Touching Our Breathing through Shape-Change: Monster, Organic Other, or Twisted Mirror

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We report on a soma design process, where we designed a novel shape-changing garment—the Soma Corset. The corset integrates sensing and actuation around the torso in tight interaction loops. The design process revealed how boundaries between the garment and the wearer can become blurred, leading to three flavours of cyborg relations. First, through the lens of the monster, we articulate how the wearer can adopt or reject the garment, resulting in either harmonious or disconcerting experiences of touch. Second, it can be experienced as an organic "other"-with its own agency-resulting in uncanny experiences of touch. Through mirroring the wearer's breathing, the garment can also be experienced as a twisted version of one's own body. We suggest that a gradual sensitisation of designers-through soma design and reflection on the emerging human-technology relations-may serve as a pathway for uncovering and articulating novel, machine-like, digital touch experiences.

CCS Concepts: • **Human-centered computing → Interaction design process and methods;**

Additional Key Words and Phrases: Digital touch, breathing patterns, uncanny experiences, soma design

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1 INTRODUCTION

Touch has a deep emotional and psychological significance; it is one of the underpinning experiences central to all areas of human development [71]. In a survey on the expectations on the *Internet*

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of Senses done by Ericsson, six out of ten surveyees believe that by 2030 we will be able to mediate the feeling of almost anything, from something as simple as a ball to the skin of another person, including experiential aspects such as texture, heat, weight, or motion [17]. Recent developments in shape-changing materials with the ability to self-modify their physical properties-their shape, colour, stiffness, temperature, or texture-allow for shaping novel types of actuation that can act in response to our bodily rhythms, movements, or biochemical changes on or inside bodies [61, 75], thereby creating touch-based interactions that unfold and proactively adapt over time. However, research on digital touch has been focused mainly on communicative purposes, where touch is used to mediate presence or connection between people, serving as a way to communicate emotions. Some believe that these materials can finally enable us to more closely replicate or mediate the types of human interpersonal touches that we are able to experience in our everyday lives. Here, we approach digital touch from a different starting point by exploring novel experiences, novel types of hybrid touch, and not necessarily mediating or mirroring human touch.

Exploring this design space requires a deep, well-grounded understanding of human morphology and meaning-making processes [2, 3, 21, 25]. Methodologically, we have a long-standing commitment to *soma design* [37, 40, 41]. This design stance entails a shift from the contemporary predominantly symbolic, language-oriented stance in interaction design, to an experiential, felt, aesthetic stance permeating the whole design and use cycle. It often entails a strong first-person experience throughout the design work [39]. In this particular design process, we engaged with shape-changing actuation around the torso, and how it can be coupled to breathing. There is already plenty of design work on breathing interactions reported in HCI, such as [9, 12, 14, 69, 74, 99]. Most of it focuses on sensing breathing and then visualising or showing various measurements of it [13, 32, 60, 83, 89], or attempts to use shape-change to provide breathing feedback on the torso [15, 49, 94]. What we came to uncover through our felt soma design process was a whole range of digital touch experiences that did not mirror human–human touch nor human–object touch. Rather, our design process and development of the Soma Corset transgressed such boundaries, allowing us to reflect on what is inside vs. outside of our bodies, what makes us perceive the system as a *monster* vs. what might let us feel "as one" with it—embodied or entangled with it—as well as what makes the system turn into a lifelike *organic other*, or a *twisted mirror* of ourselves.

As a main contribution, we draw on our design explorations to articulate and theoretically position novel types of hybrid touch that combine the physical and felt experience of touching and being touched by digital materials. We show how these materials can be perceived as different types of touch, depending on different bodies and past lived experiences. As a methodological contribution, we show that it is not enough to know our human morphology or work hard to mirror-in a "one-to-one manner"-objects from the real world. Similar to how there is nothing *natural* in natural user interfaces [63], our design process shows how digital touch needs to be carefully crafted to make sense. Furthermore-and perhaps more importantly-we show how digital touch can go beyond mirroring human–human or human–object touch to instead let designers gradually orient themselves towards exploiting the affordances of novel types of haptic and shape-changing technologies enabling other engagements and entirely novel experiences. By doing so, we also contribute to an expanded understanding of touch communication between individuals and shape-changing materials. Rather than articulating touch as an interaction between separate entities with fixed boundaries [15, 78, 94], we instead consider novel experiences of touch that start from the notion of entanglement of humans and technologies [23, 102], akin to correspondence relationships [44] or intra-actions [6], where the technologies are perceived more as an extension of the body than as a separate entity or communication counterpart [37]. We found that the perception of boundaries between human bodies and materials, as well as the perception of who is touching and being touched, was useful to guide the design of wearables for both becoming

aware of and altering somatic experiences. We further suggest that the exploration of uncomfortable interactions and frictions through soma design and a post-phenomenological analytical lens can useful to probe the limits of touch, and can come to know and understand what is possible, desirable or undesirable, and under which circumstances.

2 RELATED WORK

2.1 Soma Design

Theoretically, we build on Soma Design which is a design stance grounded in evolutionary biological models of human morphology [84, 85] as well as theories pertaining to aesthetics, or more precisely, somaesthetics [86]. Somaesthetics is a term that combines *soma*—our non-dualistic subjective self, body, emotions, and thinking—and *aesthetics*—as in our ability to perceptually appreciate the world around us and what we feel, hear, see, and engage with. Somaesthetics is a pragmatist philosophy, which means that it is not solely a theoretical stance, but also a pragmatic, analytical, and practical endeavour and—when applied to design—has turned out to be a highly generative design framework.

The soma design framework starts from the position that human intelligence is enacted in action [27, 28, 44, 92]. That is, although we approach situations with previously learned behavioural patterns or instinctive behaviours, we always adjust them dynamically to fit the situation at hand. Intelligence in action is strongly tied to the movements of our bodies, which is where meaning-making arises. By deepening our aesthetic awareness of our own proprioceptive and sensual bodily engagements with the world, we enable training intelligence, meaning-making and a richer, deeper engagement with ourselves, with one-another and with the world.

Beyond providing a firm grounding in human morphology and somaesthetic appreciation ideals, the *soma design* framework adds an active and creative design attitude [37]. The fundamental promise of soma design is that if designers train their own somaesthetic sensibilities, as well as engaging in form-giving processes, gaining tacit, and felt knowledge of the technological materials at hand, they can learn how to better shape the somaesthetics of the resulting interaction gestalt. When we hone and care for aesthetic qualities of the technologies we use to construct our interactions and when we attend to our own experiences, the designs we bring forth will orchestrate experiences that in turn spur improved aesthetic skills in users.

Soma design relies on first-person methods, sometimes engaging in what has been framed as autobiographical design processes. Neustaedter and Sengers define such design processes as "*design research drawing on extensive, genuine usage by those creating or building the system*" [62]. This can be contrasted with user-centered design which is traditionally undertaken from a third-person perspective reliant on observing, interviewing, and testing on users. While it will always be important to bring in users at some point, soma designers argue that bodily-based interactions—e.g., relying on biosensors, **Internet of Things** (**IoT**), wearable technologies, as well as considering long-term adaptive interactions—will all require designers to adopt methods that help close the loop between design and user experience [29, 37, 39, 41]. Autobiographical and first-person methodologies [39] use the designer's lived body as a resource for design, e.g., the body through which, according to Merleau-Ponty [58], we live and experience the world. As designers, we close the loop between technologies and experiences by engaging deeply with, and even changing our own ways of perceiving and being in the world. This said, there are of course possible disadvantages of first-person methodologies, including a tendency to lack proof of generalisability. However, a counterargument is that autobiographical design will instead introduce an "ethics of self-use" [62], a reflective conversation with materials, and a careful articulation of the implications of the design decisions we make—which can be deeply felt in our own bodies.

In a sense, as designers we leave behind a set of "sedimented movements" [18] embedded in the particulars of the designed system that will literally shape users' somas; changing muscles, nervous system reactions, behaviours, experiences, and feelings, and influencing users' capacity for aesthetic appreciation. Hence, when designing, the "materia" being shaped is both the hybrid digital/physical technology, but also the users' somatic selves. Both are subject to change. This provides a paradigm shift for wearable technology to not only learn and adjust to how users change, but also to proactively encourage interactions that may lead to a deepened somaesthetic appreciation and indeed, somatic change.

2.2 Digital Touch

Digital touch goes beyond the mechanics of haptics, emphasising the sociality of touch through mediating technologies [47]. Here Jewitt and colleagues offer a rich and nuanced interpretation of touching as "ways of being" in the world. Rather than a simple physiological act of sensing and perceiving, they draw explicitly on feminist literature to articulate the lived, social body as a site of meaning-making, and the skin as both the boundary between and a point of connection with others. For the purpose of this article, we will use a broader definition of digital touch: touching or being touched by a technology somewhere on your body and—in the case of communicative technologies—in such a way that it forms the basis of meaning-making [73]. Though this extensive, interdisciplinary field defies easy summation, a recent review of the state of the art of digital touch communication [47] reveals that the field has predominantly focused on communicative purposes or is aimed at capturing and replicating the qualities of human touch. There exists a vast body of research on the physiology behind touch perception [21], as well as cultural, historical, and philosophical connotations entangled with it [2, 3, 25]. In this article, we will not engage heavily with this strand of work, but focus on the felt experience and meaning-making from the interaction designers' perspective.

Engaging with the felt experience of touching and being touched, both by humans and machines, is one viable path to understanding the semantics of digital touch [39]. Such research has enriched our understanding through, for example, identifying linguistic terms to convey tactile sensitivities [31, 45], or meaningful terminology to describe haptic stimuli [68] which in turn informs the development of haptic technologies. Other approaches include turning to music to try to express the dimensions of tactile experience [19]. Yet more work focuses solely on a single dimension of tactile experience, such as its pleasantness [55] or transparency [57].

There have also been attempts toward capturing the qualities of human touch, including mimicking common interpersonal touch experiences through context and haptic actuation. Projects such as Huggy Pajama [94] and The Hug [15] convey the sensation of hugging, whilst YourGloves, HotHands and HotMit [30] replicate the feeling of holding hands over distance via movement and heat. Another example is Kissenger, which provides a physical interface for transmitting a "kis" via force sensors and linear actuators [78]. However, these works seek to replicate the familiar qualities of *human-like* touch, leaving possible novel experiences using the distinct qualities of *machine-like* touch under-explored.

As engaging meaningfully with the senses beyond sight and sound is brought to the fore in HCI [64], researchers, designers, and artists have moved into the landscape of novel digital touch applications and have sought to understand the implications of technologies that utilise our most intimate sense. One example is Soft(n), an interactive art exhibition designed around the concept of somaesthetics [80]. The installation encourages expressive interaction through tactile exploration of soft sculptures incorporating light, sounds, and vibration. In this case, the felt experience of engaging with the artwork is critical to understanding the sensory aesthetics of the interaction. Tendrils is another responsive kinetic wearable comprised of soft-circuits, lights, and motors that

respond to collective touch [81]. Again, the felt experience of engaging with the wearable or touchable artwork helps sharpen our sensory capabilities and explore the materiality of the artefact and in turn, our own body.

Hoybe's Mediated Body is a unique performative touch-based interaction [35]. A Performer, wearing a specially designed Suit, and a Participant engage in social play while both wearing a pair of connected headphones. When they touch each other's bare skin, this triggers a sound pattern that only the players can hear. This technology provided rich insights into touch as an aspect of performative immersion and emergent meaning-making, whilst facilitating an intense digitally augmented touch experience. When deployed at the Burning Man festival, the Performer said, "*Isn't it beautiful: meet a stranger, have 3 minutes of the most intense experience of intimacy and exploration, and then leave as strangers but connected [by virtue of] a common experience*" [35]. This project also shows how the qualities of novel touch experiences—in this case augmented by a machine—can foster powerful experiences and relationships between people with and through technology.

Beyond vibrational or haptic actuators, we are interested in other forms of actuation to help develop the repository of sensations that designers can employ. Relevant work in this direction includes: Force Jacket, a full-torso wearable comprised an array of pneumatically actuated inflatables designed to utilise pressure in immersive virtual reality experiences [11]; He et al.'s pneumatically-actuated arm-worn haptic interface capable of tapping, holding, and tracing [34]; Mommy Tummy uses compressed air and water actuation to simulate the experience of being pregnant, through feeling the fetal weight and movement [54]; and Takahashi et al.'s Sense-Roid Type-S, a wearable pneumatic vest made of interwoven artificial muscles and air-filled balloons that can sense and actuate force upon the body [93]. These design exemplars employ different forms of actuation, resulting in new, distinct qualities for digital touch, essential to exploring what machine-like touch–not human-like touch–could bring to the table.

2.3 Breathing in HCI

Our work explores digital touch in connection with breathing. A growing body of research in HCI focuses on designing interactive systems to extend breathing awareness. Prpa and colleagues [74] provide a literature study of the underlying theoretical frameworks and design strategies used in breathing-based interactions. They show how systems can take the form of: art installations aiming to improve the aesthetic appreciation of breathing [52]; medical applications guiding users to perform breathing exercises for therapeutic reasons [1]; biofeedback meant to help users breathe using the diaphragm [24, 99]; or interface controllers that pick up on breathing to create immersive game experiences [8, 109]. Many of these systems capture breathing data and translate it into sensory stimuli to externalise breathing, making it visually or tangibly accessible to users. The aim can be to create immersive virtual and physical environments for engaging with breathing as practiced in yoga, Feldenkrais, and other body practices [60, 70, 83, 90, 103]. Some explicitly aim to trigger physiological responses related to alleviating stress and anxiety by slowing the breathing rate [9, 69, 99], whilst others utilise breathing patterns to promote mindfulness [13, 53] and develop a sustained attention towards bodily sensations, where users gradually learn to discern nuances of the felt experience of breathing.

Many breathing awareness systems use visual modalities to communicate breathing to users. Some may use zoomorphic animations, where breathing is mapped to movements in fish [89] or jellyfish [13]. Visual feedback can be displayed in media such as desktop screens, mobile screens or virtual reality; and even tangible shape-changing structures in the environment [60]. Auditory feedback is also a common output modality. Some systems use voice to guide breathing exercises [83], manipulate parameters such as volume or reverb in existing soundscapes [32], or simply

amplify user's breathing sounds [72]. Many systems use multimodal visual and auditory feedback [26] to create more rich and immersive feedback experiences.

Tactile actuation also appears in some of these applications but is less common than other modalities. There are examples of using vibrotactile actuators such as in the work by Bumatay and Seo, [9] who developed mobile technologies for mindfulness and meditation, and found that haptic stimulation through vibration pulses in a pillow harmonised with auditory cues for guiding users towards relaxed breathing patterns. After using the tactile pillow, users reported different associations such as a cat purring, a heartbeat (seen as positive) or a cellphone vibration (perceived as negative). Dijk and Weffers [14] combined light and auditory output with a vibration matrix in the form of a blanket that created a "haptic wave" spanning the whole body from the bottom to the top of the blanket, synchronised with breathing. The multimodal experience was reported as being very positive, creating a sense of immersion.

In another strand of our work [49], we explored what **deep touch pressure** (**DTP**) can render in regards to breathing awareness when applying pressure in opposition to or in synchrony with the breathing rhythm, providing initial modes of actuation and the beginning of material explorations that were later developed as the interactions we present here. Like ours, other systems make use of shape changing materials around the torso. For example, Hu and colleagues [108] propose shape-changing inflatable interfaces as "natural mappings" of breathing as it affects the lungs and the torso. Foo and colleagues [22] noted that rhythmic pulsing compression applied on the torso showed potential to improve focused attention on breathing and helped to adopt a slower breathing rhythm, making it an interesting option for further exploration. Further work in shape-changing wearable interfaces that utilise breathing as an input, yet not explicitly examining the felt experience of touch or of materials used, include an interactive corset by Giulia Tomasello [76], a series of kinetic clothes by Ohkubo et al. [66] and a foldable origami-style dress by Ying Gao [22].

In our research, we were particularly interested in exploring the relationship between the user and their breathing through touching shape-changing materials. In this vein, Aslan and colleagues [5] designed plush toys for children that follow their breathing and change shape through servo motors, making them change shape and breathe in synchrony with the user. They discuss the danger of designing tangible interactions that externalise breathing to an artefact vs. representing breathing in a way that is perceived as inside the users' own body. Schiphorst [79] also explores this inside/outside dichotomy with different ways of actuating tactile actuators in clothing and in the environment to explore physiological data such as breathing with multiple participants in installations. This is achieved through vibrating matrices embedded in clothes and wind–generated by fans in the environment–combined with other actuators such as light and sound, resulting in playful interactions that stimulate the participants to explore theirs and other participants breathing. Earlier, we conducted a design exploration [96] of sensing mechanisms for capturing breathing through volumetric changes in the torso and muscle contractions. That design exploration culminated in the understanding that the wearer could establish a reciprocal experience of "feeling the sensor feeling you" when breathing with shape-changing biosensors. The design we present here builds on these insights and goes a step further by implementing tight interactive cycles of sensing and actuation, also combining with findings from how to design actuation inspired by deep touch therapy [49]. The result, explored through interacting with the Soma Corset, is a deeper articulation of human-technology relations between the wearer and the system.

2.4 Postphenomenology in HCI

Later in this article, we will draw on postphenomenological thinking as we turn to analysing our long engagement with the Soma Corset. It is important to note that we did not initially set out

to undertake a postphenomenological enquiry. Instead our starting point was the somaesthetic theories of body awareness and appreciation as guiding designing aims. However, as the project progressed, we sought theoretical positions to help understand the multiplicity of our relationships to and with this artefact. Postphenomenology, an approach in the philosophy of technology, aims to help study the relations between humans and technology, in particular the ways each helps shape the other and constitute different understandings of the world [42, 77, 102].

The original four human technology relations theorised by Ihde were: *embodiment* relations: occurring when technologies are perceived as forming a unity with the user and where the technology becomes transparent; *alterity* relations: covers situations where users interact with technologies that are perceived as an other; *hermeneutic* relations: occurs when users are directed at how technologies represent the world; and finally, *background* relations take place when technologies act as a form of context in the background of human actions, without offering direct contact or awareness of the technology as such [42]. Ihde did not see these relations as mutually exclusive, but instead spoke of *multistability*, that is: *"any technology can be put to multiple purposes and can be meaningful in different ways to different users"* [77]; just like a Necker cube visual illusion can be seen and interpreted in more than one way [43].

These original postphenomenological relations aimed to describe direct relations with technology. However, as technology becomes more and more integrated with everyday activities or become invisible to users, these descriptions are not sufficient to account for the myriad ways that we interact–not only with each other but also with the world–through and with technology. In particular, the relations have been expanded to account for how human intentionality can be partly constituted by technology, and vice-versa, giving rise to more complex cyborg relations [77]. These hybrid forms of intentionality, where humans and machines fuse, can be: to *combine* their intentionalities to make visible new realities; to *augment* intentionality in how humans experience the world through technology; or opening new paths for humans to experience how a technology "experiences" them, establishing *reflexive* intentionality.

The postphenomenological framework has been influential in HCI in recent years, as a way of exploring people's relationship to novel technologies and even as a generative tool for design [20, 46, 65, 67, 97]. Examples of such investigations include the Tilting Bowl, table-non-table, and Morse Things. The Tilting Bowl, a counterfactual artefact, discusses how postphenomenology can enhance our philosophical understanding of digital artefacts in the home [105]. Similarly, table-non-table–another counterfactual artefact and material speculation–explores participant relations to novel technologies beyond use or functionality [33]. Morse Things–a thing-centred material speculation–also uses postphenomenological relations to reflect on new types of technologies in the home, such as IoT and other interconnected artefacts that may withdraw from human understanding [104]. Of particular relevance to us is when postphenomenological approaches are applied to the design of wearable technology. Van Dongen and colleagues [98] show how such an approach may shift the understanding of technology from functional and instrumental purposes towards seeing it as media with materiality and context, thus facilitating the integration of digital technologies into everyday life. As we will discuss below, these postphenomenological relations shed light on the different experiences we had with the Soma Corset during our design work. They helped us discern and further explore relationships that went beyond our initial design ideas.

3 THE SOMA CORSET WEARABLE PROTOTYPE

To make the description of our project easier to follow, we will now turn to and present the most recent iteration of the Soma Corset in the still on-going design project. In its current incarnation the corset is a medium fidelity prototype of a wearable device with shape-changing actuation aimed at increasing our breathing awareness, expanding on the repertory of breathing patterns

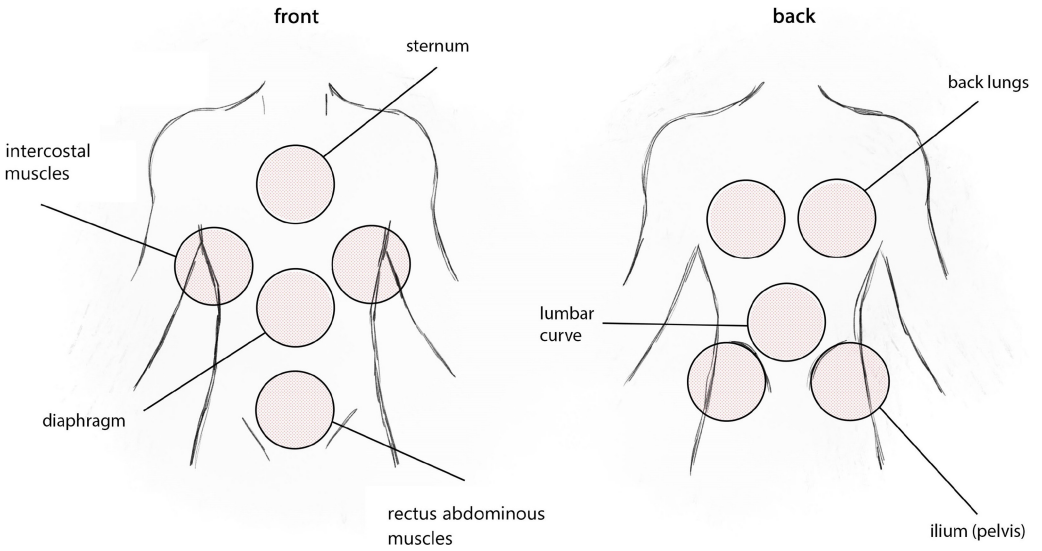

Fig. 1. Muscles/areas involved in the exercises.

we have at our disposal, and even disrupting the habitual process of breathing [96]. It consists of ten shape-changing sensor-actuator pillows, placed on top of the muscles/areas on the torso depicted in Figure 1 and an external rigid wearable structure that holds the pillows close to the body (Figure 4). The corset iteration we present here offers four different interactions in the form of breathing exercises (further described in Section 3.4 below), that emerged from our design process.

3.1 Hardware

The sensing and actuation are controlled wirelessly by an Arduino-based device. The device inflates and deflates pillows, which are fabricated in **Thermoplastic Polyurethane** (**TPU**)-coated nylon. The inflation and deflation is done through electrical air pumps working with adjustable speed (max flow 3L/min). The device operates within the pressure range of 450–1950 hPa, providing real-time pressure sensor readings via barometric pressure sensors embedded in the air circuit (Figure 2).

3.2 Software

The setup is managed using a Processing server script running on a designated PC which sends actuation commands (inflation / deflation, rate) to and receives pressure sensor readings from the actuator devices through the **Open Sound Control** (**OSC**) protocol. The communication is handled via Wi-Fi. The individual actuators are in turn controlled by an Arduino sketch. The server script is controlled via a desktop UI (Figure 3), which allows the user to select interactions and adjust their parameters. Adjustable parameters in the current iteration of the system include the duration or number of cycles, the intensity of inflation/deflation, and in-phase/antiphase feedback during which the pillows inflate and deflate in a contrary motion to the user's own breathing. Each of the interactions is coupled and time-synced with pre-recorded audio instructions.

The server script is organised into modules, each representing a single interaction, and the modules are started from a central GUI. Some interactions include a training phase where the audio instructions are augmented with bodily cues in the form of inflatable pillows pulsating (fast

Fig. 2. Left: Shape-changing sensor-actuator. Right: Inflatable pillow in relation to the body.

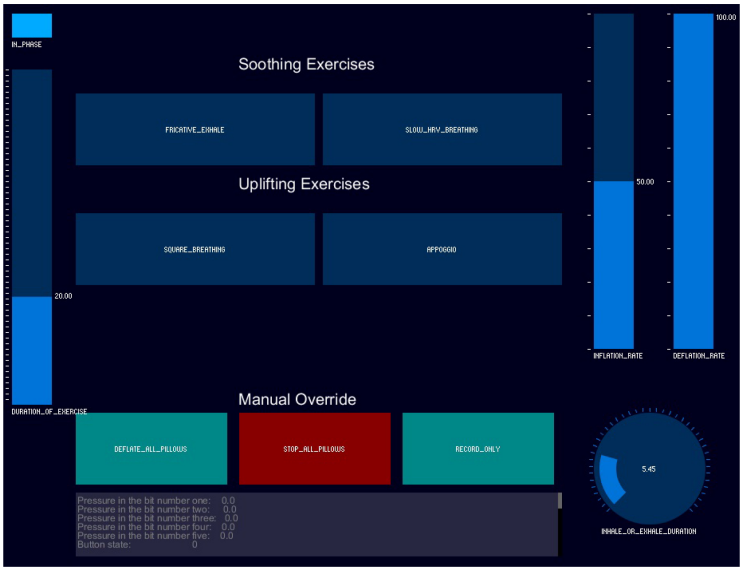

Fig. 3. UI of the desktop application controlling the system.

inflation-deflation sequences) to help the wearer to find a correct position for them on the body and direct attention to particular muscles. In the interactions recording the wearer's breathing, the pressure values from the pillows were averaged using a ten samples sliding window for filtering noise. The actuation was calculated by taking the difference between two subsequent samples (after averaging) and multiplying by an empirically found constant.

Over several iterations of testing and development, we found that state machines have proved themselves well as a programming metaphor for describing and designing the interactions. Our first attempts at designing interactions involved procedural programming that manipulated low-level concepts such as messages received and sent to the different devices. Over time, we started structuring our code using state machines [16], in which each state represents a distinct phase of the interaction (e.g., an introduction). For some interactions, phases were further broken down to internal states. This approach allowed us to quickly amend interactions and reorder phases.

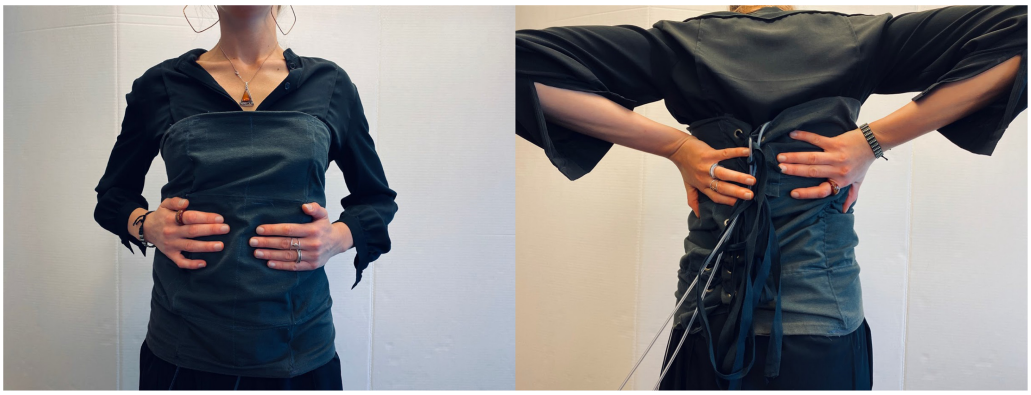

Fig. 4. Soma Corset.

State transitions were based on a combination of sensor readings from the actuators and time. A small library was written for describing a choreographed sequence of actuation by indicating the start time of each actuation and inflation/deflation rate for each actuator. These sequences, also implemented using state machines, helped to synchronise tactile cues with audio instructions.

3.3 Garment

The corset-style garment that houses these pillows forms a hard "shell", directing the pillow inflation inwards and towards the user's torso, thereby providing a potentially quite strong tactile somatic experience (See Figure 4). Our design drew inspiration from traditional steel-boned corsets, which utilise shaped fabric panels interspersed with rigid bones to "shape" the body of the wearer. However, we adopted a less severe construction using 3 cm wide plastic boning placed to provide vertical rigidity only. This structure was designed to hold the pillows in place, rather than manipulate the wearer's body. The shell is made of thick fabric and has pockets inside, strategically placed over muscles in the torso, to accommodate the shape-changing pillows. The back of the corset fastens using traditional style lacing. This allows the wearer to achieve varying levels of tightness around the torso, and thereby impact upon the felt pressure from the pillows on the user's body. Due to its adjustable lacing and non-shaped panels, the corset is also designed for any gender and for different body types and most sizes (not children). The external shell is vital for keeping the sensor-actuator pillows in a stable position and in close contact with the body.

3.4 Interactions

The latest version of the Soma Corset allows for two different broad categories of interactions: open-ended explorations where individual pillows are inflated/deflated as controlled by a mobile app, and orchestrated experiences unfolding as a sequence of different actuation/sensing experiences. Below, we describe four of those orchestrated experiences, based loosely on breathing exercises for singers. Note that while we based them on existing breathing exercises, we did not always follow the instructions slavishly, but instead manipulated and tested variants, such as shifting around the pillows, engaging with different body positions, and sometimes combining or altering the exercises altogether.

(1) *Square breathing* is intended to build physical stamina and air management for singers. We let the system guide the wearer's breathing by a combination of audio instructions and programming the pillows in the corset to inflate in the tempo prescribed by the exercise. The user follows

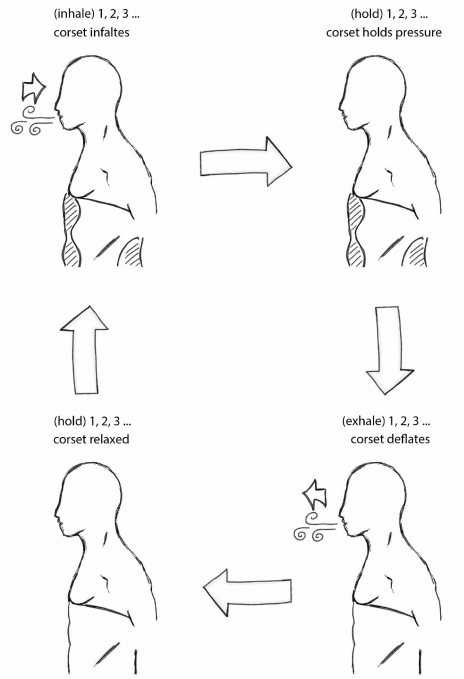

Fig. 5. Square Breathing interaction depicted in the *in-phase* version. In the anti-phase version the wearer exhales on the first state and inhales on the third state.

a cycle broken into four distinct phases: inhalation—holding breath—exhalation—holding breath. The duration of each phase is x number of seconds, starting at 3 seconds and increasing over each cycle to a maximum of 10 seconds. In the corset, this interaction can be done *in-phase* with the wearer's breathing or in *anti-phase* where the pattern of inflation and deflation is reversed, pushing when the wearer exhales. (See Figure 5)

(2) *Fricative Exhale* aims to train and increase control of the collapse of the diaphragm muscle. The wearer of the corset is first told what the exercise will be, and then bodily cues are given through the pillows drawing attention to the diaphragm and how to use it. This is followed by being guided through seven cycles of the exercise. The user inhales low and deep, fully engaging with diaphragmatic breathing. At the apex of inhalation, the breath is exhaled on a sustained exhaled fricative (a long *"sh"* or *"ss"* sound) as the lower abdominal muscles contract to maintain the stability of the released fricative sound. The pillows record the wearer's breathing and the exercise concludes by playing back the recording of the wearer's changing body through actuation. The user is prompted to reflect on their breathing (See Figure 6).

(3) *Appoggio* aims to train nuanced control of rib cage expansion through engagement of intercostal muscles. During this exercise, the wearer uses the intercostal muscles of their ribcage to support the exhaled fricative sound by rapidly flexing and releasing these muscles, which causes the rib cage to expand and collapse. At the apex of each rib cage expansion, the breath is rapidly released on a fricative sound. The four fricative sounds: *"Sh"*, *"Ss"*, *"He"* , and *"Wsht"* are repeated in a cycle consisting of four quick repeats of each sound that progressively increase in speed as the duration of the exhaled fricative becomes shorter and more articulated. The whole cycle is repeated four times and the corset records the wearer's movements. The recording is then played back to the wearer and they are invited to reflect on their breathing (See Figure 7).

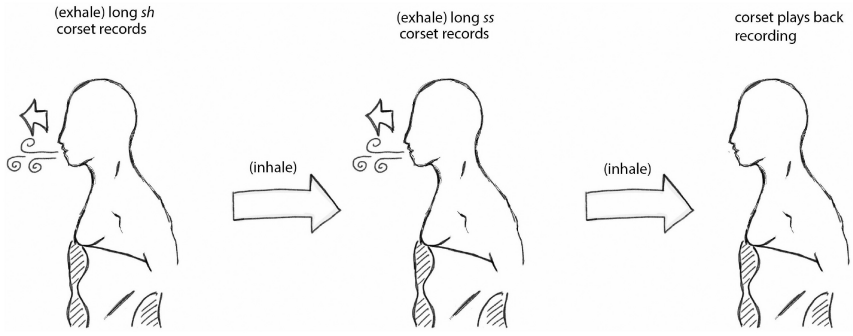

Fig. 6. Fricative Exhale interaction.

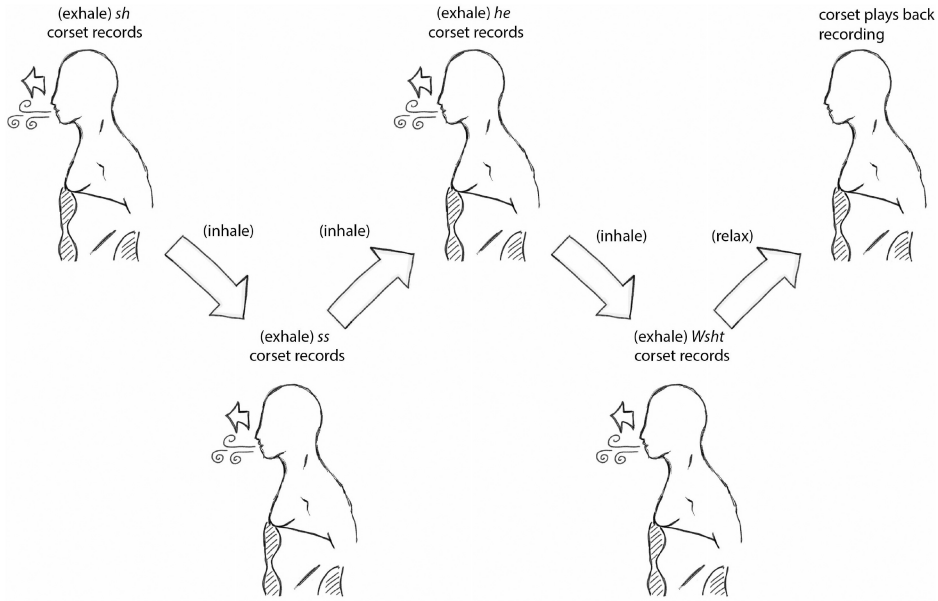

Fig. 7. Appoggio interaction.

(4) *Slow HRV breathing* aims for a slow breathing rhythm, 5.5 breaths per minute, as a path to calming down [100]. In this interaction, the corset provides a calming breathing rhythm that the wearer can choose to follow, or just let it play in the background while resting or engaging in other activities. The duration of the exercise is selected by the wearer in advance. The system performs inhalation–exhalation cycles with resonance frequency RF for HRV–5.5 breaths per minute. 5.5 breaths per minute is the most common resonance frequency according to HRV biofeedback studies [100] (See Figure 8).

As mentioned above, these four breathing interactions are configurable through the placement of the pillows in the corset, or by parameters such as the length and number of iterations, the strength of inflation and deflation, and in-phase or anti-phase feedback. These different configurations are echoed in the description of our experiences. These also are not the only interactions that we designed and tested, but merely the most developed of the interactions that emerged from our design process—which we turn to next.

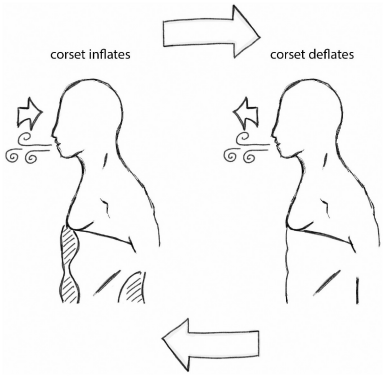

Fig. 8. Slow Breathing interaction: the Soma Corset inflates and deflates in a constant rhythm.

4 OVERVIEW OF THE DESIGN PROCESS

The design process that led to the current version of the Soma Corset spans a period of 1.5 years. The main design method used was soma design which centers on engaging deeply, slowly, and thoughtfully with the sociodigital materials at hand [37], bringing together bodies with smart materials, and discovering behaviours and practices arising from their interaction together and change over time. We, the designers, engaged with breathing exercises led by one of the authors, Kelsey Cotton, who is a professional singer. Our aim was to become sensitised to our bodies and in particular to the movements in the torso. Engaging in bodily practices for sensitising and becoming attentive to one's soma at the beginning of a design process, but also throughout its duration, is a common approach in soma design methods (e.g., [37, 106]).

Throughout the process, we regularly tried the Soma Corset, documenting our experiences, but also learnt to become sensitive to the effects of the inflatable pillows. We also explored a diverse spectrum of physical and digital materials and reflected on the experiential "touch" qualities they offered. This was a non-linear and deeply reflective process, as oftentimes we would return to some of the digital materials used earlier, in order to re-experience them in light of new discoveries at the meeting between our bodies and the Soma Corset as it gradually took shape. This translated into long-term usage of different prototypes, fast tinkering, multiple iterations of the technology, and continuous data collection through different media such as textual notes, video and audio recordings, illustrations, photographs, and body maps [56]. As such, the overview of the design process presented in this section should not be read as a timeline, but rather as an outline of how we worked within each stage. An overview of our process can be seen in Figure 9.

4.1 Becoming Attentive to our Breathing Bodies

Soma design encouraged us to cultivate our somatic sensibilities before exploring any digital materials in this novel design space. Thus, we began our exploration by engaging in breathing exercises, sensitising ourselves to the felt experience of breathing. Through this process, we developed somatic awareness and conscious control of the specific muscles responsible for inhalation and exhalation. Early in the project, we tried different breathing exercises (yoga, Feldenkrais, martial arts, and others). As mentioned above, as one of the authors–Kelsey–is a trained classical singer with a deep and nuanced understanding of whole bodily engagement in breathing, she came to act as our *somatic connoisseur* [81] during these sessions and provided some breathing exercises from her singing practice for implementation in the Soma Corset.

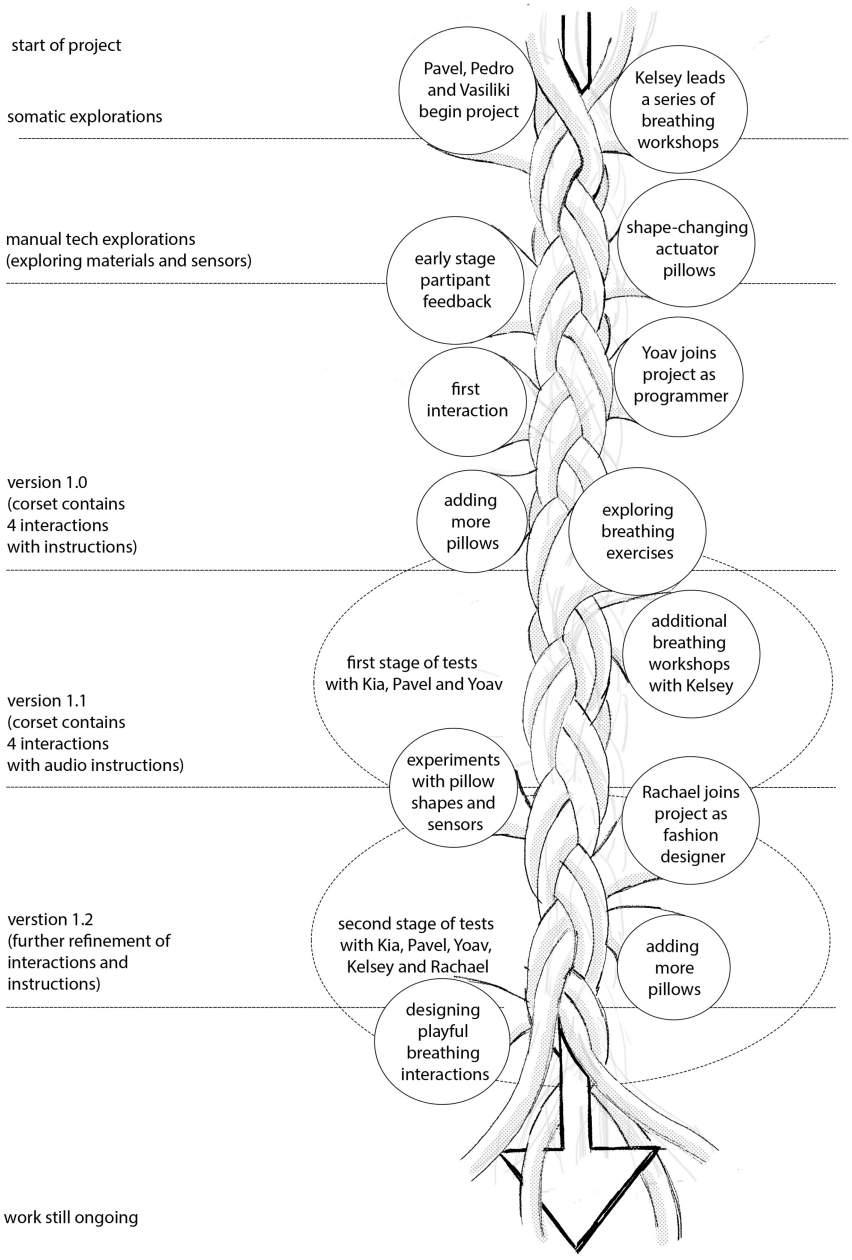

Fig. 9. Design Process: we use a braid to reflect the messiness of our research through design process. We present the stages of the process in this order to make it more readable, however, this was a process of constant engagement with and refinement of the artefact.

She selected and guided us through four exercises adopted from her singing practice, which the authors practiced on a weekly basis for a month. These exercises included three of the exercises previously mentioned in Section 3.4 (Square Breathing, Fricative exhale, and Appoggio) and a fourth exercise involving a spinal roll while inhaling to find the back muscles involved in

breathing. A typical session included practicing all four exercises consecutively. After completing the exercises, we documented our experiences in so-called *body maps* [56]. Articulation (or "making clear in our minds") of somatic experience is a key cornerstone of somaesthetic practices [86] and in a soma design process, the articulation of these experiences forms the grounding for the design work, helping to articulate the experiential qualities we seek in our design [91].

These exercises can sensitise a range of muscles and areas on the torso central to developing nuanced control over one's breathing. As depicted in Figure 1, these are the (1) sternum, (2) the rectus abdominis muscles, (3) the intercostal muscles, and (4) the thoracolumbar fascia. The exercises also cover a range of fast and slow breathing paces, which helped us become attentive to breathing in different tempos, and thus offered a broader understanding of how the torso engages in different breathing patterns and sequences. At this stage of the process, we did not include any actual sensing technologies although different sensor modalities that could capture breathing were discussed and considered in relation to the breathing exercises performed. The technologies were integrated in the next stages of our process. All the four exercises are recorded and are submitted as supplementary material to our article, in the form of audio files.

4.2 Early Explorations with the Digital Materials

The next stage involved delving into explorations with digital materials with particular focus on the areas of the torso mentioned in the previous section. We initially used the Soma Bits prototyping toolkit [106]. The Soma Bits act as accessible digital materials, enabling designers to experience what a certain actuation or property might "feel like" and to share it with others. The Soma Bits were designed around three distinct experiential qualities (*feeling embraced, feeling connected*, and *being in correspondence*) using three modalities (heat, vibration, and shape-change). The Soma Bits have been previously used in a range of different design settings [4, 106]. Then we began using sensor technologies to explore ways of detecting breathing signals and conveying these signals back to the person being sensed. Initially, we tried mapping breathing cycles to vibration using two different types of motors: the **Eccentric Rotating Mass** (**ERM**) vibration motor and the **Linear resonant actuator** (**LRA**). However, we quickly discarded vibration due to the obtrusive nature of the interaction, which evoked a disturbing somatic experience to some members of our research group: it was considered unpleasant due to its similarity to a cellphone buzzing (echoing related research with vibration motors [9]). Along with vibration we tried using temperature actuation in the form of **Micro Metal Conductive** (**MMC**) fiber heating pads. Compared to the vibration motors, the pads were able to produce a subtle bodily experience when heated. However, due to the slow speed of actuation, this modality had a physical limitation that was not suited to conveying a breathing signal.

Besides vibration and heat, we also made some early explorations with shape-changing materials. We saw an opportunity to use shape-changing elements that exert pressure on different body parts to achieve DTP. DTP involves using tools such as weighted garments and blankets to provide a comforting sensation of pressure on the body. Its calming effect can be attributed to increased activity of the parasympathetic nervous system, which plays a significant role in anxiety management [36]. (A substantial account of our long term exploration of DPT enabled by shape-changing actuation and breathing is detailed in Jung et al. [49]). We were curious about the felt experiences that shape-change evoked on the torso and decided it would be a more promising modality to convey breathing signals, and not only for DPT purposes, which is why we decided to take the shape-changing materials one step further.

Fig. 10. Exploring impact of the pillows on our bodies.

4.3 Shape-Change Sensor-Actuator Pillows

The next step was to use sensing and actuation in conjunction with the modality of shape-change to explore tactile somatic experiences on the torso while breathing. From the explorations we conducted with vibration and heat actuation, and with sensing mechanisms for capturing breathing through muscle contraction on the torso [96], we observed that the tangibility of the sensors–experienced as pressure applied against the skin–could potentially offer new insights regarding tactile experiences of breathing. In our previous work [96], we presented such reflections when capturing breathing through an **Electromyography** (**EMG**) sensor placed on the lower abdominal muscles, and through a wearable strain sensor worn around the rib cage.

To further explore the tangibility of sensing and actuation for digital touch, we developed a new type of shape-change sensor-actuator mechanism, inspired by a shape-changing actuator from the Soma Bit toolkit (Figure 2). This took the form of an actuated pillow that responds to pressure. This custom-made actuator consists of an electronics unit containing solenoid valves, an air pump, barometric pressure sensor, and Arduino microcontroller. Each unit hosting the electronics connects to a shape-change pillow via long transparent tubes. The Arduino microcontrollers are controlled wirelessly from a Processing sketch running on a laptop. We designed pillows of many different sizes from TPU-coated nylon.

As a starting point, we programmed each pillow to deflate when pressure is applied to it and inflate when there is no pressure to detect. This feature, even if not actually fully interactive, helped us explore the impact of pressure applied against the different muscles used in breathing. By applying and releasing pressure to a pillow placed over a muscle, it was possible to create a form of "mirroring" of our inhalation and exhalation. The muscles expand and retract whilst breathing, which could be detected by the pressure sensors in the pillow. The pillows would then actuate and change their shape in response.

To determine the affordances of these pillows, we tested them repeatedly. Let us provide a brief account of some of our explorations:

Testing the Impact of the Pillows on the Torso while Breathing: We began by placing the pillows on different areas of the torso, breathing against them and reflecting upon their impact on our bodies (See Figure 10). At this stage, one person was holding the pillow against another's body. As a next step, we attached the pillows to our bodies using elastic straps, in order to feel the impact of the pillows on our bodies without another person's interference. We tested five pillows attached to five different relevant muscles on the torso: the sternum, the rectus abdominis, the thoracolumbar fascia, and the intercostal muscles on the left and right sides of the body (Figure 1).

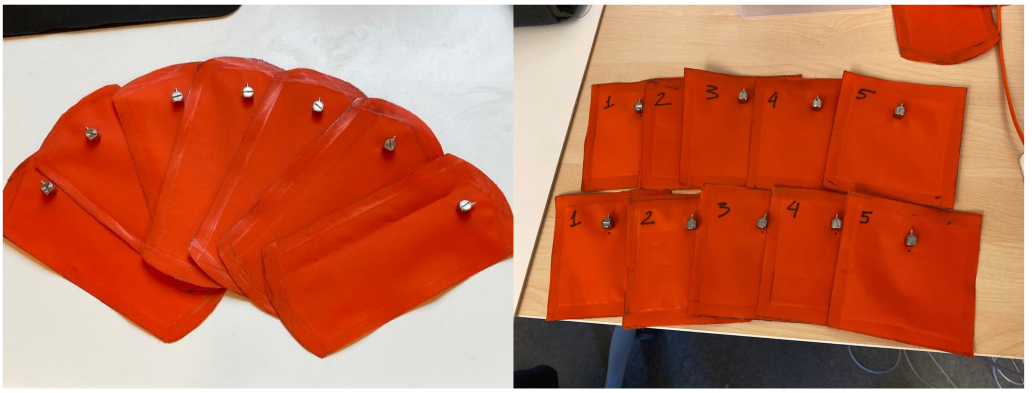

Fig. 11. Left: Discorectangular pillows. Right: Square pillows.

During exhalation, we observed that feeling the gradual inflation of the pillows instantly drew attention to the area where they were placed. As the muscles shrank in each region during exhalation, this caused each pillow to inflate and "fill" the cavities left over the muscles. The rigid shape of the inflated pillow rendered it quite separate from the wearer's own body, rather than inhabiting the same physical space. When inflated they also established an intense focus on what was occurring beneath the pillow as our muscles moved and our bodies breathed. The felt experience elicited by the meeting point between pillow and body was felt as "*the pillow 'growing' out of the body*", as expressed by one of the authors. Additionally, the expansion of the body caused by inhalation provoked the sensation of interacting with this sensor-actuator material: an experience of "pushing" against the pillows and to immediately feel their compression in response. There was also a feeling of slight re-expansion as our bodies collapsed during exhalation, and a feeling of having this phenomenon reflected by the movement of the external material.

Breath felt externally: The shape-changing pillows provided a distinct somatic experience, which we framed as the ability to *feel externally* one's own breathing. By this experience, we refer to how the shape change pillows evoked a tactile and tangible impact on the body. Breathing became an event not exclusively residing *within* the body, but an experience with a tactile consequence that could be felt in the touch of the shape-changing pillows. By applying pressure against the skin, as one would a hand pressed to one's flesh, and expanding to fill the negative spaces (the curvatures) of our bodies as our muscles moved with our breath, the pillows provided an externally felt sensation of breathing. The tactile feedback provided by the pillows also brought these areas to the forefront of our awareness.

Filling the negative space on different muscles and different sized- and shaped bodies: After testing several sample pillows on different areas on the torso, we noticed their shape and size were important both in relation to the data that could be captured and for adequately *filling* the negative space over a muscle—something which varies from body to body. This quality of their touch, and the filling of his negative space, can affect the tactile sensation evoked. During testing, we found that covering the lower abdominal muscles (rectus abdominis) required a longer pillow than other areas (about 20 cm × 9.5 cm deflated) (See Figure 11). This length felt most comfortable as it approximated the perceived physical width of that muscle. It also provided the additional benefit of capturing the rate of expansion and collapse of the rectus abdominis muscle during diaphragmatic breathing. On the other hand, smaller square pillows (10 cm × 10 cm deflated) (See Figure 11) felt most comfortable over the intercostal muscles and sternum, as their smaller size fit comfortably against the planes of the body in this region. To use multiple pillows on different areas of the

torso, we initially placed them beneath neoprene fabric strips, tied around the area in question (see Figure 10).

We observed the shapes of the pillows corresponded to how one would place a hand on their own body to feel their muscles change while breathing. This was a tactic that we adopted earlier in our research process when we engaged in the breathing exercises. For example, the rectangular pillow shape and placement on the rectus abdominis mimics how a hand would be placed on the same area (palm and finger flat against the rectus abdominis and hand parallel to the floor), whilst the square shaped pillows mimicked how the hands would be placed on the intercostal muscles (palms over the intercostal muscles with finger pointing to the front of the body), and the sternum (the palm placed in a "hand on heart" position with the finger angled slightly towards the shoulder). The relatively small size of the square pillows also afforded the possibility to fill the convex planes of the body in exhalation and provide a localised reading of shape-change data when suitably inflated. These reflections and learnings led us to develop a prototype that could package the experiences offered by these shape-changing pillows into more structured or orchestrated experiences with a clear beginning and end.

4.4 Early Experiences of the Soma Corset

After testing the tactile impact of the pillows on the torso we found that a shell container was required to provide an external limit for the pillows to be pressed against when inflating. Thus, following the material exploration and experiments with shape changing pillows, we developed a wearable prototype consisting of shape changing pillows housed in the corset garment presented earlier. This corset garment mimics the internal environment of the rib cage within which the lungs inflate and deflate. We experimented with two different types of fabric, one sturdier and less elastic than the other, with steel and plastic boning, and with differing overall lengths of the corset. The wearable we ended up using for our first-person experiences and for conducting testing sessions with others, presented in this article, is made of a sturdy cotton fabric to balance rigidity and adjustability. It encloses the torso of the wearer but without intervening much in the experience of feeling the shape-changing pillows placed next to the body. The vertical boning and the lacing are important material elements for keeping the corset in place and for keeping the pillows in place, and in direct contact with the torso. Thus, the decisions taken regarding the materiality of the corset's shell were mainly driven by the experience offered by the shape-change sensor-actuator pillows. The materiality of the pillows, experienced as pressure against the body when touching the torso during inflation and deflation, became the focus of our explorations driving our design process forward (as articulated in Section 4.3) and allowing us to reflect on touch qualities between body and wearable. The shell functioned as a hosting unit for the shape-change pillows, supporting experiences of breathing in it, and being touched by the shape-change breathing pillows.

In order to get feedback at this early stage, we invited 22 participants from different backgrounds to engage with the corset in an informal manner. These 22 participants included an industrial designer, an engineer, a material science expert, a bionics expert, a senior computer science expert, a somaesthetics philosopher, and a data scientist, as well as two interaction designers, three senior HCI experts, three women's health experts, and six music computing experts. Different constellations of these participants engaged with the system during thirteen informal testing sessions.

During these sessions, the participants wore the corset while the researchers manually controlled the inflation and deflation of the pillows through the mobile app. The participants were also given an opportunity to control the actuators themselves. It is worth noting that this informal testing proved to be a fruitful ideation opportunity as the participants expressed many ideas that their experiences with the corset evoked. These sessions were video recorded and then transcribed, allowing the researchers to revisit the conversation as well as the participants' engagement with

Fig. 12. Informal testing session. The Soma Corset's behaviour is controlled via a smartphone.

the artefact. We were not looking for generalisable points, but rather for themes that could help us expand the design space, and especially to inform ways we could make the artefact interactive. We therefore relied on an interpretivist stance, where the analysis involved open-coding the interviews, and later organising the codes through an affinity diagram. First, and most importantly, the explorations confirmed that: the inflatable pillows helped make breathing tangible; that they could serve a guiding role as a constant reminder to breath in a particular manner; that the compression made the relationship between cause and effect clear; and that the corset's ability to provide 3D-feedback made instructions for the breathing patterns clearer. The participants also reported on experiences of feeling embraced, echoing qualities from our Soma Bits explorations. But more interesting to us were the participants' insights that went beyond our own experiences and expectations. As this was an early prototype, it sometimes exerted excessive force—an experience that some found unpleasant, but also interesting. The pillows sometimes evoked unexpected or uncanny experiences, which our participants reported in diverse experiences such as: a day on the beach; being embraced by a octopus; being touched without an actual touch; being backwards pregnant; and getting a massage of the inner organs. After removing the corset, some reported that the corset felt present despite no longer being strapped on. The participants also asked for social interactions, asking what it would feel like to sense someone else breathing on their torso.

Based on this input, we decided to experiment with the corset interactions with parameters such as: high versus low pressure, giving users full versus no control over the interaction, providing rhythmic versus non-rhythmic feedback, placement of pillows on bones versus soft tissue, the size and form of the pillows and their placement, and ways of sharing breathing with one-another or mirroring back our own breathing.

One of our early attempts to explore mirroring of the breathing back to the wearer was implemented by assigning the role of a "leader" to one of the pillows and the role of "followers" to the rest of the pillows in the setup. The "leader" pillow was manually inflated, after which the pressure in that pillow was maintained so that the system could monitor how strongly the wearer was pushing back at this pillow through a breathing cycle—in effect using this "leader" pillow as a sensor. The "followers" conformed by adjusting their pressure to match that of the "leader" pillow, thereby performing as actuators.

Pilot-testing of this interaction with three participants revealed several issues with this approach. First, the act of following or matching one's breathing rhythm cannot be implemented by a simple "measure and match" loop (as was previously discussed in [90]), and instead it is necessary to predict the breathing pattern. Otherwise, the actuators will always be slightly "behind" the

inhale-exhale-cycle, making the interaction off beat. Second, it is a non-trivial task to measure pressure and actuate at the same spot: doing so requires a precise model of how actuation alters the measurement of pressure, allowing us to separate the actuator's and wearer's contribution to the measured pressure signal. Third, as the interaction only allowed for one sensor pillow, the degree of detail for capturing all the muscles movements involved in breathing was severely limited.

We are currently developing solutions to this problem.[1] In order to get more feedback from wearers, we decided to separate sensing and actuation so that all pillows would either be sensing or actuating at any given moment. This way we could, for example, record breathing patterns from the wearers and then, in the next stage, play it back to them. This form of interaction also proved to be evocative, so we decided to explore it more before returning to the problem of simultaneous sensing and actuating.

At this stage of development, changes were also made to the set-up and configuration of the corset. The actuator units were standardised by unifying air circuits, valve configuration, shape, and size of the pillows. We created a set of uniform disco-rectangular and square shapes for the corset, following our earlier pillow exploration (Figure 11).

We also moved onto implementing the more advanced breathing interactions adapted from exercises that Kelsey demonstrated to us during our early somatic explorations (as detailed in Section 3.4 above), as well as the HRV-breathing as it is a common breathing technique.

5 FORMING LONG-TERM RELATIONSHIPS WITH THE SOMA CORSET

The later stage of the design process involved exploring and reflecting upon our experiences of the corset with these four orchestrated breathing exercises, including playback of our own breathing or letting a breathing exercise run in the background while doing something else. Our engagements with the interactive corset were conducted in two stages, first with three researchers participating (Kia, Pavel, and Yoav) and then with another five using a slightly altered system (Kia, Pavel, Yoav, Kelsey, and Rachael). The three researchers participating in the initial stage of this process tested all of the four interactions every day for a week. Following this, the corset underwent some further development of the interactions, which was tested by the group of 5 participants. This included adding recorded voice instructions to the guided exercises, refining the bodily cues that instruct the users, and adding additional controls to make some of the exercises more adjustable in terms of exercise duration (in the Slow HRV exercise) or in the length of breathing phases (such as in Square Breathing). During this second stage of testing—with the five wearers—the protocol remained the same, except that each of the participants was asked to select only two of the four exercises to engage with each day.

During both stages, we followed the same protocol. Before engaging with the Soma Corset, we articulated our current feelings and bodily sensations by manipulating a three-dimensional version of a body map [56]. This consisted of a small wooden figurine, the type commonly used for artistic sketching (see Figure 13), to which we would stick coloured plasticine shapes to represent our feelings and bodily sensations and use as a prompt to articulate these experiences for a short video recording. We would then strap on the Soma Corset and test all or some of the interactive behaviours, intermittently noting down our experiences on a digital whiteboard [59] where we would detail how we had chosen to place the pillows on our bodies for the different breathing exercises. Finally, we would each repeat the 3D-body-mapping process and record a second video articulating how we felt after using the corset.

[1]We have continued to explore alternative solutions, such as separating pressure measurement and actuation by using additional sensors and pillow shapes, such as stretch sensors and machine learning algorithms to measure movement and predict breathing gestures [51] or using doughnut shaped pillow with a non-actuated centre carrying a sensor.

Fig. 13. Left: Body map with a figurine. Right: Digital whiteboard snippet.

Finally, based on their respective overall experiences or on some particularly important experience, each participant created a short personal vignette describing their feelings and experiences of interacting with the Soma Corset. Let us now turn to these vignettes.

5.1 Autobiographical Engagements with the Soma Corset: Vignettes of First-person Experiences

In this section, we provide five short vignettes of our experiences of the corset. Note that each of the researchers whose accounts are presented here tested slightly different iterations of the device and interactions, in different contexts, and at different stages of the design process.

5.1.1 Pavel's Story. I was the primary researcher on this project, and so, I was intimately involved with every iteration of the artefact. In my journey, I tried to expand our understanding of felt experiences beyond those usually foregrounded in somaesthetic research, such as subtleness and slowness, tacitness and timidness. I wanted to know what uncomfortable, restricting or even painful interactions could bring to the table. This vignette describes my intentions and focuses on the experiences of engaging with the interactive version of the Soma Corset.

Since the early stages in the design process, my goal was to play on the borderline of the uncomfortable interactions. I was interested in creating these experiences to be articulated and prominent, but not annoying or obtrusive by trying to capture the moment when the interaction starts to become uncomfortable, unpleasant, or slightly scary and provide a release of tension at exactly that moment. Being inspired by the qualities of deep touch, my hunch was that shape-changing actuation in the form of inflatables was an under-explored modality potentially capable of providing these sensations. My preferred "flavour" of interaction centered around not being afraid to cause discomfort nor being too shy to show presence. However, as my design explorations unfolded, I realised that these qualities I wanted to capture could easily be lost by simply putting the pillows on the wrong locations on the body or exceeding certain perceptual thresholds with applied pressure. This made me realise that the qualities I sought were illusive and hard to capture.

While I was keen to explore uncomfortable experiences, I also started to appreciate the more gentle, slow interactions. For example, the slow breathing as a background interaction created an evocative experience. With the inflatable element placed on my back and without much control over the actual interaction, it felt like being embraced from behind by some foreign entity. The interaction evoked a feeling of being held upright by a breathing chair or being hugged by a monstrous animal and sensing its breathing on my back. Alongside the breathing of this mechanical organism, the sound created by the pneumatics gave the impression of a singing robotic chorus. The experience created an interplay of perception. At the beginning of the interaction, it felt disruptive and I could easily distinguish that this was not my body: it did not belong to me. After a while, I got into the flow and the interaction faded into the background. It felt more like an organic continuation of my body. This mechanical continuation of my body was breathing for me while I was not consciously following this pattern. I was soothed and I felt the effects of slow paced breathing. It made me wonder if I was following it without noticing? Or did my parasympathetic nervous system truly recognise this mechanical body as my own?

At one point, I was attempting to find a more "organic" way of presenting the breathing pattern back to the wearer. Switching between in-phase and antiphase helped me explore how it feels when the actuation occurs either with the exhalation or inhalation. Both evoked curious, but very distinctive experiential qualities. When the inflation of the pillows was mapped to the inhalation, the artefact felt like an extension of my own body: an external pair of lungs attached to the surface of my skin—similar to my experience of the slow breathing interaction. When my breathing was played back to me in this phase, the interaction reminded me of a twisted mirror. The corset was a "mirrored" recording of what I was doing—it showed me the mirror of myself and allowed me to actually *feel* my reflection. I felt like I was wearing my own body or that I was inside the mirror or reflection of my own body. I speculated that if I were to engage in the exercise simultaneously while feeling the captured sensations actuated back to me via the pillows, then I would be competing against myself. In the opposite phase, when the inflation of pillows happened during exhalation, it created the sensation of being guided or aided in the breathing process. In more instrumental, fatiguing interactions—such as square breathing—this helped me to be more resourceful with my lungs during the exercise by somatically showing me how much to inhale and exhale, when and how fast.

5.1.2 Kia's Story. This vignette is based on two of the latest iterations of the corset. At the time, the Soma Corset could both sense breathing, record it, and replay it, and also engage the wearer in breathing exercises through voice and rhythmic inflation of the pillows. Prior to this experience, my role in the project had been mostly as a passive follower, providing occasional input as I am the supervisor of Pavel, but I had also been acting as a design participant/contributor – especially in the very early and very late stages of the project.

My account will be more or less verbatim copying what I wrote right after one of the sessions with the corset. In this particular session I was at home (during the pandemic) engaging with a version of the corset where it could register my breathing and then let it play back my own breathing to me. The corset had a fairly long HRV-breathing sequence that could be run in the background as I was working. I had placed the inflatables in a circle around my waist—three on my belly and two on my back. I started with the HRV-exercise and played it twice while attending an on-line meeting. After that, I engaged with the breathing exercise named Appoggio:

This was probably the most interesting session I have had so far. I managed to get the corset on before a meeting. The meeting was one where I could mute myself and just listen. I put on HRV in order to not disturb my focus on the meeting. I was laying on my bed. The HRV was REALLY easy to follow when lying down. The two pillows on my back helped me a lot as they gently lifted my torso

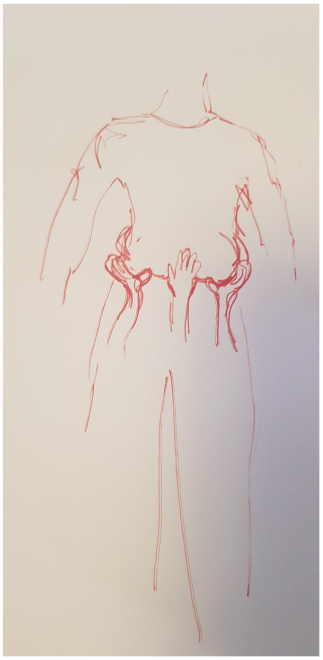

Fig. 14. Kia's organic monster.

upwards from the bed. Really, really nice. Relaxing to the point where I closed my eyes! Before I laid down on my bed, I was sitting up. At that point it was hard to follow the HRV. I did a whole cycle while sitting up (almost) and I never synced with the movements of the Soma Corset. I am guessing it was because I was also a bit stressed out about this meeting. Once that whole cycle was done and I did a second cycle, this time laying down on my bed, I was really happy that I could synchronise my breathing so quickly, without any effort. It made me feel that there is something in this interaction that really makes sense.

I then moved on to the breathing exercises. I tried the Appoggio. It was a bit hard to follow as [the instructor] was speaking so fast. But as I have done it before, I understood approximately what to do. And I did not let it bother me that I might not have done the right "shhheee"-sound at the right moment. After doing the whole exercise, when it started replaying my own breathing back to me I was absolutely astonished by the experience. It was unlike something I had experienced before and still never ever experienced before in my whole life. The squeezing was happening like a ring below my diaphragm. I had placed the pillows so that the two front ones were pushing partly on my hip bones, and the controlling one was in the middle. It felt as if my stomach was this round, squishy big bag of fluids, and the pillows were lifting it rhythmically. Extremely organic experience. Like some animal coming towards me from my legs, from the floor, from outside, pushing upwards. I was absolutely mesmerised by the experience. I was unable to catch what it was that it resembled. I still can't.

Now that I am back sitting on my chair, it feels like my whole belly and lower back are bigger than normal. Almost a bit tender. I think I managed to put on the corset quite tight today. I think this was good. The tight feeling is interesting, soothing. Makes me feel supported.

After this particular session, I felt I could not describe or represent the experience using the 3D-figurine. Instead, I drew a picture of myself (see Figure 14). I put small hands pushing upwards around my waist even if I did not really want to convey the idea that it was a human being or animal

that pushed my belly upwards—more of an unknown, organic entity. While I knew this was my own breathing exercise being played back to me, it did not at all feel like me. The uneven rapid pushing, three times in a row, followed by a break, that had been created from my engagement with the Appoggio exercise, was strangely unfamiliar to me. The experience is still, months later, vivid in my mind.

5.1.3 Kelsey's Story. I'm a classically trained singer, working in contemporary, experimental, avant-garde music and free improvisation and have been looking extensively at the physical experience of singing. I joined the Soma corset project quite early on as a somatic connoisseur, sharing insights into my breathing practice as a professional singer and tested the corset system at various points throughout it's development. I have a reasonably close relationship with the corset, and recorded the audio instructions in the most recent version of the corset.

This vignette is based on my experiences of testing a later version of the corset. In this iteration, the corset was programmed with audio and physical/touch instructions. It had four programmed interactions, and was also programmed with an antiphase modality, where, in the more active exercises, the pillows would behave in a contrary motion (i.e., inflating when I was exhaling and vice versa). During each of my sessions, I used an arrangement of five pillows positioned over various points on the torso, but mainly centred around the rectus abdominis, intercostals, and thoracolumbar fascia. I used pillows of varying sizes, tailoring my choice of pillow to the kind of touch experience I imagined it would elicit.

I have spent a lot of time strapped into the current iteration of the Soma Corset, and my relationship to it is very much framed within it as a guide or physical instructor. The fact that it has my voice (literally providing audio directions and explaining the exercises) always gives me the impression that I am listening to a past version of myself—feeling a past version of my self—as the pillows squeeze me, push against me or crawl up my back and belly. Wearing and interacting with the corset reminds me of the thousands of voice lessons I have had over the years, and throws me back into a practice room with a teacher pressing on parts of my body and guiding me to listen to and feel what is happening in my body as I breathe. Hearing my voice coming from the Soma Corset as I do these exercises helps me to turn inwards, and pushes me deeper into my body. It is hard to draw a line between myself (as the person wearing the corset) and the corset when it speaks with my voice. I think hearing myself (corset-Kelsey) talk and guide myself (corset-wearer) makes me instinctively read my experiences with the corset as a sort of introspective exploration with my actual body, mediated through my external body as presented in the corset. I feel like I am being sonically and physically guided by my conscience or inner voice: "*Kelsey the Singing Technician*" takes over, and starts to push on my torso.

The feel of the pillows pressing on me as we go through the exercises together bears a curious similarity to how I press and touch my own body during my personal singing practice. I wriggle and wobble muscles with my fingers to loosen and relax them, I push and pull my abdominal muscles in different directions as if to show them how they need to move—following my hands. Whenever I have felt the corset doing these sorts of actions on my body, it feels like I am in communication with a duplicate version of myself.

When I am engaging with the exercises that record and playback my biofeedback changes—my breath—I feel like I am giving something precious to the corset, to the alternate Kelsey. I am giving it *my* air, giving it life. We enter into an exchange together, sharing air as I do the exercise, exchanging space as we allow each other to move and shift and press. Sometimes it feels almost conversational, sometimes transactional. But typically I am always "listening" back to corset-Kelsey to see how much of her I recognise, how much of myself I recognise in what she (or is it me?) is doing to me. Sometimes the corset "plays back my body" in a way I struggle to recognise. Is it really me?

Have I mutated into something else, or is corset-Kelsey just not listening to me today? Sometimes I can not recognise myself at all in the played back actions. I ask myself if the corset has taken on something more than what I have breathed into it. But other times, when I am engaging with the more in-the-background exercises, I forget I am wearing it. The Soma corset becomes a part of my body, just extending me, like an extra layer of skin.

As a summary of my relationship with the corset, my experiences are very much framed within a context of the Soma Corset as an instructor of sorts—using touch to turn inwards to the physiology of my breathing. This was emphasised in the corset's ability to record and playback my breathing, the kinds of touch it would give through playback, as well as all of the physical experiences unfolding alongside my pre-recorded voice guiding me through the interactions.

5.1.4 Yoav's Story. I joined the project as research engineer at the latest iterations of the project reported here. I have programmed or modified all of the interactions up to their current version, usually in an iterative process involving wearing the corset, experiencing an interaction, and then modifying the code.

One of my first contributions as a programmer to the corset was the creation of the breath mirroring interaction, which became part of the Appoggio and Fricative Exhale breathing exercises. My goal when putting on the corset was to see whether the replay of a recording of my breathing would indeed be a high-fidelity playback of my breathing pattern. This is why my attention during the playback was often directed at finding familiar "landmarks" in the interaction. For example, I was delighted by the time when I happened to hiccup midway through the exercise and could feel the corset hiccup back at me at the replay!

But at most times the sensation of the playback was quite foreign. For example, at one time I felt the playback more pronounced on one side of the body and I kept wondering if that is a true reflection of my own breathing and posture, or is there some error in the corset? When I started experimenting with putting the pillows on my back, around the lumbar area and on my lower shoulder blades, the playback on these areas became more dominant compared to how it felt when doing the exercise. At the same time I had a pillow in my sternum that I could not feel at all during the playback, although I am pretty sure that my chest moved quite a lot. After a while, I came to feel that the corset reflected back what *it* felt of my body and movement, which was not always what *I* felt while breathing, like it had its own mind, learning how to breath from me, and then showing me what it learnt.

When we started to combine the interactions with the voice recordings of Kelsey, we wanted to explore how we could feel the instructions enacted in the corset instead of just hearing them. Having only Kelsey's recorded instructions, I started to explore how these instructions should feel like when enacted in the corset movements. The exercises were completely new to me and I was not even sure if I was doing them correctly, or how the movement should feel like. For example, we had an explosive breathing exercise, which involves a very strong movement of the abdomen, how would this movement feel like if some had to do it for me? Or on my body? Is it just a very rapid expansion of the pillows? The movement shook my whole body, so I tried to get the pillows to mimic that pulsating motion. As it turned out, the best version of the instructions was never a mirroring of my own sensation of following the instruction, but instead, it was enough if the pillow-inflation helped bring my attention to the relevant part of my body, the one Kelsey wanted us to focus on, giving it a pleasant nudge.

Once I managed to give Kelsey's vocal instructions a "body" (in the corset movements) with which to move, suddenly other parts of interaction felt more lively. For example, when the pillows inflated all at once before recording, in the start-up phase, I started to feel as if the corset was telling me to stand straight, "don't slack!" giving me a strong squeeze through tensing itself. The reflective

part was also very instructive, at one time I could really feel through the corset that my inhalations were smooth and slow, but my exhalations were instead choppy and kept breaking up. During another interaction, following the Square Breathing exercise, managing to follow the instructions was very rewarding, and I felt as if the corset was doing the exercise with me, putting more pressure the more I inhaled, holding its breath when I was holding mine, releasing alongside my exhales. Doing the exercise with the corset created a feeling of connectedness, similar to practicing with other people in the same room and acting in synchrony with them.

From my role as a research engineer, my relationship with the Corset was that of a two-way teacher-student relationship: I programmed the Soma corset to do certain movements, responding to data, effectively teaching it how to be what we intended it to be. In return, the corset taught me about my breathing and helped me develop. Even though I tried to embody my understanding of the exercises into the corset, the corset remained a separate entity in dialogue with me, a dialogue in which I spoke in code and the corset replied in movement, never quite striking a complete understanding.

5.1.5 Rachael's Story. I was the final person to join this project. I previously trained as a fashion designer and am currently working towards a future high-fidelity prototype of the artefact. This vignette is based on my experiences of testing the latest version of the corset. In its present iteration, the corset has four exercises – Fricative Exhale, Slow HRV Breathing, Appoggio, and Square Breathing. I predominantly used five square pillows placed on my lower abdomen, sternum, both sets of floating ribs and lumbar curve.

Originally, I treated the Soma Corset as any other garment—a matter of finding the right materials and construction to create a product to suit the (however odd) specifications. However, I soon discovered that people viewed the corset as much more than a garment and in ways I did not fully understand. Eventually, I was given the Soma Corset to take to my home for a week to engage with it.

The first thing that struck me when I tried the corset was its shifting materiality. It did not feel as though just it was simply inflating and deflating, but that everything about it changed. It shifted from being a regular flexible garment to something that felt like a rock. I went from wearing clothes to having my torso encased in a rigid sculpture. The corset also had *presence*. Between the garment, the wires, plugs, pneumatic actuators and so on, it filled the spare room in my apartment where I set up the device. This, I think, really helped me to understand that the corset was not simply a garment, but a whole bizarre kind of agency that emerged from all these components. An agent that you then encase your body within—a strangely alienating but intimate experience.

Early in the week, I struggled to keep up with some of the exercises. I was unable to modulate my breathing to keep inhaling or exhaling in time with the instructions. It was very uncomfortable, trying to keep up with the exhale until my body was emptied of air. It felt like the machine was draining me of oxygen until I had nothing left to give. As I inhaled, the corset also became almost immovably solid against my skin. I felt like a weak, soft, squishy part of the machine—a faulty organic cog bent out of shape in the system. The corset was testing me; using its rigidity and force to push me further than I was able to breathe. This, mixed with Kelsey's friendly, calm voice relaying the instructions to me, made the whole experience vaguely unsettling.

The whole process began to feel like a strange kind of performance. I would need to entangle myself in the garment surrounded by its plethora of wires and flashing lights, place all the pillows and tubes in the right positions on my body, strap myself in with extra belts (the corset did not quite fit my slim frame) before negotiating my way back and forth to the laptop to begin each test, without tripping over the pipes. Eventually, I began to feel like a very strange piece of performance art. This feeling was at its strongest when I had the corset as a background interaction. Sitting

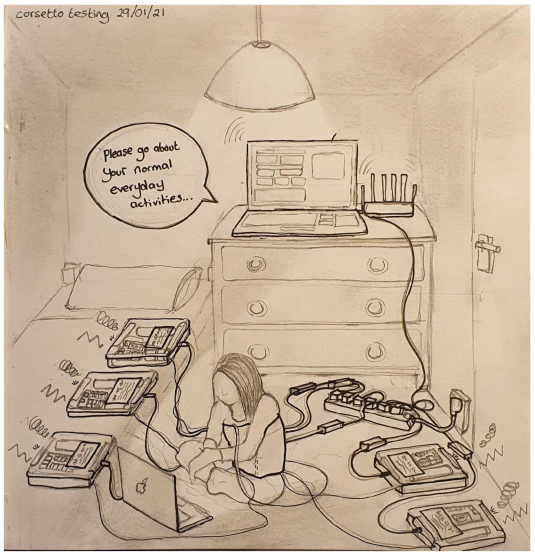

Fig. 15. Rachael's performative experience.

at the tiny desk in my tiny spare room idly using my laptop, strapped into this contraption that nearly filled the entire room, making loud whirring noises as the pneumatics worked alongside my breathing, I felt acutely aware of how alien the experience is. Our human lungs can breathe silently and effortlessly, whilst this machine can not replicate it without enormous—almost ridiculous – effort. It is like the simple act of breathing has been isolated, and then recreated as a human-machine performance—either showing how much work goes into keeping us alive in the world or showing how alien machines become when they try to imitate us. It was reminiscent of a life support machine—showcasing how much effort is required to keep a person breathing.

The strangest feelings I had were around the reflective exercises. It never felt, no matter how much I improved at following the exercises, like *my* breathing or even human breathing at all. Fricative exhale played back discordant pulsating sensations on my body: it felt like the corset was poking and prodding me, trying to explore (and not in a friendly way) my body. When the pressure was strong, it felt like the corset was trying to extricate me—squeeze and wiggle until I became disentangled from it—getting rid of me from the machine. Appoggio resulted in equally strange sensations, however, unlike the harsh pressures of the Fricative Exhale, it played back weaker sensations. It almost felt like a pale mimicry of human breathing—lacking both depth and quality—a half-hearted attempt to understand my body and my breathing. Or perhaps it was mocking me—showing me how weak I was in comparison to the forces the corset could exert. Both of these exercises made me feel like I could not communicate with the corset or that it could not communicate with me. Several times, it felt like there was some meaning behind the weird pulsating that I could not interpret. Perhaps both the human and the machine breathe in their own way, and we cannot understand each other. This was also reflected in changing materiality of the corset; when it breathed on its own it felt smooth and even, but when it tried to imitate me it became discordant and stuttering. Likewise, when I tried to follow the machine, sometimes I could not keep up with it. It was a strange feeling of finding new ways to be out of sync with each other.

Over the week, I gradually began to feel more in sync with the corset and improved at the exercises, although I never reached the point where I recognised myself in the corset's breathing. It always felt like two entities trying to breath in ways that the other could not quite understand.

It is difficult to summarise my relationship with the corset. I recognise that some of my reflections might suggest I perceived the corset as a negative entity or that I did not enjoy my interactions with it. However, that is a simplification. The corset is full of juxtapositions that I find to be intriguing–intimate and alienating, human and machine, habitual and disruptive, and more. It is something that has changed my understanding of what a garment can be and what wearing a garment can entail. To me, the corset is ultimately fascinating.

6 RELATIONSHIPS WITH TECHNOLOGY FRAMING NOVEL DIGITAL TOUCH

Based on the experiences reported in these vignettes and the experiences gained from the overall design process, we now turn to analysing and describing the different digital touch relationships emerging through our engagement with the corset. Although we did not initially set out to undertake a postphenomenologically-informed design enquiry, we, like others [33], turned to postphenomenological theory whilst trying to understand how we related to this technology in our long term engagements.

The experience of the corset is inherently multistable [77]. That is, we each developed different meanings when interacting with the corset and our individual understanding and relationship to it often changed over time or even within a session as we were making sense of the interactions. Certain relations we all experienced, such as the corset's role as an *instructor* or how it could engage us in an unnoticed *background* relationship. None of these are especially surprising as those relationships were the ones we explicitly designed for. Other forms of relationships, such as occasions where the technology became *embodied* or transparent to us, mirrors experiences thoroughly discussed in the design literature for other forms of technologies. But Rosenberger and Verbeek's *cyborg* relations [77], and particularly their articulation of different forms of hybrid intentionalities between wearer and technology, moves us closer to understanding some of our more unexpected relationships with the corset. An inherent quality of cyborg relations is that the boundaries between human and technology become blurred, and a new entity emerges: that of the cyborg, an entity partially constituted by human and partly by technology [102].

Below, we articulate three specific nuances or subtle dynamics that we experienced within such entangled cyborg relations to the corset. The first of these lenses we have termed *a monster*: where we experienced ourselves as being a part of a cyborg relation, but with a distinct discordance or disharmony between the wearer and the technology. The second we call *an organic other*: when the boundaries between wearer and technology became blurred in a way that the technology becomes perceived as being almost lifelike—not just as an *alterity* or demonstrating intentionality—but as something alive in an uncanny or strange way. The final of these lenses, we term *a twisted mirror*: wherein we recognise certain intentionalities as being our own but mirrored in a distorted or twisted manner. It should be emphasised that we do not present these three lenses as a radical departure from Rosenberger and Verbeek's cyborg relations, but instead that we intend to foreground a specific nuance or "flavour" to the experience of being within these entangled relationships - flavours that may help us develop a richer palette for digital touch interactions.

6.1 A Monster

The first lens through which we explicate on these subtle dynamics is that of *a monster*. We use this term to illustrate how being entangled within a cyborg relation can not only be experienced as harmonious or co-operative but also as frictional or disconcerting. This distinction can best be seen in the contrasting accounts of the corset as described by Kelsey, who often felt the corset as a supportive extension of herself, and by Rachael, who more often found the experience to be discordant. The emergence of a harmonious cyborg relation was noted by Kelsey after one of the testing sessions: *"We are giving the machine our life force. Is it giving us our life force back? We breathe to*

keep ourselves alive. And we are giving it back to the machine. Where do we end and where does the machine begin?" This intimate exchange of air between wearer and artefact, perceived through the touch of human on machine, and vice versa, curated a perception of the artefact as exchanging information with the wearer—or that it was taking something from the user and transforming the breath/touch/shape-change into a novel output. The two separate bodies became amalgamated and fused together through their exchange of touch and breath. Kelsey, in her vignette, describes the corset as a supportive extension of herself - like a continuation of her inner voice, helping her "*turn inwards*" and guiding her through the exercises. For Rachael, however, the experience of the corset was less harmonious. She describes herself as feeling "*like a weak, soft, squishy part of the machine – a faulty organic cog bent out of shape in the system*" as she noted her difficulty in following some of the exercises. In contrast to Kelsey's reflection on the mutual exchange of breath, she felt as though the corset was "*draining*" her, her body was being emptied of air until she had "*nothing left to give*" More often, Rachael reported to feeling herself "*fighting*" or "*struggling*" with the corset during her engagement.

The materiality of the corset underscores a further dimension to this relation. Kelsey often recognised her own bodily practice in the corset. The feel of the pillows pressing on her as she was going through the exercises carried a curious similarity to how she would press and touch her own body during her personal singing practice. Since we used Kelsey's voice recording for guidance in the interactions, it was reinforcing this sensation to her. For Rachael, in contrast, the corset presented a defamiliarisation from her previous practice and experience of working with garments as a fashion designer. Ultimately, she needed to engage with the felt experience of wearing the corset to change her "*understanding of what a garment can be and what wearing a garment can entail.*"

To develop the concepts of discord, alienation, unfamiliarity, and challenged assumptions, we turn to the narratively rich lens of the *Monster* [10]. The Monster has been imported from the humanities to reflect on strategies to adopt technologies in everyday practices, which can be particularly useful for conceptualising discomfort reactions to novel technologies. The idea of the Monster has been applied to technologies such as nuclear power or artificial intelligence as they enter the public realm: people may fear and try to dispel them (monster exorcism), transform and tame the monster (monster adaptation), or embrace it as a utopia, or assimilate it by co-adapting the monster/technology and society [88]. We build on this metaphor to highlight how engaging with the corset changed both our bodies and our understandings, as both wearer and corset together reconstituted these dimensions to our experience, to assimilate the "monster" or to become familiar with it.

We take care not to present these–the supportive extension and the alienating monster–as two binary ends of a spectrum of experiences, nor do we position one as "good" and the other as "bad". We use these terms to illustrate that, through engaging with our felt experience of the corset, we came to two markedly different accounts of what it *feels like* to be a cyborg. However, as Kia noted in her reflection, her engagement with the corset left her "*tender*" but ultimately the experience was "*interesting, soothing*", and made her "*feel supported*". This reflects that our entanglements are multifaceted, and that binary distinctions between good experiences that support us and bad experiences that discomfort us do not serve to probe deeply into our relationships with new technologies. However, using problematising lenses such as the Monster are perhaps a generative and rich way of revealing and concealing different facets of human-technology relations.

6.2 An Organic Other

The second lens we use here is that of *an organic other*. Unsurprisingly, the corset was often experienced as an alterity, or an otherness, that engaged us in a "dialogue" of sorts. This alterity can be experienced in multiple ways; Kelsey saw it a version of herself in the role of instructor; Yoav

spoke of how it created a feeling of connectedness, "*similar to practicing with other people in the same room and acting in synchrony with them*"; Rachael described a "*whole bizarre kind of agency*" that encased her body. But we emphasise here that the lens of organic other goes beyond an alterity relationship, recognising the intentionality [102] of the technology, but perceiving a certain quality to this intentionality, namely that of being life-like, organic, yet still strange.

Many participants used animistic metaphors to refer to the sensations of touch performed by the corset. In the early stage of testing the Soma Corset with specialists from different backgrounds, a plethora of evocative descriptions were used: one person spoke about the experience as a slimy animal–a big octopus–touching him with its slimy tentacles. Another participant also referred to the corset as capable of giving "*tentacle hugs*".

We developed the interactions with attention to this early feedback, and these sensations are also echoed in the later versions of the corset. For example, Kia describes it as something "*organic*" approaching her from the outside, coming from the floor and pushing her body upwards; she describes how the movement of the pillows gave the sensation of "*these hands pushing and moving my body in different ways*". In Kia's reflections, she drew a picture representing this experience of the "hands" of the corset physically grabbing her flesh and pushing it upwards (Figure 12). Kelsey reported in her post-exercise interview how "*pillow number five did a jellyfish-like crawl up my back*" when playing back her back muscles movements as recorded by the corset during one of the exercises. One of the participants described his initial impressions of the Soma Corset when it was starting up and making all the pillows inflate in preparation for the exercise, as if the pillows grabbed him: "*I had this immense feeling of being grabbed, or being grabbed by something*". Another participant's experience drew parallels to Kia's in their respective idea of how the Soma Corset's movements resembled hands, with its grip and grasp on their bodies. The perception of many users about being grabbed and squeezed by the "hands" or "tentacles" of the Soma Corset emphasises its touch as "near-lifelike" or "uncanny".

Again, the morphology of the corset and the materiality of its touch and movement emphasise these dimensions to the experience. Both Pavel and Rachael spoke of the presence of the corset, both in its sound—"*a robotic choir*"—and in its body—"*its plethora of wires and flashing lights*". We believe that this large, unusual assemblage of parts–including the wearer entangled within its pillows and tubes–is a large contributing factor to why so many perceived it as alien and strange. Moreover, we think the perception of uncanniness, or near lifelikeness, is rooted in the distinct way the corset changes shape and touches our bodies; in the way it *moves* on the torso. Our perception of movement is deeply rooted in our experience of how we move in the world, and a central aspect to how we perceive and ascribe intentionality to others [84]. Movement, in this case, how we both touch and are touched by the corset, plays a fundamental role in constituting our perception and understanding of the technology and its intentionality.

When we built the corset, it shaped our intentionality towards it. As we shape its movements, the corset continuously reshapes ours, and this process reconstitutes our understanding of it and its intentionality. In this case, we see this relationship clearly in the uncanniness of the corset's touch, something deeply connected to movement as the human condition and our experience of being in the world. In the case of the corset, movement (through touch) has blurred the boundaries of human and technology in such a way that the technology is perceived as lifelike and organic.

6.3 A Twisted Mirror

The final lens we offer is that of *a twisted mirror*. We use this lens to describe our experience of a cyborg intentionality where the corset opens a new distorted reflexivity towards ourselves or demonstrates its own distorted intentionality towards us. We specifically use this lens to address our experiences of having the corset replay its recording of our breathing, such as in Appoggio

or Fricative Exhale. During these exercises, the corset and wearer together constitute a new reflexive intentionality–where the corset allows the wearer to experiencing themselves in a new way–feeling their own breathing as sensed by the corset. It becomes a *hermeneutic* relationship of sorts [42], but where the sense-making process of these experiences again reveals multiple nuanced dimensions to experiencing ourselves through the cyborg relation; sometimes we recognised ourselves, at other times the corset distorts us in ways that make us feel alienated. At yet other times, this distortion is so great that it shifts our attention away from experiencing ourselves, moving instead into an induced intentionality, where we become fascinated by the corset's intentionality towards us, thereby bringing our attention to the distorted way in which it seems to "experience" us.

These shifts between recognition to alienation are echoed by many participants. Pavel explicitly characterised it as a "*twisted mirror*", sometimes able to mimic, sometimes feeling like an alien. Yoav recognised himself in certain moments, such as when he "*hiccup[ed] midway through the exercise and could feel the corset hiccup back at me at the replay!*" but sometimes the playback felt foreign to him. Kelsey recognised a "*past iteration of my body*" but would sometimes rapidly shift into asking herself whether this was indeed herself she was experiencing or "*whose body is it?*" Other participants instead described these experiences in terms of the corset's own intentionality towards them. Kia reflects on a "*mesmerising*" experience, having her body pushed upwards by an "*unknown, organic entity.*" Rachael, in her vignette, describes the experience of her own breathing as the corset trying to "*extricate me – squeeze and wiggle until I became disentangled from it – getting rid of me from the machine.*"

Again, we draw attention to how the materiality of the corset helps shape our experiences with it. Though occasionally these distortions made us question whether there was some "*error in the corset*", moments of recognition confirmed to us that the corset was indeed working properly (even if what it was replaying back to us could only ever be a reductive account of all of our torso's movements). It was possible to disobey the instructions given in the exercises and, for example, breathe faster. A really fast breathing pace would, in turn, make the corset twitch and vibrate wildly when it was trying to replay what it had recorded. These non-normal patterns were mostly perceived positively, as it confirmed to us that the corset was able to record our movements properly. But further, these recorded distortions arise from the corset itself, in its strangeness as an artefact, its presence and morphology, and its own way of moving and touching our bodies. Subsequently, we think that it is not a matter of simply refining the corset until it offers us an exact mirror of our breathing, but instead deeply exploring the ways in which it is different and the new experiences it offers.

This lens highlights several subtle dynamics to our experience of this kind of cyborg relation. First, it focuses specifically on how our own perception of ourselves is partially constituted by technology. Secondly, it foregrounds the distinctions between experiencing ourselves through the corset, experiencing the corset's perception of ourselves, and experiencing the corset's intentionality towards ourselves and further, how each sheds light on a slightly different facet of the human-technology relation. As with the monster, the problematising lens of the twisted mirror can be used to draw attention to ethical aspects of our relationships to technologies, and as with the organic other, expand this discussion on how cyborgs are always being reconstituted. Furthermore, we argue that nuanced lenses reveal different dimensions to the multifaceted, temporal nature of our experience of human-technology relations. Engaging with these multiple dimensions, and the material qualities of artefacts that help shape them, can be another path to realising the somaesthetics appreciation ideal by Shusterman [86]: attending to all our senses, deepening our appreciation of what we feel, widening our repertory of movement and thereby our experience, and ultimately teach us how to live more fully and wisely.

7 CONCLUSIONS

The three lenses outlined above are not intended to fully capture the multi-faceted nature of our relationship to the corset. We recognise that each lens only captures a reductive dimension to the complex experience of a human-technology entanglement. However, they are significant for two reasons:

First, they are representative of the subtleties and nuances that emerge through focusing on the felt experiences of human-technology relations—as in soma design. Soma design helps foreground the lived body, felt experience and through its deep engagement with the sociodigital materials, and has proved to be a fruitful method for us in expanding the design space of digital touch beyond "natural", human-like, interactions and towards meaning-making of machine-like touch. The articulations of these lenses also shows how postphenomenology can add clarity to what these relations might be and how soma design can add the felt dimension to a postphenomenological analysis.

Second, these three cyborg relations, revealing different forms of perceived hybrid intentionality between wearer and corset, shed a new light on digital touch and what machine-like touch might bring to the table.

Let us turn to each of these two contributions in turn.

7.1 Felt Experience of Human-Technology Relations

As mentioned at the beginning of this article, what we came to uncover through our felt soma design process were digital touch experiences which do not mirror human–human touch nor human–object touch, but instead revealed the potential of machine-like touch. As shown by Höök and colleagues [38], soma design offers a non-dualistic design stance with strategies for bridging the body-mind divide. Soma design asks us to attend to our inner universe, and in turning our attention inwards we "dissolve or traverse dichotomies between inside and outside; individual and social; body and technology" [38]. These blurred boundaries can be seen in the accounts of the Soma Corset above: the wearers shift between feeling their own breathing on the inside, to feeling it replicated on the outside, and to situations where it is not clear where the breathing is taking place.

Postphenomenology proved a useful tool for helping us approach the analysis of our engagement with the corset and offered a concrete set of relations as the starting point from which to examine our vignettes. However, this approach was further augmented by our commitment to the soma design stance and first-person engagement with the felt experience of being entangled with the corset. Rooting our analysis in "how it *felt* to be a cyborg" allowed us to develop richer and more nuanced lenses that highlighted specific nuances or dynamics to the cyborg relation.

Our accounts of our design process and wearer experiences shows how cyborgs are mutually constituted. Humans and technology together do not only co-constitute, for example, a seamless constructive intentionality where the human and technology together bring forth a new combined intentionality. Human and technology are continuously establishing and reconstituting the intentionality of the other part of the cyborg. This position in turn harmonises with the fundaments of somaesthetic theory that posits that not only are movements and the living body the lens through which we can understand the world, but that this "tool of tools" is also moldable [86, 87]. That is, digital touch can serve a productive role, adding to ours and our end-users' somatic selves.

We further emphasise the Soma Design position on deeply engaging with the materiality of artefacts [37]. The material qualities of an artefact have long been shown to be critical to our relationship with technologies [65, 67] and this is reflected at many points in our analysis, not only in the morphology, sounds and other material qualities of the artefact but also in our familiarity with the artefact as designers and practitioners. This further underscores the potential of postphenomenology to augment soma design as a means of understanding the role materiality

plays in such relations, and also the potential of soma design to offer practical methods to engage with these materials in the design process.

Engaging with the technology in this way also allowed us to uncover multiple facets to a single relation. Not only could we categorise our experience at times as being—for example—a reflexive intentionality [77], but we could identify how this relation was experienced (as distorted or twisted), as well as a nuanced account of the relation's effect in how we perceived both ourselves and the technology. The implications here for digital touch are profound. We touch, and are touched by, these technologies. Our relationship to them is unequivocally felt and experienced though the body. Therefore, engaging in our relationship with them through the body is key to understanding how they are experienced and uncovering multiple dimensions. These dimensions could help shed light on how digital touch technologies are experienced. Not only could this enhance our ethical understanding of such, but also offer insights in how to design technologies that engage our most intimate modality.

7.2 Implications for Designing "Unnatural" Digital Touch

Through our open-ended design explorations, repeatedly feeling and reconfiguring shape-changing materials and how they can be applied to our torsos, we managed to move beyond mediating touch or replicating human–human touch, and instead entered a different landscape of digital touch experiences. This in turn led to debates in our project. First, it made us question the idea that touch is intuitive and natural, and therefore should be mediated in high fidelity, mirroring how it unfolds between people, or between people and physical objects. Second, we came to see how a deeper understanding can be gained by reflecting on the boundaries of the cyborg relations: what is inside vs. outside of our bodies, what makes us perceive it as a *monster*, what might let us feel "one" with the system–embodied or entangled with it–or what makes the system turn into a lifelike organic *other*, or a *twisted mirror* of ourselves.

7.2.1 There is Nothing Natural About Digital Touch. Our design journey has led us to question what digital touch entails. A first common interpretation of digital touch might imply that a certain stimuli, applied to the skin or pressuring our muscles or inner organs, should render certain perceptual reactions. Another established interpretation of digital touch emphasises solely the gentle, the positive, the kiss, the hug, or the light caress mediated through technology. The belief is, that all we need to do is to translate the positive aspects of touch to arrive at a closer connection to one-another. A third interpretation of digital touch is that it should stay close to the experience it is mediating, be it human–human touch or touching an object. While these assumptions hold true and have been successfully employed in healthcare and rehabilitation domains [48, 82, 94, 101, 107], we wanted to provoke another perspective to digital touch by questioning these assumptions in our interactions. The corset is not gentle. It does not mediate the singing teacher's breathing exercises unaltered. It does not even let us re-experience our own bodies, mirroring our breathing patterns in an unequivocal manner. Instead, it brought novel experiences and novel reasons to engage with our breathing apparatus. The touch mediated by the Soma Corset was at times harsh and brutal. It led to experiencing an inner massage, of having our organs, muscles, bones, and fascia being pushed around, squished, enforcing other body postures. Afterwards there were sometimes lingering effects that would last for hours. At other times, it was gently acting in the background, letting us get on with our work while subtly influencing our breathing pattern.

Similar to how Norman argues that "natural user interfaces are not natural" [63] but instead are purposefully designed novel gestures feeding off the glass screen's affordances, we argue that digital touch is not "natural touch", but needs to be carefully designed to feed off the material properties of haptics, in this case, pneumatically driven shape-changing materials.

7.2.2 Playing with Boundaries. Through our design explorations, digital touch became a rich space enabling not only utilitarian aims (such as learning a novel breathing repertory or training your muscles and nervous system reactions), but also reconnecting us with ourselves in novel, defamiliarised manners or even experiencing an otherness, an alien, a monster.

Our design exploration, and particularly our articulation of the cyborg relationship, highlights how wearable technologies can alter the proprioception of the users' bodies [50], both during wear and even after removing the corset. This has consequences for how we design with digital touch. As the proprioception of the wearer changes, with the corset being felt as if it was both "*growing out of our bodies*" and "*massaging the internal organs*", we can also put in question the skin as a site where we evaluate and locate touch experiences. As the corset can uncannily touch our insides through exerting deep pressure, we wonder what other novel forms of on-skin shape-changing actuation can be designed, aimed at altering bodily perception not over but under the skin, be it through squeezing or other forms of actuation.

Additionally, this suggests that attention should be paid to how are we changing the bodies of those we design for, a question that has ethical implications [18]. Ultimately, our aim as soma design researchers is to expand upon our repertory of somaesthetic experiences, to increase our aesthetic appreciation of ourselves, others and the world around us. A richer repertory of possible digital touch designs, will offer a richer repertory of possible somaesthetic experiences, leading to larger freedom, more choice, an enriching, generative ethical stance—both for designers and to future end-users. Building on previous work [7, 95], we suggest that the exploration of uncomfortable interactions and frictions can be a way to probe the limits of touch, and to come to know and understand what is possible and (un-)desirable, and under which circumstances.

Finally, as we design wearables for both becoming aware and altering somatic experiences, we found that touch was a useful concept to think about where the boundaries lie between bodies and machines, and who is touching and being touched.

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