

# “Vibrant Wearables”: Material Encounters with the Body as a Soft System

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## Keywords

Soft systems; soma design; wearables; vibrant matter; body

## Abstract

As new materials become available for textile and interaction designers, it is crucial that we develop an understanding of the lived experiences of such materials and explore meaningful contexts for their development. In this paper, we engage with systems in which bodies as materials and materials as bodies constitute an assemblage of vitalities in constant flux with one another. In particular, we address how such systems in their interactions with (non)human bodies blur boundaries between inside and outside the body, and between human and machine, acting as *soft systems*. Drawing on our first-person, designed research, we present three design explorations of soft systems that deeply engage with the body: Breathing Wings, Fiddling Necklaces and Menarche Bits. We analyze how the three projects contribute towards what we conceptualize as “vibrant wearables”: wearables that through their material vibrancy surface design qualities of *leakiness*, characterized by a multi-directionality of “spilling over,” *ongoingness*, which attends to non-linear temporalities and cycles of life and death, and *mutuality* that emphasizes the interdependency, and becoming, of vibrant encounters. These three design qualities all conceptually trouble boundaries of bodies and materials and are practical resources for designers and researchers working with the body in/as a soft system. Our work offers concrete examples of how to work with material vibrancy, which is particularly relevant to new materialist discourses in textile, fashion and interaction design. We argue for the generativity of these design qualities for other designers and researchers aiming to elevate materials and soft systems in interactions with bodies. Moreover, we contribute towards design research that conceptually and materially troubles the boundaries of the body, and we argue for attending to the material power of (non)human bodies as a soft system.

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## Introduction

Within interaction design, the notion of the human body is often bounded by the skin (Figure 1). From this perspective, a body might be designed for or designed to participate in external systems. Examples include wearable devices that augment human senses or ride-sharing infrastructures that facilitate transportation of people. When technology breaks the boundary of the skin, such as a biometric chip inserted into a hand, it is often positioned as *being inside* a body (Heffernan et al. 2016); and when technology is used to examine a secreted bodily fluid, it is often implied as *looking inside* (Homewood et al. 2019). While these approaches can be both useful and meaningful, the implied physical boundaries between inside and outside of the body, and between human and machine, risk strict assumptions that the materiality of a system is limited to computational components.

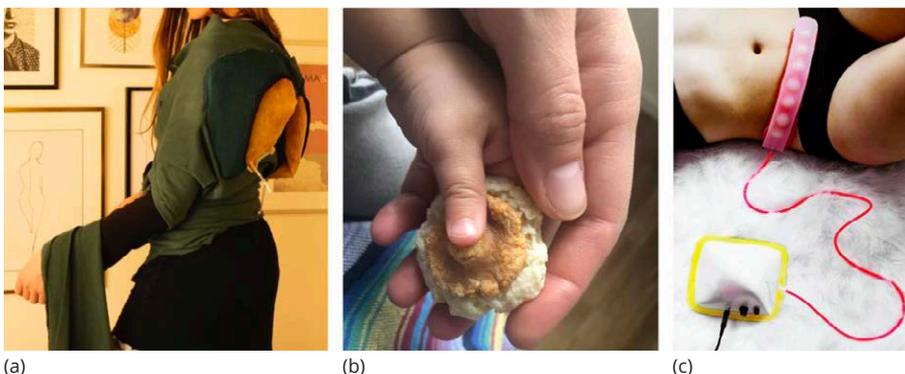
Conceptualizing design materials as inherently “active” (Fuchsberger et al. 2013) is an approach that has been taken to investigate boundaries and entanglements between the body and technology. This includes exploring how materials participate across social and cultural contexts (Jenkins et al. 2018) and articulating how the experiences of materials in turn shape ways of doing design (Giaccardi and Karana 2015). Such appreciations for material properties and their relation to the body have also been used for the design of shape-changing interfaces (Schraefel et al. 2018) and new design practices (Vallgård et al. 2016). Further blurring of material encounters are co-productions between humans and machines in hybrid making practices (Devendorf and Ryokai 2015). We build upon related work through Bennett’s (2010) articulation of *vibrant matter* in which all human and not-quite-human matter “*always depends on the collaboration, cooperation, or interactive interference of many bodies and forces.*” Bodies and/as materials are vibrant through their efficacy as animate entangled things rather than passive individual objects. Our definition of a soft system is grounded in this material agency in which bodies as materials and materials as bodies are an assemblage of vitalities that are in constant flux with and through one another. Through this lens, we aim to open new design spaces that question bodily notions of inside/outside and embrace a plurality of bodies and experiences (Höök et al. 2019).

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**Figure 1:** Design explorations of the body as part of a soft system, through (a) the Breathing Wings (b) the Fiddling Necklaces, and (c) the Menarche Bits.

We present three rich design-led inquiries that place the body in dialogue with materials and wearables: The Breathing Wings, the Fiddling Necklaces and the Menarche Bits. These distinct design explorations investigate particular material encounters with the body as a soft system in relation to the vibrancy of the materials used in each case: textile, latex, silicone, bodily fluids and technology. They explore designing wearables in tandem with bodily materials including breast milk, breathing, menstrual blood and flesh, and thus expand the notion of wearables beyond or beneath the boundary of the skin. We find inspiration in soma design (Höök 2018) as an approach that rejects the dichotomy between body and mind, and that fosters a slow cultivation of attunement and appreciation for the soma as a whole, including body, emotion, and movement. Pragmatically, a soma design process has the body as a starting point and leverages on the aesthetics afforded by sociodigital materials, meaning digital, physical materials and our own somas, and the act of shaping them into orchestrated experiences (Höök 2018). In soma design, the body is not an isolated system but a lively mess of social, political, and biological mechanisms that can be designed *with*. It is from this perspective that we view the body as a soft system: not rigid but fluid, always acting and reacting, fleshy yet porous.

Each design exploration in this paper evolved as a Research through Design (RtD) process (Gaver 2012; Redström 2017) in which three design strategies common in soma design were used (Höök 2018): 1) estrangement and de-familiarization, 2) somatic exploration of materials and technologies, and 3) first-person reflections. Uniting our explorations is a crafting towards textiles that through their proximity to and relations with the body foreground material alliances between the soma and technology. Through analyzing our three projects, we propose “vibrant wearables” as wearables that via their vibrancy surface qualities of *leakiness*, characterized by a multi-directionality of “spilling over,” *ongoingness*, which attends to non-linear temporalities and cycles of life and death, and *mutuality* that emphasizes the interdependency, and becoming, of vibrant encounters.

Our work offers new pathways for making and living with the material vibrancy of bodies that breathe, lactate, and menstruate. Through a focus on the experiences of vibrant wearables, we foreground the entangled material agency of bodies and soft materials through design. We delve deeper into the properties of material vibrancy when bringing your own body into this design space, not a neutral/passive body to be only designed *for*, but a body with agency to be designed *with*.

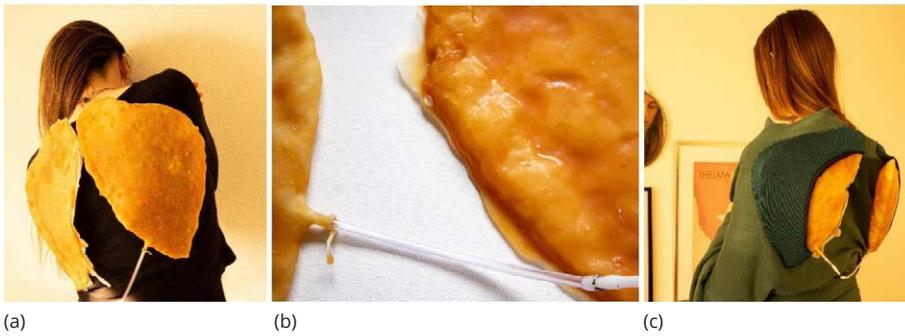
### **Research Positionality and Methods**

The three projects share Research through Design (RtD) as their methodologically approach and the human body as their main point of departure. Research through Design is a practice-based research approach that, through design work and the making of things, produces new knowledge (Gaver 2012; Redström 2017). Situated within interaction design, our research focuses on the design and use of new technologies,

and in this context, RtD methods allowed us to engage with processes of material exploration, interactive prototyping, and shared experiences. Within RtD, our projects employ Soma Design (Höök 2018), which takes a holistic perspective on the mind and body — the soma — as a starting point for design. From its roots in somaesthetics theory (Shusterman 2008), soma design emphasizes becoming attentive to and improving connections between sensation, feeling, emotion, and subjective understanding and values (Khut 2016).

There is a variety of soma-based design strategies to improve designers' somaesthetic awareness and design rich experiences. We followed three strategies: 1) estrangement and de-familiarization, 2) somatic exploration of materials and technologies, and 3) first-person reflections. Making "strange" or disrupting the habitual ways of engaging with bodies (Wilde et al. 2017), helps attend to what is non-habitual and thereby raises awareness to what is habitual. Through de-familiarization, designers become attentive to the entanglement of nuanced perceptions and fine-grained experiences as design resources. Engaging in the somatic exploration of materials and technologies allows extracting the aesthetic potential and affordances of materials through careful touching, moving, giving form, and slowly experiencing (Höök 2018). Finally, using first-person reflections is a common approach in RtD and soma design (Höök et al. 2018) that puts an emphasis on subjective experiences arising from the other two strategies. First-person approaches draw on phenomenology and rely on the designer's lived experience and perception of their fleshy body, through which, according to Merleau-Ponty (2002) we live our lives and experience the world. Taken together, these strategies help each project trouble assumptions of the body, explore its material agency as part of a soft system, and blur encounters between the body, materials and technology. In addition, reflection-in-action (Schön 1983) was central in our design processes, serving as a form of validation and critique for our design choices based on the subjective review of our experiences along the way. This follows the argument that research rigor in autobiographical processes implies careful reflection on one's work, focused on being critical, explicit and thorough, rather than aiming at generalizability (Desjardins and Ball 2018).

For each project presented, we do not depict the entire design process, and instead draw attention to a potential stage of a design process. The project Breathing Wings investigates in-depth encounters with a wearable body extension through breathing, both the wearer's and the wearable's breathing, and puts focus on experiential body implementation. The project Fiddling Necklaces examines the felt materiality of mammalian milk and puts focus on an understanding of material execution. The project Menarche Bits notices and appreciates experiences of the menstruating body and menarche, the very first menstrual bleeding, and puts focus on shared and participatory applications.



**Figure 2:** The Breathing Wings: (a) The Wings touching the upper back and shoulder blades, (b) The materiality of latex, (c) Latex shapes and textile on the shoulder blades, breathing in and out through shape-change actuation.

### Three Design Explorations of Soft Systems

In the following, we present our design explorations of the body as a soft system. Each project is presented as a first-person account from the perspective of the author who was leading it. We present each project's background and motivation, what it is and what it does, and how each project blurs the boundaries of body and wearable and approaches the body as a soft system through the vibrancy of materials.

#### ***Breathing Wings***

*(1st Author: Vasiliki)*

The Breathing Wings is part of a larger project exploring paths towards creating evocative and aesthetic somatic experiences through shape-changing soft materials worn on the body. The garment itself, seen in Figure 2, is a wearable body extension that invites the wearer to pay attention to and reflect on their body and in particular on the area of the upper back, where the shoulder blades are positioned. It is made of textile and has latex shape-changing elements that can inflate and deflate using an Arduino Pneumatics microcontroller connected to air pumps that can be controlled through an application developed on a mobile phone. The wearable covers mainly the back side of the body, extending from the neck to the lower waist, and it has pockets covering the areas of the left and right shoulder blades, where the inflatable latex shapes are inserted and stay in place. Having a garment that breathes, while being attached to the breathing body, messes and troubles the perception of where the body ends and where the wearable begins, as both body and wearable breathe and have vibrant qualities.

Following first-person experiences and reflections on my body, I considered my back and shoulder blades as a somewhat "forgotten" body part and designed the Breathing Wings to help me raise awareness of this forgotten bodily area. When the "wings" inflate and deflate, I can experience different patterns of shape-change on my back. The shapes are "breathing" in and out, touching the back and evoking a range of somatic experiences, suggested by this body extension and materialized at the meeting between body and wearable. Feeling the soft latex bladders changing their shape against the skin evokes a sensation of someone touching me on the back -a touch that can either be soft and

subtle or more abrupt and sudden, depending on the rate and speed of inflation and deflation. Wearing this garment and feeling the shape-change against the skin on the shoulder blades also evokes a feeling of imagining having wings or having something alive attached to the back that breathes in and out. But at the same time, it evokes creepy feelings of "aliveness" extended from the inside of my body (breathing as an internal mechanism) to the flesh and to a wearable acting almost like a parasite attached to the body, that might suggest, or even force me on how to breathe.

The design process was guided by soma design methods, in which close attention was put on the felt experiences and sensations evoked when wearing the Breathing Wings and when the actuation was applied on the skin. Through an RtD approach I investigated felt somatic experiences evoked through encounters between soft shape-changing materials and the skin/flesh on the area surrounding the spine. This is an area on our bodies that we cannot see, and we cannot easily touch ourselves. Additionally, the experience of wearing it carefully and making sure it is firmly positioned on the body resembles a kind of ritual, as it needs attention and time to wear it -there is a commitment in the wearing process. When the Breathing Wings are in place, the boundaries between where the body ends and where the wings begin becoming blurry, i.e. it becomes an extension of one's back. It also feels intimate and personal -it is a secret experience and interaction, as only the wearer can experience and feel the breathing of the wings (their inflation and deflation) touching them, and this is barely visible to an external viewer.

The wearable was inspired by the work of the artist and performer Rebecca Horn, who investigated the body and its movements through different body prosthetics, known as *body modification sculptures*. Similar to her early body sculptures produced in the 70s, the Breathing Wings was designed as a body extension for "*investigating into the body's limitations and its sensory and tactile perception as an extended form of self-perception*" (Horn et al. 2019). The Breathing Wings is also in line with previous research conducted by Wilde and Andersen (2009), investigating the body through a series of speculative body-devices, as referred to by the authors, designed without a predefined function. Similarly, the Breathing Wings was made as a rather poetic artifact that initiates the wearer into a unique experience of (re)discovering their soma and exploring new sensations felt on their back, emerging through the encounter and interaction at the meeting of body and wearable. Another related project was made by Dobson (2005), who designed a series of wearable body organs to explore the interplay of people and machines. As she describes, these wearables are "*very visible, spectacular or carnival even, play-use objects-devices-equipments that [ ... ] announce their own need for existence by being used in public without being hidden*" (Dobson 2005). Similarly, the Breathing Wings resembles a speculative body organ that is attached to the upper back, inviting the wearer to question the boundaries of the "inside" and "outside" of their body. Feeling the wearable changing its shape in a breathing-like function that

makes it seem like an alive entity, invites for reflecting on where the body ends and where it begins.

## ***Fiddling Necklaces***

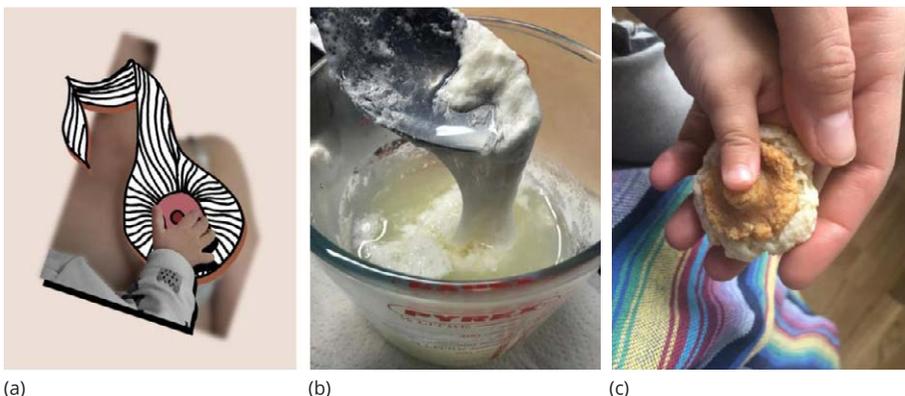
*(2nd Author: Karey)*

Fiddling Necklaces (Figure 3a) explores maternal care and the somaesthetic appreciation of a secreted bodily fluid through making intimate jewelry from mammalian milk. In this project, both milk as a biomaterial and jewelry as a desired result are considered textiles.

Necklaces worn by a mother for a baby to fiddle with while breastfeeding are common to prevent hair pulling and environmental distractions. My desire to make fiddling necklaces is grounded within my own physical and social frustrations during which my baby wants to fiddle with the other nipple while breastfeeding. While this discomfort drove the initial inspiration, I further desired for the hard components of the necklaces to be made from preserved and solidified breast milk. In this way, by temporarily taking away the other nipple and removing fiddling as a mechanism of milk stimulation, I am reciprocating something else of the breast in return. Though working with breast milk as a design material has been more challenging than expected, and it is through my process that bodily relations and mechanisms are exposed.

The preservation of breast milk into jewelry is not new and is often seen in external services that create keepsakes to commemorate a breastfeeding journey. Such services capitalize on the preciousness of breast milk as unique to each nursing relationship, temporally bound, and often not without physical and emotional suffering. They typically employ proprietary chemical techniques of which it is unclear if toxins could be leaked. In addition to this concern, I did not want to go through the labor of expressing breast milk solely for this project and thus used what I considered to be “waste” breast milk: expressed milk that had either been frozen and was expired, or would otherwise be thrown out once “tainted” from backwash.

The labor I wanted to leave untampered was not only the explicit work involved in pumping and cleaning, but also the work of a suckling baby. Mammalian milk is based on supply and demand: the more



**Figure 3:** Fiddling Necklaces: (a) A Fiddling Necklace design, (b) Cow's milk experiment, (c) Nipple model from casein plastic.

one feeds or expresses milk, the greater the supply. And while the potential of manipulating my supply for a purpose other than normative breastfeeding expectations might be considered socially perverse (Giles 2004), my own hesitations lay intimately within the “invisible, immeasurable and unknowable” hunger, or gentle cannibalism, between a mother and a child (Otomo 2014). Despite a recognition of the inherent contradiction of the designs themselves as an intervention, I was uncomfortable further interfering with our unique bilateral exchange of bacteria, hormones, affect, and physiological and psychological thirsts without knowing the potential immediate, daily, and long-term effects on myself, my baby, and our milk. For these reasons, I opted to first design with cow’s milk as an abundant and established design material that I assumed would yield similar results.

Solidifying and preserving cow’s milk was invented in the early 1900s (Brother 1940). It involves extracting a protein called casein and mixing it with formaldehyde, which results in a plastic. While more recent bioplastic design research has revisited the making of casein plastics as a sustainable plastic alternative (Silva 2020), the process of extracting casein from cow’s milk can safely and easily be achieved at home. This process entails: warming a cup of cow’s milk in a pot over medium heat until steaming, removing from heat and adding four teaspoons of vinegar, stirring with a metal spoon until curd-like solids (casein) separate, removing and molding curds into desired forms, and letting dry for at least 24 hours until cured.

I made a series of casein plastic beads using cow’s milk with different fat percentages to explore the material consistency and pliability (Figure 3b), as well as adding spices for different colors. As I became acquainted with the technique, I made a model of my left nipple aligned with one of the sketches (Figure 3c). While I was excited about the results, the chemical interaction and molding process felt uncomfortable and disturbing. Knowingly extracting a protein from cow’s milk incited recognition of the liveliness of my breast milk, and in particular its microbial composition and cellular structure that classify it as a living tissue even after secretion (Witkowska-Zimny and Kaminska-El-Hassan 2017). Despite not working with my own milk, I felt as if I was “killing” the biomaterial through a chemical transformation rooted in a contradictory desire for it to live forever. I imagined the resulting artifacts akin to an appendage, brought forth through an external replication, yet buried alive in its creation. This revulsion towards the process soon shifted towards the artifacts as they later began to smell foul and seep greasy substances. Although unintentional, these process byproducts and my reactions echo related research deliberated aimed to evoke ambivalent feelings of disgust and interest towards milk to challenge societal perceptions (Sutherland 2020).

Despite my initial reactions, I next experimented with my breast milk. The making of casein plastic out of my own milk completely failed, resulting in an acidic smelling pot of unusable milk. Following

subsequent reading that I naively should have done before, I learned about the fat and protein compositions and differences between cow and human milk that resulted in this failure. My assumption that they might be interchangeable signifies my own cultural biases towards an interspecies entanglement that hid the mutuality between a mother and child that itself is a soft, intimate system driving the “unseeable” mechanisms that make breast milk unique to a species and within a particular breastfeeding relationship.

## ***Menarche Bits***

*(3rd Author: Marie Louise)*

Menarche Bits is part of a soma-based participatory design research project that explores how wearable textiles and technologies can create freer movements and appreciation of the menstrual cycle for young adolescents (Søndergaard et al. 2020). Menarche Bits is designed for experiences of menarche—the first menstrual bleeding typically occurring between the ages of 9-15.

Textile, soft systems, and biomaterials have historically been used to “control” and “contain” the leaking menstruating body while promising free movements in the world. Belts with cotton linen, sphagnum moss pads, menstrual extractors, “hygiene” pads, tampons and menstrual cups: Access to and use of such materials are critical for menstruators’ movements in the world. Menstrual cramps are also a crucial matter that can shape menstruators’ movements. Like menstrual blood, cramps can be experienced as an “otherness,” although within. While textiles can further constrain movements during menstrual cramps, for instance through tight pants and spandex, textile can also allow subtle massage of the painful pelvis through the use of pockets in dresses within which hands can move freely.

Starting to menstruate can be associated with feelings of pain or pride. It may be something one shares with trusted ones or hides from the world. Whether menarche experiences are positive or negative, they add to other crucial transitions through puberty. With Menarche Bits, I wanted to make a space for attending to and caring for the young menstruating body. Given that it is many years since I experienced menarche, to design for it meant that I had to remember and resurface my past experiences of starting to menstruate: experiences such as seeing menstrual blood for the first time in my underwear, looking for access to toilets, carrying menstrual pads in my sleeves or pockets, or feelings of deep menstrual cramps.

Menarche Bits is a collection of heat pads and soft pneumatic actuators made of silicone that can be in contact with the skin or inserted into fabric pockets as part of a garment. When pressed down into the skin, the bits sense the touch and create a soothing feeling, massaging and molding the flesh and muscles. The shape-changing actuators allow for freedom in movement, as well as expansion, bending and wrapping around by twisting. The interaction is orchestrated by a control unit



(Bobel and Fahs 2020). Menarche Bits seeks to make space for such material encounters through encouraging movements and playful exploration by using the heat pads and soft silicone actuators on the body. Together with the menstruating body, Menarche Bits forms a soft system where one's phenomenological experience is co-shaped by the technology, one's biological materiality, and the body's discursive representation and social context.

## **The Vibrancy of Wearables**

The three projects are examples of wearables (in the shape of garments and jewelry) that use new soft materials to deeply engage with the vibrant materiality of the body. We see common threads running through all projects, as well as frictions that make each project stand out. These offer a broadened perspective on how designers can approach the body as a soft system, and what a "vibrant wearable" might be. In our projects, "vibrancy" is a theoretical commitment to the creative efficacy of all human and not-quite-human bodies as animate and entangled materials (Bennett 2010). In particular, we focused on three qualities that we encountered in exploring vibrant matter (leakiness, ongoingness and mutuality), which we traced back to the making, use and experience for each project. Through these three qualities we reflect on how each project highlights aspects of vibrancy within making and living.

In the case of the Breathing Wings, the material vibrancy was highlighted through the latex material used, and through their performed act of breathing. The tactile and visual properties of latex experientially resemble human organs or skin. While being in close contact with flesh, the latex shapes "breathe," which adds an additional layer of "liveliness" and enhances the dynamic embracing experience of wearing. According to the designer/author, the more she worked with this material, and the longer she experienced the Breathing Wings, the more aware of its vibrant material qualities she became. To her, the shape-changing latex shapes have a life of their own while being attached to her. This experience troubles the boundaries of her body through the skin felt in between her and the body extension, and through the co-breathing experience shared between wearer and wearable that evokes creepy feelings of shared agency and control over one's breathing.

For Fiddling Necklaces, the use of breast milk put a strong focus on vibrancy during material transformation, which also influenced the perceived vibrancy of Fiddling Necklaces as wearable artifacts. As the designer articulated, while working with milk and while knowing it is "alive" as a bodily-produced substance, the process felt like she was "killing" the milk through the chemical transformation and desire to preserve it. Even if she did not actually use her own breast milk in that particular material exploration, there was an imagining that happened as she worked with this biomaterial: she felt like she was replicating an appendage only to bury it.

Finally, in the Menarche Bits, the vibrancy of menstrual blood was a

strong motivation and starting point for design. Taking the menstrual blood as a vibrant bodily material one step further and combining it with heat actuation and soft silicone shape-changing materials opened up for new encounters with the menstrual cycle. It allowed for embracing the “otherness” of the menstruating body, but also for co-existing with the fleshy fluid menstruating self and the body as a soft and vibrant material system that experiences transitions and changes.

However, what we would like to draw attention to is not so much the actual existence of the material vibrancy in each project. We argue that material vibrancy exists in any encounter with materials regardless of them being soft or hard, since materials themselves are vibrant (Bennett 2010). What our research offers is the articulation of how this vibrancy is encountered, brought forth, observed, and even reconfigured through design. We present lenses through which designers can become attentive to and design with the vibrancy of soft systems. Specifically, we discuss our contribution using the concepts of *leakiness*, *ongoingness*, and *mutuality*. These three entangled qualities emerged through a shared analysis and critique (Bardzell 2011) of the three projects conducted by the authors. We discuss each concept as a design quality and provocation that troubles the vibrant material encounters of the inside and outside, the flesh and the system, the textile and the body. They are far from being exhaustive, yet offer a fruitful ground for researchers and designers working with soft systems.

### ***Leakiness***

The first design quality that we propose is *leakiness*. Within interaction design, leakiness has been conceptualized in the light of leakage of digital information from, e.g. surveillance cameras (Pierce 2019; Helms 2017) and knowledge leakage from low-fidelity artifacts (Andersen 2017). Our account of leakiness distinguishes itself from this prior work, by primarily drawing on feminist theories of leaky bodies (Shildrick 1997). We see leakiness as a core material force that creates vibrancy, and which is present at the meeting between materials and the body. Leakiness is observed when materials and bodies (or materials produced by the body) spill over: from one state to another; from one material to another; or between soft materials and soft flesh. We propose that one can actively design with leakiness as a quality of material vibrancy, and through this trouble and question the directionality of material forces. To which direction are material entanglements leaking and how does the body participate in this leakage?

Reflecting on our projects, the leakiness of each is manifested in different ways, and consists of diverse material entanglements of flesh, skin, soft materials, and various forms of technology. In the Breathing Wings, leakiness is observed and experienced upon wearing. The actuation felt on the skin in the form of inflation/deflation, which causes the shape-changing materials to expand, creates an effect of “pushing back” against the skin and into the body. Having this wearable tightly wrapped around her body, the designer experienced a leakage

towards her flesh, feeling like it spilled towards the inside of the body, reaching the muscles and bones. Leakiness in this case has the effect of making her “feel” the anatomy of her back or imagine it when the latex shapes touch her in different ways (softly, hardly, on the bone, on the muscle, or on a cavity between muscles and bones). Leakiness in the Breathing Wings is also experienced as “the leakage of breathing” that spills over from the wearable simultaneously towards the body and against it. This messes with the breathing experience, usually perceived as an internal bodily process that gets externalized, by becoming a multi-directional bodily experience.

Menarche Bits on the other hand, takes inspiration in the already present leaky qualities of menstrual blood and liquid silicone, and translates these into the design of the soft robotic bits, which are red/pink organic shapes. If Menarche Bits are used for menstrual cramps, the material force of their air inflation can further leak back into the cramping uterus that expels the menstrual blood, “pushing back” and massaging the inner flesh as also experienced in the Breathing Wings. Similar to menstrual blood, breast milk is often considered to have leaky qualities. Yet it is often only thought of leaking “out” of a breast or “into” a child; the latter of which is evidenced in concerns for toxic material-flesh encounters. The Fiddling Necklace process blurs these conceptions by exposing other directionalities in attending to, within a fear of tampering with, bilateral exchanges between a mother and baby. In this context, leaky milk can be in response to leaky thirsts that are hormonally conveyed through suckling, crying, and other fleshy and non-fleshy sensory stimuli that can be thought to “pull forward” a spilling over.

We see leakiness as an important quality of material vibrancy that needs to be considered when designing textiles, through its strong focus on the material forces being present and the spilling of such forces in diverse directions. By becoming attentive to the “spilling over,” we can re-consider what vibrancy might not only mean, but also do, in complex soft systems that include bodies, new materials, and technology. As exemplified through our design cases, we argue that it is by exploring leaky body materials in tandem with technology, textiles, soft matter, and by designing with the leaky qualities of such diverse material combinations, that vibrancy can be brought forth and worked with as a design material. Furthermore, we conceptually see the forces of “pushing back” and “pushing forward” as experiential qualities of leakiness to design with. By attending to such forces, designers can be more attuned to potential unintended and intended material consequences and thus practically care for leakiness. Reflecting on our design examples, an “outward” leaking from the body can be also considered as leaking “inward” or “toward” the body, the flesh or the skin. We propose that leakiness can offer a lens to work with an expanded notion of directionality that does not reduce material leakiness to only an “outward” direction.

On a more concrete and practical level, we offer leakiness as a design and experiential quality to work and play with when designing wearables. We propose achieving this through:

- Engaging actively with “leaky” bodily materials, such as a breast milk, breathing, and menstrual blood.
- Becoming attentive to and working with the multi-directionality of leakiness that does not reduce it to only an “outward” direction.

## **Ongoingness**

The second design quality that we propose is *ongoingness*. With ongoingness we put attention to the temporality of the body and of (non)human materials: time passes and things change, which bring out indeterminacy and liveliness of things. We suggest that in design practice, we can further notice and engage with the ongoingness of materials. This includes how materials come alive and decay, and the meanings this brings to the experience, e.g. disgust or preciousness. With the temporality of ongoingness we focus on a cyclical understanding of time, hereby questioning linear time, and the idea that materials are born and die. Ongoingness is a core concept in biodesign (Ginsberg and Chieza 2018), including the research space of making textiles and wearables from bacteria (Chanet al. 2018). In interaction design, it has been previously studied in relation to material preciousness arising through imperfection, impermanence and incompleteness (Tsaknaki and Fernaeus 2016), whereas time and temporality have been central in research focusing on working with materials from a perspective that highlights their heirloom properties (Wallace et al. 2018) and their temporalities in relation to personal data (Odom et al. 2018).

Reflecting on our projects, all encompass and imply qualities of “ongoingness” in how their diverse material encounters co-exist and intertwine. Menarche Bits draws on the cyclical rhythm of menstrual cycles to imagine how a wearable can become useful at particular times along (approximately) a month. The ongoingness of menstruation informs the design space: it is not only the menstrual cycle repeated cyclically every month, but also the soft silicone, the heat and the textile materials that co-habit a vibrant material space every month. At the same time, this cyclical co-habitation is never repeated, never the same: it has different temporal material qualities as the body enters into different, unique experiences of menstruation every month. Similarly, the breathing patterns of Breathing Wings are mimicked in cyclical rhythms through the inflation/deflation. In this way, “ongoingness” foregrounds an agency in the material itself that changes and evolves through time. The materials are not static, but continuously redefine themselves as they change shape and properties. Along with the soft and breathing materials that are a combined latex, the body also participates in a temporal and ever-changing experience of being embraced by the Breathing Wings while being guided in an ongoing co-breathing

experience between wearable and soma. The Fiddling Necklace demonstrates ongoingness through the use of biomaterials, cow and human breast milk, which change properties as they become mixed with other materials: an entanglement that not only changes the materials themselves but also how the author and designer related to her breast milk. Notions of life and death become blurred as “killing milk” might also mean “living forever” as it is materially transformed and preserved for other uses.

Design is often posited as never finished and ongoing through use: a perspective recently foregrounded in the instability of designing with digital materials (Redström and Wiltse 2018). With “ongoingness” we want to address that soft materials and systems similarly have vibrant temporalities, yet through interacting with our bodies we can come to appreciate and further understand how we perceive and design with such temporalities. Non-linear conceptualizations of time foreground new ways of materially engaging with bodily rhythms that might be cyclical, fast, slow, and variable. As depicted in the three projects, this might include designing with rather than against menstrual cycles, even noticing new breathing patterns, and commemorating the death of a biomaterial through reconfigured use. Ongoingness signifies unclear beginnings and endings within soft systems, and thus draws attention to how they age or might come alive again or anew through a material-led “rebirth.”

On a concrete level, ongoingness offers two lenses to think about and work with the vibrancy of materials when designing soft systems with and for the body:

- Taking into account and designing for the non-linear temporalities of bodies and materials, both as two separate entities with different temporal qualities, and as a vibrant material with intersecting temporalities.
- Becoming attentive to the continuous re-configurations of vibrant materials, as they evolve, decay, become alive, and leak in new or different ways.

### ***Mutuality***

The third design quality that we propose is *mutuality*. Mutuality troubles the boundaries between bodies and materials as it highlights the (inter) dependence of their combination rather than them being separate entities. Mutuality and interdependency have been central concepts in new materialist philosophies, as they speak to the efficacy of materials and their assemblages, what Bennett has described as a *swarm of vitalities* (Bennett 2010). In interaction design, the mutuality of materials and bodies has been present in studies on human-machine agency (Devendorf and Ryokai 2015), and in discussions on design as a process of co-production to break the categories and dichotomies of humans/ machines and digital/physical (Devendorf and Rosner 2017). In textile design, mutuality can be seen in textile research that cultivates symbiotic

relationships between wearables and skin flora (Tomasello 2018).

Looking at the three projects, mutuality can be observed in different ways. In the Breathing Wings, the experience of having a body extension troubles the boundaries of the inside and the outside, separated through the skin, and thus the mutuality and interdependency between body and wearable. According to the designer/author, there is a mutual relationship of care between the wearable and the wearer. When it breathes, and when she lives with it, she starts to “depend on it” as it speaks to her through the shape-change actuation felt on the skin that relaxes her. She feels it is nice to have it attached to her body, carrying it almost like a baby that needs care. On the other hand, the Breathing Wings start “having a life” when she wears it. It depends on her. The material vibrancy changes from “it” and “she,” to “them”—a new material agency at the meeting between the body and wearable, breathing in and out together. This results in a new configuration of matter which is the combination of her flesh and the latex shapes pushing in and out against her skin.

For Fiddling Necklaces, mutuality takes form in needing to produce or having access to breast milk as a design material. Production and extraction are bound within supply and demand, which entangles design use with biological use. A hesitancy to design with the designer's own breast milk encapsulates a resistance from which she turns to cow's milk as a substitute and “waste” breast milk as a resource. The former highlights different and sometimes conflicting scales of mutuality: although humans also consume cow's milk, it produced different results as a design material substitute. The latter highlights how “waste” was reconfigured as a potential resource through a careful consideration towards mutuality.

The mutuality arising through designing and interacting with Menarche Bits is one anchored in the cyclical state of menstrual cycles and the phenomena that the soft silicone reacts with. How Menarche Bits feels on the body, e.g. placed on the pelvis, deeply depends on bodily feelings in the moment. This for instance meant that the designer was extra careful in/on designing during the days she experienced menstrual cramps, as this embodied painful feeling was crucial for molding the interaction between flesh and soft silicone. When used with menstrual cramps, the pain becomes re-configured into (more) comfort and relaxation. Experiencing using Menarche Bits with menstrual cramps also created a new experience of (inter)dependence where these two (body)materials created new mutual encounters only experienced a few days, or even hours, per month.

(Soft) materials and bodies depend on one another and there is often a resistance at their meeting. Resistance can take form in the labor of caring for the body, caring for the wearable, and caring for their entanglement and the ways in which they push against and pull towards each other. Working actively with the mutuality of vibrant materials in design practices can be a way of highlighting the entangled relationships

underlying when we, sometimes, take material vibrancy for granted, without observing or questioning what it cares for and what it resists against. One interesting observation pertains to how leakiness and ongoingness can be seen as an interdependent mutuality in which the body and the material in their vibrant entanglement affect each other in uncontrollable ways that change over time and blur leaky limits.

We see mutuality as a design quality that offers two fruitful lenses to attend to and work with the vibrancy of materials when designing soft systems with and for the body:

- Working with material resistance through care and labor as a give-and-take mutuality.
- Noticing new alliances among vibrant materials and surfacing non-authoritarian relationships among (non)human bodily materials through design.

## **Conclusion and Future Work**

We presented three design-led explorations that trouble boundaries of the body by approaching it as a soft system: Breathing Wings, Fiddling Necklaces, and Menarche Bits. All three projects draw upon first-person methods within soma design and use lived experiences to analyze diverse material encounters. These encounters include textiles, yarn, silicone, latex, as well as breathing and soft sensing/actuating technologies, breast milk, menstrual blood, and the molding of flesh with those materials. Together, the projects highlight alliances between flesh and materials that trouble bodily notions of “inside” and “outside” through the vibrant qualities of materials.

From our analysis, we offer two contributions. Our first contribution is a conceptualization of “vibrant wearables” as textiles that bring forth material forces and lively mechanisms through encounters with the body. While we view all (non)human bodies as inherently vibrant, “vibrant wearables” emphasizes attending to the encounters between textiles as a broader notion of soft materials worn on the skin and bodies, by which qualities of vibrancy emerge. Our second contribution is the articulation of three generative design qualities surfaced by “vibrant wearables”: leakiness, ongoingness, and mutuality. Leakiness is characterized by a multi-directionality of “spilling over.” Ongoingness attends to non-linear temporalities and cycles of life and death. Mutuality emphasizes the interdependency, and becoming, of vibrant encounters. These three design qualities conceptually and materially trouble boundaries of the body and (non)human soft materials, and are practical resources for designers and researchers working with the body as a soft system.

We see our work as being of particular relevance to new materialist discourses across the disciplines of textile, fashion and interaction design, since it offers concrete examples of how to work with and reflect on the vibrancy of materials, and with the human body as the starting

point (Townsend et al. 2020). Thus, we hope to inspire others working in design contexts that include emerging materials, such as data, robotics or biomaterials through highlighting the commonality among the different disciplines. Our work offers a new materialist approach across disciplines, rather than a concrete “recipe” of how to work with the three qualities that we present. On a broader level, by drawing on the experiences of making and living with vibrant wearables, we trouble material encounters between bodies and soft materials (systems), which highlights wearables’ vibrant qualities in tandem with the vibrancy and plurality of bodies and bodily experiences. In the context of designing wearable systems, our research shows a path towards conceptually troubling boundaries of the body, as previously done by e.g. Campo Woytuk et al. (2020) and Helms (2019).

In our design practice we are often asking ourselves: “*For what body and for whose body are we designing?*” In terms of future work, our research aims to stress the importance of becoming attentive to the material agency of *different* bodies: bodies and bodily mechanisms not always accounted for in design processes, yet inseparable from the artifacts we design.

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