with the world in an active continuous-sustained manner, that our active perception is holistic and does seek for grip, and that people are able to engage through artefacts, not just with them. It is thus worth considering that bodily meaning emerges *in* interaction constituted in-between the body and the world, as a fit between the actionable possibilities of the body and the world and that both our bodies and skills grow and depreciate through experience. For designing for respectful embodied interaction it is crucial to pay attention to that people behave intentional, i.e., we have a focused engagement, that this is highly context-dependent and that this *contextuality* is hardly determined but extremely dynamic of nature. Phenomenology acknowledges that meaning emerges against a background of past experiences, that enables us to anticipate the future, that we gear ourselves to what is most needed, and even incorporate 'other things' through which we engage. Evidently, the theories urge to centralizing people and their bodily skills in their *here-and-now* engagement within an active more-than-abstract world.

For interaction design, the phenomenology- and ecological psychology-informed idea that meaning emerges in interaction is easily misunderstood and superficially taken for granted. There is more to it than that meaning emerges somehow independent of bodily capabilities. Rather, the reciprocal and developing relation between body and the world holds a directive value for design. To turn this into a workable notion to investigate the relation between body and world – between human and technological capabilities – the work articulates previously developed frameworks on *perceptual-motor, emotional,* and *cognitive skills* in terms of their form of information, their '*about-content*'. These frameworks were extended with a fourth skill, *social skills,* a skill that unites how people affirm, appreciate or acknowledge *perceptual-motor, emotional,* and *cognitive skills* of other people and act upon them *appropriately*. Phenomenology of perception and ecological psychology place emphasis on bodily skills as the core and departure for design research and aspiration to redress the fundamentally different nature of people and designed artefacts.

The primary means to investigate the consequences of a phenomenology-inspired approach to design is through design itself; research through design. That is, knowledge about theory and practice is generated through the act of making, experiencing, and reflecting upon the results as well as the design process; an approach to design research that supports a designerly way of doing; an approach in search for its own rigor. The perspective and implications of respectful embodied interactions is iteratively developed in a process that embraces making, thinking, integrating, exploring, and validating in context; a process that seeks to flesh out implications in real, contextualized, direct, subjective experience, and use; a process grounded in subjective sensitivity that is evidently compatible with a phenomenological stance.

Part I: Departure for Interaction Design articulates the theoretical tendencies embodied in phenomenology and ecological psychology, outlines their basic implications for the design of interactive and intelligent products and systems, and stages an initial theory-informed perspective on designing for respectful embodied interactions.

Part II: Designed Exemplars treats four theory-informed design explorations and explains why they were developed, the design specifics, how people interact with them, and how they relate to the aspirations of respectful embodied interactions. First, the Augmented Speed-Skate Experience is discussed. This is a device that provides the athlete auditory information about their movement, a mapping that unites *feedback* and *feedforward* which enables speed-skaters to obtain a more thorough grip on their technique.

Second, the Sensible Alternative is discussed, an operating system for smartphones that allows people to bypass the menu structure and other hierarchies. A pressure-sensitive spot on the back of a smartphone enables people to access relevant applications as they can be pushed through the screen. In this work, bodily skills of people, and inter-relatedness of applications and their content was capitalized to emanate a context for action.

The third exemplar presented concerns a series of designs for (empathic) interaction in an independent living context. In this work, a robot serves as a supporting agent for elderly people in a smart home environment. The exemplar consists of movement behavior designs and an interface that utilizes the dynamic qualities and action-possibilities of the robot, people, and their *contextuality*. In this work, the interplay between human and technological capabilities, i.e., the robot as well as the smart environment, was used to reveal compatibility, challenge the robot's and shared *affordances*, and systemic implications in a quest to achieve empathic interaction.

The fourth and final exemplar discussed is the Sensible Door. In this project opportunities that were identified and left open by the previous exemplars were explored. In particular, the Sensible Door was developed to explore in which way several products and entities serve as one integral socio-technical ecosystem; capable of being responsive, and showing social behavior in an appropriate manner.

Part III: Annotations & Reflections clarify how the design exemplars translate into design theory and vice versa. In the first chapter, *Doing Design Research,* the work specifies and reflects upon the taken design research approach; a designerly take on research-through-design, the role of the prototype, subjective evaluation and the design researcher's attitude.

This is followed by the chapter called *Respectful Embodied Interactions*. Here the core of the contribution is reemphasized by elaborating key insights about how the exemplars are used in relation to other work and the theory. Here the term, *interactive materiality* is posed to identify characteristics embodied in the respectful embodied interaction exemplars. What Respectful Embodied Interactions are about is further articulated by comparing it to research endeavors that share aspirations such as design for natural interaction, aesthetics of interaction, embodied interaction, and ubiquitous computing.

The closing chapter, *Supportive Design Approach & Tools,* dives deeper into the tools and methods that were used, attuned, and shown to be valuable in designing the exemplars. This departs with a critical view on the mismatch between the available tools and those arguably beneficial for the development of the exemplars. Consequently, the dissertation discusses practical design approaches derived from the work and proposes *designerly handles*; tools that enable exploration and *reflection-in-action*. As such, the work concludes with practical design pointers that are useful to designing for respectful embodied interactions.

Samenvatting

De wereld die wij dagelijks beleven, wordt gedomineerd door abstractie, hiërarchie, generalisatie en symbolisatie. Domeinen als accounting, wetgeving, het beurswezen en onderwijs hangen op mechanismes van bureaucratie en controle. Maar ook buiten deze gereguleerde domeinen, namelijk in ons alledaagse leven, worden we omringd door (interactieve) artefacten die zijn ontworpen vanuit een zelfde perspectief, namelijk gebaseerd op acties, regels, discrete representatie, vaste sequenties en hiërarchieën. Dit geldt ook voor opkomende technologieën als *Ubiquitous Computing* en genetwerkte producten: veelal lijken deze gericht op dezelfde principes van efficiëntie. Het lijkt wel alsof we geabsorbeerd worden door technologieën die als enige doel hebben om ons leven gemakkelijker en efficiënter te maken. Technologieën lijken meer en meer zelfstandig beslissingen voor ons te nemen.

Dientengevolge moeten wij, mensen, ons alledaagse bestaan aanpassen aan de mechanistische principes van de technologie en raken wij vervreemd van onze fysieke, *belichaamde* relatie met de wereld en elkaar. Het lijkt wel of technologische ontwikkelingen over het hoofd zien dat mensen tot meer in staat zijn dan regels volgen, daar waar mensen van nature juist zeer bekwaam zijn in het omgaan met ambiguïteit en complexe situaties; mensen hebben een rijk repertoire aan emoties en vaardigheden die ons in staat stellen zaken vast te houden, ons uit te drukken, te delen.

Dit proefschrift bekritiseert de huidige benadering tot ontwerpen en het ontwerp en pleit voor een alternatief perspectief; een perspectief dat uitgaat van het idee dat mensen fundamenteel verschillend van aard zijn en pleit voor interactieve artefacten die hierbij aansluiten; een perspectief dat pleit voor het omarmen van (lichamelijke en sociale) vaardigheden die op dit moment lijken te zijn ondergesneeuwd binnen de *interaction design* discipline; een perspectief dat ons zijn-in-de-sociale-wereld vanuit een humanistische houding probeert te integreren in technologie.

Respectful Embodied Interactions grijpt in op een blijkbare (maar vaak genegeerde) mismatch tussen de rijkheid van menselijke vaardigheden en de meer deterministische modus operandi van technologie, en heeft als doel alternatieven aan te reiken die zijn verankerd in filosofieën waarin 'het mens-zijn' centraal staat, voor het ontwerpen van intelligente en interactieve technologieën. Respectful Embodied Interactions streeft ernaar de sterktes van computer en mens beter op elkaar af te stemmen door ruimte te maken voor de complexiteit en uniciteit die inherent is aan mensen in hun sociale wereld. Dit proefschrift beschrijft de exploratie van voorgenoemd alternatief en stelt een visie op ontwerpen voor die is verankerd in theorieën waarin de mens wordt benaderd als holistisch en bekwaam; een ontwerpvisie die ervan uitgaat dat een mens kan *doen, voelen, denken, en synergie kan ervaren met anderen*. Respectvol Embodied Interactions schetst een ontwerpperspectief dat streeft naar interactieve producten en systemen die uitgaan van ons zijn-in-de-wereld en hoe zijn-in-de-wereld ons in staat stelt betekenis te geven aan de wereld: namelijk op een continue, holistische en concrete wijze.

Dit onderzoek bouwt grotendeels op de filosofische stroming van de Fenomenologie, en op Ecologische Psychologie. Kort gezegd zet fenomenologie zich af tegen de meer deterministische, objectieve filosofieën die—in de ogen van fenomenologen—geen aandacht hebben voor onze alledaagse beleving van de wereld om ons heen. In

tegenstelling tot andere filosofieën omarmt fenomenologie directe ervaring in open en dynamische omgevingen, en benadrukt dat leven en wereld volledig verweven zijn. Zowel fenomenologie als ecologische psychologie gaan ervanuit dat de betekenis van de wereld ontstaat *in* interactie met de wereld, en stellen de relatie tussen wereld en lichaam centraal. Dit betekent dat de betekenis van iets niet gevangen is (of te ontwerpen is) in de persoon of het object, maar ontstaat als gevolg van de wederkerige relatie tussen de twee.

Zowel fenomenologie als ecologische psychologie wijken op enkele punten af van de meer *mainstream* wetenschapsbenaderingen. Fenomenologie en ecologische psychologie benaderen wereld en betekenisvorming als *subjectief, holistisch* en *dynamisch*, waar de meer traditionele benaderingen uitgaan van objectiviteit, hiërarchie en determinisme. Dientengevolge lijkt een fenomenologische benadering tot het ontwerpen een andere esthetiek en systeembenadering te vergen, en daarmee een radicaal andere manier van het denken over en doen van ontwerponderzoek. Dit proefschrift exploreert de gevolgen van het nemen van een fenomenologie dan wel ecologische psychologie benadering tot het ontwerpen van interactieve en intelligente producten en systemen op twee aspecten: ten eerste onderzoekt dit werk de impact op de manier waarop mensen met 'fenomenologie geïnspireerde' ontwerpen omgaan; ten tweede, illustreert het werk hoe voorgenoemde benadering kan worden toegepast op het ontwerpen van intelligente, genetwerkte en interactieve producten en systemen.

Voor het nemen van voorgenoemde benadering tot het ontwerpen is het essentieel om te accepteren (1) dat mensen op een actieve en continue manier met de wereld om hen heen omgaan; (2) dat onze actieve perceptie holistisch is en continue op zoek naar 'grip' op de wereld; (3) en dat mensen in staat zijn om *via* artefacten te handelen in/op de wereld, en dat onze actie niet bij het artefact zelf ophoudt. Dientengevolge is het belangrijk te realiseren dat ons begrip en onze handelingen worden gevormd *in* interactie met de wereld, zowel progressief als degressief. Voor het ontwerpen van Respectful Embodied Interactions is het dan ook cruciaal om aandacht te houden voor de intentionaliteit van het menselijk handelen: mensen handelen met een gefocuste betrokkenheid, op een contextafhankelijke wijze, waarbij de context ook nog eens dynamisch en veranderlijk is. Fenomenologie gaat er bovendien vanuit dat betekenis mede wordt gevormd door eerdere ervaringen, hetgeen ons in staat stelt te anticiperen op de toekomst, ons voor te bereiden op toekomstige behoeftes en zelfs om 'andere dingen' te betrekken in ons (toekomstig) handelen. Kortom, fenomenologie en ecologische psychologie vergen een houding waarin de belichaamde mens centraal staat, in een wereld die actief en *hier-en-nu* wordt beleefd voorbij abstractie.

Voor het ontwerpen betekent dit dat de ontwikkeling van betekenis op basis van de wederkerige relatie tussen wereld en lichaam leidend moet zijn, waar dit begrip vaak met enige nonchalance wordt benaderd. In dit proefschrift wordt gepoogd dit begrip werkbaar te maken voor ontwerpers door aan te sluiten bij bestaande *frameworks* die helpen bij het beschouwen van de lichaam-wereld-relatie, met name de technische wereld. We sluiten aan bij *frameworks* die uitgaan van menselijke vaardigheden—*perceptueel-motorisch, emotioneel* en *cognitief*—en hoe deze ons informeren. In dit proefschrift introduceer ik in deze context de term '*about-content*'. Voorgenoemde drie vaardigheden worden in dit proefschrift aangevuld met een vierde vaardigheid, namelijk de *sociale vaardigheid* die ons in staat stelt de andere drie vaardigheden te (h)erkennen en er passend op te handelen. Vanuit een fenomenologisch ontwerpperspectief bieden deze menselijke, belichaamde vaardigheden een lens voor het beschouwen van de balans van menseigenschappen en artefacteigenschappen.

De primaire manier om onderzoek te doen naar de consequenties van een andere ontwerpbenadering is via het ontwerpen zelf; door het doen van *research-through-design*. Deze onderzoeksbenadering gaat ervanuit dat kennis over ontwerptheorie en – praktijk gegenereerd wordt door middel van het ontwerpen, ervaren en evalueren van ontwerpen. Met andere woorden, het is een benadering die ontwerpers in staat stelt onderzoek te doen op een ontwerpende manier. Zo wordt in dit proefschrift op een iteratieve manier geschaafd aan het theoretisch alswel praktisch inzicht in Respectful Embodied Interaction.

De structuur van dit proefschrift is als volgt.

In *Deel I: Departure for Interaction Design* wordt ten eerste ingegaan op de onderliggende theorie. De kern van fenomenologie en ecologische psychologie worden uitgebreid behandeld, alsmede de basale implicaties van deze theorieën voor het ontwerpen van intelligente of interactieve producten en systemen. Deel I schetst als zodanig het toneel voor het gedane onderzoek.

Deel II: Designed Exemplars gaat in op vier theorie-geïnformeerde ontwerpexploraties en beschrijft waarom ze werden ontwikkeld, gaat in op ontwerpdetails, op hoe mensen met de ontwerpen omgingen, en hoe de ontwerpen zich verhouden tot de ambities van Respectful Embodied Interactions. Eerst wordt de Augmented Speed-Skate Experience besproken, een ontwerp dat schaatsers auditieve informatie geeft over hun schaatsbewegingen. De auditieve mapping van *feedback* en *feedforward* stelt de Augmented Speed Skate Experience schaatsers in staat om meer grip te krijgen op hun schaatstechniek.

Het tweede ontwerp dat wordt besproken is The Sensible Alternative, een smartphone besturingssysteem dat mensen in staat stelt om de menustructuur en andere hiërarchieën van de telefoon te omzeilen. Een drukgevoelig punt op de achterkant van de telefoon stelt mensen in staat om naar relevante toepassingen te navigeren door ze 'naar voren te drukken'. In dit werk is geprobeerd om krachtiger gebruik te maken van onze menselijke, lichamelijke vaardigheden en van de onderlinge, contextuele relatie tussen individuele smartphone applicaties.

De derde ontwerpexploratie betreft een serie ontwerpen voor (empathische) interactie in een semi-zelfstandige wooncontext voor ouderen. In alle ontwerpen wordt de context gevormd door een robot die optreedt als ouderenhulp, en een oudere. De ontwerpexploraties betroffen bewegings- en gedragsontwerpen van de robot, alsmede diverse interface-ontwerpen, gebaseerd op de contextuele dynamiek en actiemogelijkheden tussen robot en oudere. Deze wisselwerking tussen menselijke en technologische mogelijkheden heeft diverse inzichten opgeleverd, onder andere op het gebied van compatibiliteit, *affordances,* en systemische consequenties.

Het vierde en laatste ontwerp dat wordt besproken is de Sensible Door. Het doel van deze vierde ontwerpexploratie was het onderzoeken van kansen die werden geïdentificeerd in de drie andere exploraties. De Sensible Door was met name gefocust op het ontdekken hoe meerdere producten en mensen kunnen optreden als één integraal sociaal-technisch ecosysteem.

Deel III: Annotations & Reflections gaat in op hoe de ontwerpen uit Deel II zich vertalen in ontwerptheorie, en *vice versa* hoe ontwerptheorie de ontwerpen heeft geïnformeerd. Het eerste hoofdstuk van Deel III, *Doing Design Research,* gaat in op de genomen benadering, op *research-through-design*, op de rol van prototypes, op subjectieve evaluatie en op de houding van de ontwerponderzoeker.

Het hoofdstuk erna, *Respectful Embodied Interactions,* gaat nogmaals in op de kernbijdrage van dit onderzoek. Er wordt uitgebreider stilgestaan bij de meest prominente inzichten van de ontwerpvoorbeelden uit Deel II in relatie tot ander werk en de onderliggende theorie. In dit hoofdstuk wordt de term '*interactive materiality*' geïntroduceerd. Het idee Respectful Embodied Interactions wordt verder uitgewerkt, en vergeleken met soortgelijke ontwerpbenaderingen zoals *natural interaction*, *aesthetics of interaction, embodied interaction,* en *ubiquitous computing.*

Het laatste hoofdstuk, *Supportive Design Approach & Tools,* gaat in op de middelen en methodes die zijn gebruikt, aangepast en die waardevol zijn gebleken tijdens dit onderzoek. Het hoofdstuk vertrekt vanuit kritiek op bestaande middelen en methodes, om vervolgens in te gaan op praktische wendingen. Deze worden gepresenteerd als *designerly handles*, ontwerphulpmiddelen voor exploratie en *reflection-in-action*. Het proefschrift besluit met praktische ontwerptips voor het ontwerpen van Respectful Embodied Interactions.

Curriculum Vitae

Jelle Stienstra was born in Groningen, the Netherlands on the 24th of May 1985. He obtained his VWO diploma at the 'Zuyderzee College' in Emmeloord and subsequently studied Industrial Design at Eindhoven University of Technology. In 2010 he received his Master's degree with honours for his graduation project entitled "The Sensible Alternative, Associative Navigation Interaction", in which he developed an alternative operating system for smartphones. Two years after design consultancy at his own design firm, Jelle started his doctoral studies at the Designing Quality in Interaction group at Eindhoven University of Technology in collaboration with the Social, Political and Cognitive Sciences Department at the University of Siena (UNISI). His research focuses on developing a phenomenology- inspired approach to designing intelligent products and systems.

As part of the "Future of the Kitchen" project commissioned by IKEA of Sweden AB, he directed several student projects and modules within the Department of Industrial Design at Eindhoven University of Technology and the Institute of Humanities, Arts and Sciences at the Federal University of Bahia (UFBA) in Brazil.

After briefly holding a position as assistant professor *design for interaction* at University of Twente, Jelle is currently appointed by the creative commerce team of Amsterdam-based digital accelerator NEWCRAFT.