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Haplos: Towards Technologies for and Applications of Somaesthetics

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Haplós: Towards Technologies for and Applications of Somaesthetics

by

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Author's declaration and word counts

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Maranan, D. S., Loesche, F., & Denham, S. L. (2015). CogNovo: Cognitive Innovation for Technological, Artistic, and Social Domains. In *Proceedings of the 21st International Symposium on Electronic Art*. Vancouver, Canada. http://hdl.handle.net/10026.1/5076

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Related awards:

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Abstract

How can vibrotactile stimuli be used to create a technology-mediated somatic learning experience? This question motivates this practice-based research, which explores how the Feldenkrais Method and cognate neuroscience research can be applied to technology design. Supported by somaesthetic philosophy, soma-based design theories, and a critical acknowledgement of the socially-inflected body, the research develops a systematic method grounded in first- and third-person accounts of embodied experience to inform the creation and evaluation of design of Haplós, a wearable, user-customisable, remote-controlled technology that plays methodically composed vibrotactile patterns on the skin in order to facilitate body awareness—the major outcome of this research and a significant contribution to soma-based creative work. The research also contributes to design theory and somatic practice by developing the notion of a *somatic learning affordance*, which emerged during course of the research and which describes the capacity of a material object to facilitate somatic learning. Two interdisciplinary collaborations involving Haplós contribute to additional fields and disciplines. In partnership with experimental psychologists, Haplós was used in a randomised controlled study that contributes to cognitive psychology by showing that vibrotactile compositions can reduce, with statistical significance, intrusive food-related thoughts. Haplós was also used in Bisensorial, an award-winning, collaboratively developed proof-of-concept of a neuroadaptive vibroacoustic therapeutic device that uses music and vibrotactile stimuli to induce

desired mental states. Finally, this research contributes to cognitive science and embodied philosophy by advancing a neuroscientific understanding of *vibrotactile somaesthetics*, a novel extension of somaesthetic philosophy.

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Chapter 1: Introduction

1.1. Research motivation: An embodied "Eureka" moment

One afternoon thirteen years ago, a subtle discovery I made about my back profoundly changed the way I felt about myself and my relationship to the world. At the time, I had been living in Canada for eight years, had just finished a degree in computing science, and was in the middle of a university-based contemporary dance training programme. During a Pilates class in which I was working with a particular piece of training equipment, I experienced a glimmer of the neuromuscular coordination required to fully move my shoulder blades in relationship to the ribs upon which they rest. In a moment of insight, I suddenly became aware that I had increased capacity for movements that in kinesiology are referred to as depression and retraction of the scapulae. I could also differentiate them from their respective opposite movements of elevation and protraction. In moving my shoulder blades, I could also sense concomitant activity in what I have now come to realise are my acromioclavicular and sternoclavicular joints. The overall sensory impression was an upward lengthening of my head and neck and an opening of my chest. In short, I found a different way of organising my upper torso than what I was habitually used to. My eyes also felt different; I was under the impression that I could see more clearly. It felt good. *I* felt good. It seemed as if for the first time in my life, I was utterly present, ready, and open. Upon leaving the studio, I felt myself walking with newfound confidence amongst the crowd of the city that I had chosen to call home.

While the intensity of the experience diminished as the day wore on, it remained nothing short of a revelation.

It was nothing short of a puzzle as well. From it, three key questions seemed to emerge. How did a subtle change in my postural organisation and movement abilities lead to the cognitive and affective shift I experienced? What led me to discover new neuromuscular organisation in the first place? And how can I facilitate or expedite the discovery of new neuromuscular possibilities for self-organisation, both in myself and in other people who would benefit from it? These questions were further backgrounded by positionality (England, 1994): I am a non-white immigrant to Anglo-American geography and culture, having migrated on my own from the Philippines to the West Coast of Canada in the mid 1990s while I was in my late teens. Around the time I experienced my moment of embodied insight, I had begun to question the applicability and utility of the Western-based embodied, introspective, movement-based practices to which I was exposed during the course of my contemporary dance training. However, the embodied "Eureka!" moment that I experienced that day led me to believe that they indeed might have value in non-Western contexts, and I felt compelled to interrogate more seriously questions around the causes, discoverability, and utility of embodied insight.[1]

Inasmuch as personal experience can motivate the conceptual context of any qualitative research study (Maxwell, 1996, p. p.4), these questions lingered long after that initial experience over a decade ago. They provide the impetus for the inquiries I have pursued in the interdisciplinary, collaborative, practice-led research in art and design reported in this thesis.

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[1] I elaborate on these interrogations in my article, "Speculative Somatics" (Maranan, 2015).

1.2. Research overview: aim, question, methodology

The principal aim of this research is to explore how a somatic practice for developing body awareness can be translated into a technology-mediated somatic learning experience. *How can somatic aims, theories, epistemologies, and strategies lead the design of a wearable technology for facilitating somatic learning?*

To address this question, I have engaged a design methodology where embodied phenomenological (1st person) and observational (3rd person) methods are incorporated in an iterative, collaborative creative process. Building on previous work in somatic technologies and design, the prototype I have developed is called Haplós, which means "caress" in the Tagalog language and also references the related notion of the haptic. Haplós is a novel body awareness tool that applies programmable, vibrotactile patterns to an individual's back. But importantly, and contrary to the current trend in wearable technologies, Haplós does not incorporate any digital sensing devices. Instead, Haplós is meant to assist the human user to become better at sensing themselves, using their own existing proprioceptive and tactile sensory capabilities. Haplós is inspired by the Feldenkrais Method (FM) (Feldenkrais, 1990; Rywerant, 2003), a movement-based learning system and "somatic" practice (I elaborate on somatic practices in section 1.2) that aims to improve the organisation of the body in action by creating more finely differentiated and integrated cortical representations of body representations. It is similarly motivated by Richard Shusterman's framework of *somaesthetics*, in which the lived body (the "soma") (Hanna, 1988) is taken as a "site for aesthesis (sensory appreciation) and creative self-fashioning" (Shusterman, 2008, p. 1). In this thesis, I describe how the development of Haplós is grounded in—and contributes to—

somatic education, cognitive perspectives on body awareness, design research, and cross-disciplinary study on vibrotactile perception and aesthetics.

1.3. Institutional context: CogNovo and its partners

This research has been shaped by its membership in two research groups at the University of Plymouth. The first of these is the Art and Sound cluster, which spurred my interest in exploring vibration as a sensory modality for facilitating body awareness. The second research group—which has immensely influenced the trajectory of this project—is the three-year CogNovo doctoral training programme at the Cognition Institute. CogNovo aims to foster interdisciplinary research in cognition, novelty, and creativity through exploration, speculation, explanation, and synthesis. The 24 research projects at CogNovo (including this current study) are conducted by doctoral students from experimental psychology, interactive and creative arts, cognitive neuroscience, the humanities, computational modelling, and cognitive robotics. It is for a research audience affiliated with one or more of these fields that I write this thesis.

In addition to committing to interdisciplinarity, CogNovo also attempts to bridge the gap between academic institutions and the larger community through public outreach initiatives, and to discover solutions that may have potential commercial value. I have thus attempted to align my research approach with these broader institutional targets. Consequently, the initial part of the development of Haplós was accomplished during a secondment I spent at Kin, a design company based in London, UK. Kin's work spans a wide range, from artistic to educational to commercial design.[2] They have also received private commissions to create speculative designs—some of which include future-driven wearable technologies—by leading technology companies. I discuss the prototyping work I did at Kin in section 4.5.2. Additionally, I held a prototype-evaluation workshop (to be discussed in section 4.5.1) in collaboration with Curiosity, a design strategy firm I had previously co-founded in Manila, Philippines.

1.4. Conceptual contexts

This project draws on the conceptual context of what I regard as *embodied cognitive studies*—the "rhizomatic" (Deleuze & Guattari, 1987) network of disciplines, fields, and other "knowledge formations" (Carp, 2001) that explore how humans think, feel, and experience the world through and as a result of the body. These include (but are not limited to) the following:

- Analytical strands from the humanities, including philosophies of the body, sensation, perception, and movement (Bergson, 1911; Merleau-Ponty, 1962; Noë, 2006; Gallagher, 2005; Sheets-Johnstone, 2011; Shusterman, 2008)
- Embodied perspectives within the social sciences such as linguistics (Lakoff & Johnson, 1999), anthropology (Hutchins, 1995; Ingold, 2000), and archaeology (Malafouris, 2013);
- Embodied approaches developed in the cognitive sciences of experimental psychology (Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005; Thelen & Smith, 1996), experimental neuroscience (Damasio, 2004; Varela, Thompson, & Rosch, 1991), and cognitive robotics;

[2] http://www.kin-design.com.

- Artistic and creative practices in which the living, breathing, moving body is the foundation for understanding and engaging with phenomenal (first person) experience, including dance (Batson, Quin, & Wilson, 2012), interaction design (Antle, Marshall, & van den Hoven, 2011; Dourish, 2001; Levisohn & Schiphorst, 2014; Loke, Larssen, Robertson, & Edwards, 2007; Schiphorst, 2007), and interactive art that focuses on first-person embodied experience (which I review in section 2.3.2);
- Knowledge formations that have been generated by communities of body-based practices, such as T'ai Chi Chuan (Wanning, 1993), the Pilates Method (Caldwell, Adams, Quin, Harrison, & Greeson, 2013), Yoga (Wanning, 1993), the Alexander Technique (Alexander, 2001), and the Feldenkrais Method (Feldenkrais, 1972). These practices are referred to collectively by a variety of names, including "bodyways" (Knaster, 2010) and "body-mind therapeutic and educational systems" (Payne & Crane-Godreau, 2015).

1.4.1. Embodied cognition

This research finds its home in the embodied cognitive studies network most proximally to two clusters—somatic education, and art and design—and takes inspiration from the cognitive sciences. While the aims, theories, epistemologies, methods, and assertions within this network are divergent (sometimes to the point of conflict), all proceed from, elaborate on, and interrogate the *embodied cognition* hypothesis—namely that the body has "a central role in shaping the mind" (Wilson, 2002). Embodied cognition stands in contrast to disembodied and reductionist models of human consciousness that have dominated Western cognitive science research up until the latter half of the 20th century. Influenced by rationalist paradigms based on Cartesian dualism and by theories of intelligence such as those developed by Alan Turing in the late 1940s, cognitive theories modelled cognition as serial, procedural processes and blackbox input-output systems (Dourish, 2001; Thelen & Smith, 1996). Moreover, the body was regarded as a mere sensory input apparatus whose primary function was merely to gather sensory information and "carry the brain" to wherever it needed to go (Pfeifer, Bongard, & Grand, 2007). The (re)turn to the body in Western culture as a site of knowledge production and inseparable aspect of the mind emerged towards the end of the 20th century, led by (among others) neuroscientists such as Antonio Damasio and Francisco Varela and developmental psychologists such as Ether Thelen, and anticipated by body philosophers such as Maurice Merleau-Ponty. Embodied accounts of cognition confront dualist models of human intelligence by advancing, for instance, that cognition happens in parallel with perception and that even the most abstract cognitive activities or concepts are body-based (Lakoff, 2003; Wilson, 2002). Marchand (2010) describes such embodied and situated approaches as belonging to "second-generation" (p. 5) cognitive sciences.

Indeed, embodied cognition offers rich explanatory frameworks that address one of the motivational questions I posed at the beginning of the chapter: How did a small change in my postural organisation and movement abilities lead to the mental shift I experienced? The answer is hinted at in nearly three decades of experimental research in embodied cognition, which suggests that many aspects of the physical organisation of the human organism influence its affective processes. For instance, tricking human subjects into frowning or smiling can induce the associated negative or positive affective responses (Larsen, Kasimatis, & Frey, 1992; Strack, Martin, & Stepper, 1988). Assuming an open, expansive pose or a closed, contractive one can lead to positive or negative changes in mood (Carney, Cuddy, & Yap, 2010; Zabetipour, Pishghadam, & Ghonsooly, 2015). Stepper and Strack (1993) found a correlation between posture and the feeling of pride even though subjects were passively manipulated into achieving the required posture and not through the active, intentional positioning of their body. A recent study found that the motor areas of the brain that control the axial muscles of the trunk (known in common parlance as the "core" muscles) also connect to the adrenal glands and thus could influence stress response (Dum, Levinthal, & Strick, 2016); conditioning these muscles might therefore improve stress response (Hamblin, 2016). These examples demonstrate embodied determinants of affect and the "reciprocal relationship between the bodily expression of emotion and the way in which emotional information is attended to and interpreted." (Niedenthal, 2007)

Movement, posture, and structure influence cognitive dimensions of experience as well. In a series of experiments done on "body swapping," van der Hoort et al. (2011) exploited the plasticity of the body image (Longo & Haggard, 2012) to show that our perception of our body size affects how we perceive the world. When made to believe that their bodies were smaller than their actual size, using an ingenious full-body application of the "rubber hand illusion" (Longo, Schüür, Kammers, Tsakiris, & Haggard, 2008), participants reported objects to be far away and big. Conversely, when they were made to believe that their bodies were larger than their actual size, their estimation of distances and sizes correspondingly decreased. Posture has also been found to mediate the content of existing thoughts, in a process that Briñol et al. (2012) have called "embodied validation." Gesturing while speaking facilitates "the thinking that underlies speaking" (Iverson & Goldin-Meadow, 1998). Many more examples are reported within the embodied cognitive studies network (for example, by Batson & Wilson, 2014; Beilock, 2015; Lynott, Connell, & Holler, 2014; Moore, 2005) on how cognition and affect are influenced by movement, gesture, posture, and other bodily activities and properties of the human organism.

1.4.2. Body awareness and its significance

My research builds on a proposition that I propose is affined with the embodied cognition hypothesis, namely that body awareness[3] can mediate, influence, and enrich the human organism's functioning. In particular, body awareness can help facilitate wellbeing. I introduced this thesis with an anecdotal account of an experience that I suggest is illustrative of this. In my account, I suggested that my awareness of new options for reorganising my head and upper torso subsequently influenced how I organised myself physically, which in turn positively influenced how I felt and thought.

My observations are consonant with research from the past two decades in the cognitive neurosciences, which suggest that body awareness—developed, for instance, through Basic Body Awareness Therapy (Lindvall, Anderzén Carlsson, & Forsberg, 2016; Roxendal, 1985) and other body-oriented psychotherapies (Mehling et al., 2011; Payne & Crane-Godreau, 2015)—can contribute to subjective reports and objective measures of wellbeing by helping with pain management (Calvo-Merino, Glaser, Grezes, Passingham, & Haggard, 2005; Eriksson, 2007); reducing unhealthy cravings (Kavanagh, May, & Andrade, 2012; May, Andrade, Kavanagh, & Hetherington, 2012); recovering from emotional trauma (Price, 2005; Van Der Kolk, 2006); increasing physical mobility and stability (Lindvall, Anderzén Carlsson, &

[3] In Chapter 2, I develop more precisely what I mean by body awareness and flesh out aspects of body awareness on which this research focuses. For the purposes of this section, an intuitive understanding of the term—one that implies a process of bringing or having one's own body to mind—will suffice.

Forsberg, 2016; Sjödahl, Jarnlo, & Persson, 2001); and improving self-perception (Catalan-Matamoros, Helvik-Skjaerven, Labajos-Manzanares, Martínez-de-Salazar-Arboleas, & Sánchez-Guerrero, 2011; Miller, 2016), mental awareness (Gyllensten, 2003), and subjective reports of well-being (Lindvall et al., 2016; Brani, Hefferon, Lomas, Ivtzan, & Painter, 2014). Neves (2013) showed that body awareness exercises significantly reduced subjective and objective measures of stress. Body awareness contributes to what is known in sports eduction as physical literacy, "the motivation, confidence, physical competence, knowledge and understanding to maintain physical activity throughout the lifecourse… as appropriate to each individual's endowment" (Whitehead, 2010, p. 11). Physical literacy frames "the fit body as the mindful body," through which educators can develop "embodied subjects instead of docile bodies" (Markula, 2004, pp. 70, 75).

There are likely to be many causal pathways between body awareness and wellbeing. Developing body awareness could facilitate new neuromuscular organisation by revealing to the individual both new possibilities for, as well as limits to, optimum movement and postural organisation (Connors, Galea, Said, & Remedios, 2010; Lindvall et al., 2016). Kerr et al. (2013) theorise that activities that start with "mindfulness of the body" (such as meditation) modulate sensory inputs to the somatosensory cortex and make the subject more aware not only of their body but when their attention wanders away from the body; this could then lead to "enhanced cognitive regulation and metacognition" (Kerr et al., 2013). An exhaustive discussion of causal relationships between body awareness and wellbeing is beyond the scope of this thesis. In section 2.2, however, I discuss body awareness in the context of the framework of somaesthetics, while body awareness and its relationship to movement, posture, cognition, and action from the perspectives of FM is taken up in section 3.3.

1.4.3. Somatic practices

One of the ways in which body awareness is developed is through *somatic* practices.[4] Somatic practice is best introduced through direct experience. I ask you, the reader, to participate in an exercise that I now detail in a set of instructions. To get started, find someone who can read out—over the span of 5 to 10 minutes—the following to you:[5]

- Start by making yourself more comfortable in the current position you are in. If you are sitting, for instance, sit as comfortably as you can.
- Close your eyes. Turn your attention towards yourself.
- Are you aware of your breathing? Which parts of your torso are moving when you inhale? Which parts are moving when you exhale? Don't try to change anything, just lightly direct your attention to your breathing. Throughout this exercise, try simply to observe yourself and resist the temptation to change or 'fix' anything about yourself.
- Notice how your weight is being supported by the chair, table, ground, or whatever surfaces you are in contact with. Which parts of you are in contact with these surfaces? If the parts of yourself that are in contact with these

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[4] The term "somatic" is used within other disciplines to signify different concepts. In biology, for instance, somatic is used to refer to particular cells and structures of an organism; additionally, the somatic nervous system refers to the part of the nervous system that is concerned with motor action. Neuroscientist Antonio Damasio's somatic marker hypothesis describes how emotion and affect influence cognitive processes (Damasio, 2004). Other uses of the term abound. In this paper, I use it exclusively to refer to the phenomenological study of physiological experience.

[5] An audio recording of the exercise instructions is available on https://archive.org/details/speculative-somatics. Borrowing from various somatic practices, particularly the Feldenkrais Method® (Feldenkrais, 1990; Rywerant, 2003)—this exercise is inspired by one given by Emilyn Claid at a keynote talk at the 2015 Dance and Somatic Practices Conference in Coventry, UK.

surfaces—for instance, the back of your thighs, your calves, your back—were smeared with ink, can you imagine the sizes and the shapes of the ink blots that you would be making on the surfaces?

- Notice the space between the lower tip of your ear and the top of your shoulder. How far apart are your ears from your shoulders? Is the distance between your right ear and right shoulder the same distance as that between your left ear and left shoulder?
- Notice where your shoulders are relative to your pelvis. Are you leaning forward, or backward? Is your torso balanced on top of your pelvis?
- Notice your fingers. Are they curved inwards towards your palm, or are they extended out flat? Are the fingers of one hand more curved than the other?
- Now open your eyes and bring your attention back to the room.
- Notice if you feel any differences in the way the chair, floor, or table feels to you compared to when you began the exercise. If there is another person in the room with you, notice if anything has changed in the way you feel or think about them. Notice any other differences in what you can sense and feel compared to when you began this exercise.

Notice if you still feel comfortable in your current position. Would you arrange yourself differently in your current position so that you can feel more comfortable? If so, do it now.

The term 'somatics' is attributed to Thomas Hanna, who used the word *soma* to refer to the "living, self-sensing, internalized perception of oneself [that] is radically different from the externalized perception of what we call a "body" (Hanna, 1988, p. 20). There are a multitude of somatic practices; readers are referred to Schiphorst (2008), Knaster (2010), and Neves (2013) for a review, though new ones emerge continually. Despite the plurality, some common themes and approaches run through many somatic practices, as I review in this section, in which I also begin to introduce some of the principles of FM (which I expand on in Chapter 3) by comparing them to those of somatic practices in general.

1.4.3.1. Overall goal of individual and social wellbeing

The Western philosophical tradition that the body is a fundament of wellbeing goes back to the Greek philosopher Thales, who Diogenes credits with the notion that happiness requires "a healthy body, a resourceful mind and a docile nature" (Diogenes Laërtius, 1925, p. 192). Improving the quality of life is a key goal in somatics. Physiological benefits include correction of various disorders and conditions, prevention of injury and illness, improving balance and coordination, reversal of ageing symptoms; and increased sexual pleasure (Knaster, 2010, sec. "Benefits from Working with the Body").

Some asserted positive outcomes of somatic practice are social in nature—including "friendlier relations and increased connectedness with self and others, "definition of personal boundaries," and a "shift from victim role to position of self-autonomy and power." (Knaster, 2010, sec. "Sensitivity, Flexibility, and Communication") Indeed, we experience our bodies in relation to our experience of other bodies. Referring to the immigrant positionality I introduced in Chapter 1, I found the ability to feel secure and confident within an unfamiliar culture a critical skill to develop; somatics has played a hand in this. While I do not primarily aim to advance the rich discussions around the social shaping of the soma (Ginot, 2010; Giorgi, 2015; Green, 2015), they are part of the background of this research (as described in Chapter 1) and motivated my decision to conduct a series of exploratory workshop in a non-Western context (as described in section 4.5.1).

1.4.3.2. Three assumptions in somatic practices

Knaster (2010) identifies three basic assumptions common to many somatic practices: the primacy of the body in human development, the plasticity of the body, and the necessity of a body-based intervention. To begin, the body is seen as "*the* place for transformation" (Knaster, 2010, para. 3, "What Are Bodyways") not only just physiologically, but emotionally, cognitively, and spiritually (Staugaard-Jones, 2012). In the case of FM, Smyth (2016) notes that the Method "functions in many people's lives like practices such as Tai Chi, Qigong, and Yoga, but it does not have an explanatory system based on the concept of energy, nor any explicit spiritual philosophy, imagery, or practices." (p. 5) Secondly, somatic practices work with the premise that some aspect of the body is "constricting, restricted, blocked, misused, or out of balance—generally because of excessive muscle tension and habit" (Knaster, 2010, para. 3, "What Are Bodyways"). Along a similar vein, Hanna (1988) proposed that adults often acquire patterns of "sensory-motor amnesia" (p. xiii), in which "normal" functioning of the body degenerates due not to a structural problem, but to "sensory deficiency" (p. 5). In FM, however, while practitioners seek to heighten the capacity for self-sensing and improve action in individuals (as I describe in section 3.3.1), terms such as *blocked*, *misused*, or *out of balance* are avoided; I elaborate on this matter in section 3.3.3.2. Finally, somatic practices assume that "the body is… plastic and moldable, repairable and educable" (Knaster, 2010, para. 3, "What Are Bodyways") through non-pharmacological means, such as through movement, the channelling of awareness or through the application of touch. Where FM might depart somewhat from this point is its emphasis on the *brain's* plasticity for improving embodied experience, as discussed in section 3.3.1.2.

1.4.3.3. Methods in somatic practice

Somatic practices differ in the methods they use. Some involve the application of either manipulative or non-manipulative touch by a trained practitioner (e.g., massage therapy, Reiki); others involve self-initiated movement (e.g., T'ai Chi Chuan); yet others involve a combination of both (e.g., Contact Improvisation). Moreover, somatic practices are often either largely *structural* or *functional* in approach, meaning that they either alter or adjust a physical aspect of the organism in order to improve its functioning, or intervene with some aspect of the organism's functioning (e.g., how it moves) in order to reorganise the underlying physical structure (Schiphorst, 2008, Appendix B). Rolfing and Cranio-Sacral Therapy are examples of structural approaches; both involve 'correcting' or intervening with purported inefficient or suboptimal structural systems in the body in order to improve functioning. The Alexander Technique and FM, on the other hand, are functional approaches in that they proceed from the assumption that many ostensibly structural issues are actually due to habitual patterns of behaviour.

Whether structural or functional in approach, however, somatic practices commonly develop knowledge through accumulated investigation, rehearsal, and application in a process which, while unfolding in time, is nevertheless non-linear. That is to say, one does not achieve 'perfect' understanding in one area in order to be able to move on to similarly faultless comprehension in the next. Rather, development occurs "in overlapping waves with each stage containing elements of all the others" (Hackney, 2004, p. 44). An example of this non-linear development can be seen in the "developmental movement patterns" described by Bonnie Bainbridge Cohen (Hackney, 2004). The patterns are not to be interpreted as a sequence of learnt skills to be mastered in succession. Instead, understanding and enactment of these patterns is refined iteratively because the patterns are interrelated and inform each other.

Similarly, in FM, revisiting previously experienced lessons often generates new insight about self-functioning, even after years of exploring the same lesson, as I touch on in section 3.3.3.7.

1.5. Methodology

I developed throughout the course of this work a "research through design" (Frayling, 1993) methodology that was inspired by "design thinking" (Brown & Katz, 2009) methods and "designerly" ways of knowing and creating (Cross, 2006; Fallman, 2008; McNiff, 2008). Johansson-Sköldberg et al. (2013) helpfully distinguish between five perspectives on design thinking methods: as the creation of artefacts, as "reflective practice" (Schon, 1984), as a problem-solving activity, as a way of reasoning or making sense of things, and as creation of meaning. My process particularly leans on the first three of these perspectives: through reflective practice, I seek to create a set of related artefacts that speak to a family of problems or challenges around specific aspects of embodied experience. In addition, the methodology relies on the use of "somatic sensitivity as a methodological tool" (Green, 1993) to allow me to gather experiential evidence—from both myself and other research participants—as well as to formulate investigations.

The methodology was a "braided structure" (Sullivan, 2006) composed of three strands of investigation:

- *immersive* explorations into the content of somatic experience, and into the observational and instructional skills that facilitate somatic insight;
- *prototyping* hardware, software, textile, "usage scenarios" (Ambler & Lines, 2012; Xiao & Ishii, 2011), and vibrotactile patterns based on somatic insights and methodologies; and

- *evaluating* prototypes with respect to the original research questions, and gaining insights that inform subsequent framing, immersion, and prototyping activities.

All three strands were pursued simultaneously and iteratively, with investigations from one strand influencing the other. Investigations varied in scale, scope, and duration. Some were nested within each other, and an investigation might cross more than a single strand of inquiry. In this regard, my methodology is similar to agile software development processes in that it follows a "non-linear" process and incorporates "short feedback-loops" (Dingsøyr, Dybå, & Moe, 2010, p. 2). What unites these strands is a shared commitment to exploring questions around designing for embodied experience: What are interesting, significant, or novel aspects of somatic experiences? What about them makes them interesting, significant, or novel? How are these experiences achieved? How can technology facilitate their development? I discuss this line of questioning in more detail in section 1.5.1. Table 1 lists each investigation and the strands of inquiry to which it contributes; I defer detailed discussion of each investigation to the indicated section.

Investigation	**Strand**	**Discussed in sections**	**Dates conducted**
Participation in an FM training programme	Immerse	3.2.1	2015.05.20 - 2016.09.03
Practice-teaching FM lessons (FIs and ATMs)	Immerse	3.2.2	~2015.12.19 - ~2016.12.30
Somatic self-exploration sessions	Immerse	3.2.3	~2015.02.13 - ~2017.03.17
Experiencing the Balloon Spine-Legs Somatic Costume™	Immerse/ Evaluate	4.4.3	2015.07.12
Hack the Brain 2017 Hackathon	Create	4.5.3	2016.06.21 - 2016.06.27
Continual making process	Create	4.5.2	~2015.09.29 - ~2017.03.04

Awaken Your Spine Workshops	Evaluate	4.5.1	2016.01.09 - 2016.01.10
Informal prototype trials	Evaluate	5.5.1	2016.05.21 - ~2017.03.04
Bizarre Bazaar demonstration	Evaluate	5.5.3	2016.10.22
Manufactory	Evaluate	5.5.2	2016.10.20 - 2016.10.21
Cravings Study	Evaluate	5.7.1	2017.02.13 - 2017.03.03

Table 1: Overview of key investigations.

1.5.1. Immerse: Understanding somatic experience, its structure, and how it is facilitated

My use of the term 'immersion' in this methodological strand designates the goal of learning the conceptual framework of a somatic practice. I describe in greater detail the three types of immersive explorations I conducted (participation in a portion of an FM training programme, conducting somatic sessions with participants, and somatic self-explorations) in section 3.2. Immersive explorations had three purposes: to understand the structure of somatic experience; to identify features thereof that were most prominent, interesting, and relevant to my aims; and to outline principles for generating somatic insights. Because of my interest in validating somatic learning techniques in non-Western contexts, I conducted some of these immersive explorations in the Philippines, as I discuss in greater depth in section 4.5.1. The insights from immersive explorations were continually integrated within a process of artefact creation (as outlined in section 1.5.2 and elaborated on in Chapter 4). To these ends, I developed a method I call *integrating somatic reflection for design* (ISRD).

1.5.1.1. Integrating somatic reflection for design (ISRD)

ISRD uses somatic introspection to probe for somatic experience and is based on first-person methods and embodied phenomenology (Petitmengin, 2006; Varela & Shear, 1999). It further borrows from ethnographic methods in that it aims to produce "thick descriptions" (Geertz, 1973, p. 197) of bodily experience. In ethnographic research, field notes are "written records of observational data produced by fieldwork" (Montgomery & Bailey, 2007, p. 67) which are then subsequently reviewed for emerging themes or "codes" (Glaser & Strauss, 1967). Memos, on the other hand, are records of the "interpretative process," and "of the researcher's developing ideas about codes and their interconnections." (Jupp, 2006, p. 198) I have found the distinction between notes and memos conceptually useful for creating a framework for inquiry and interpretation of embodied experiences that I can apply across the various investigations I conducted in this research. In particular, I used ISRD in both immersive exploration—both when working alone (section 3.2.3) and when working with other participants (section 3.2.2)—as well as in the *evaluative investigations* of the design prototypes (section 1.5.3).

The core of ISRD is a bank of principal questions (shown in Table 2) from which I picked and pursued. Follow-up and related questions inspired by these principal questions are also elaborated on. The questions seek to understand the structure of somatic experiences, probe for interesting and relevant features within the structure, evaluate the prototype's current state, and generate new possible design directions.

Context-setting	What is the context of the experience? Where is the subject? What activity are they doing?
Observational questions	What is the subject experiencing, specifically with respect to proprioceptive and tactile sensory phenomena? Where in themselves is the subject experiencing it? What are the relationships between the different phenomena the

	subject is experiencing?
Theoretical questions	What is interesting in the subject's experience? Why is it interesting? Why is the subject experiencing this interesting phenomenon now? What might have led to it? How do these observations bear on the felt experiences of tension, size, and movement possibility? Do possible interventions, mediating factors or confounding factors suggest themselves? How might my analysis be inaccurate? What alternative interpretations exist?
Design questions	How might the particular sequence of instructions (in the case of a guided exploration) or decisions (for self-guided exploration) have led to the experience? How might material properties of the environment or the exterior of the self have led to these experiences? How might these suggestions translate themselves into a design intervention or interventions, perhaps as an instructional principle, an interaction design pattern; or a material or form factor into consideration? How might these affect the current prototype?

Table 2. Integrating somatic reflection for design (ISRD) principal questions

Insights from or responses to ISRD questions form my primary sources, which are documented in a series of notes and memos composed of text, images, sketches, and media files archived in Appendices 3 and 5. To illustrate how ISRD is applied in practice, Table 3 presents the documentation of a somatic self-exploration session on the 6th of July, 2015, which was recorded and analysed using the ISRD method, and is included in Appendix 3.

Ran with M__. For the first time in literally YEARS, i decided to a full-on, 20 minute hamstring stretch. it's so different now that i'm aware of my pelvis more. At one point, I was lying down and I decided to put my hands on my lower abdominal muscles, just where they're about to insert on my pubic bone, the southernmost tip of the "diamond" as it were… and i realised (again? or more than ever? with shocking clarity?) how little i know about that area. AND THEN i realised what i meant by that phrase "how little i knew about that area". I could feel it moving up and down with my breath and i realised that i've never really recognised what that moving was like. and i realised that this was one of the disconnects in my body, one of the bridges between upper and lower halves that just seemed to be missing. and i'm wondering what would happen as i increasingly make the connections between my upper and lower halves again… tech tool idea: what about a phone or device that just constantly or occasionally vibrates? to just remind you of a body part?

Context	Doing some stretching post-running
Theoretical Implications	• Disconnects in the body (breaks in the pattern) that interferes with Gestalt pattern formation? [170309] • Learning process (Burch competence model?). Could this be from http://www.doceo.co.uk/tools/knowing.htm [170309]: you don't know what you don't know you know what you don't know you know what you know you don't know what you know
Design Implications	– First mention of vibration for body awareness in my notes and memo; "tech tool idea: what about a phone or device that just constantly or occasionally vibrates? to just remind you of a body part?" [170309]

Table 3. An example of a somatic self-exploration session as recorded and analysed using the ISRD method

1.5.1.2. ISRD and somaesthetic reflection for industrial design ideation: a comparison

A related precedent to ISRD—which I discovered in the process of developing my methodology—is Lee, Lim, and Shusterman's application of "somaesthetic reflection" (Shusterman, 2008, p. 40) to industrial design ideation (Lee, Lim, & Shusterman, 2014). Somaesthetic reflection—and indeed somaesthetics as a whole—is derived in part from the FM and the psychology of William James (Lee, Lim, & Shusterman, 2014, p. 1056; Shusterman, 2008, pp. 7–8). Working from the perspective of industrial design, Lee and his colleagues were motivated by the potential of somaesthetic reflection to "improve the ideation process of interactive product design" (Lee et al., 2014, p. 1055). They reasoned that somaesthetic reflection attends not only to bodily perception but also to "related affective experiences," including experiences of "tactile and kinesthetic qualities" of objects external to the body—that is, physical artefacts and the environment enfolding the user (Lee et al., 2014, p. 1056).[6] These strategies were then used in a two-day workshop involving graduate student designers and engineers from Korea Advanced Institute of Science and Technology (KAIST), who were trained during the workshop to conduct somaesthetic reflection, share their experiences, and then prototype design ideas (Lee et al., 2014, p. 1057).

Lee et al.'s application of somaesthetic reflection to product ideation bears similarities to ISRD. However, there are distinctions between the methods in this research and in those by Lee and his colleagues. First, design implications and questions were persistently kept in the periphery of my consciousness throughout the progress of the research, enfolding designerly thinking throughout every aspect of the process, as evidenced in the archive of data in Appendix 3. In contrast, during the workshops reported by Lee et al., the somaesthetic reflections were done primarily as preparatory work to ideation. This is not a criticism of their method, as the workshops were conducted on a small timescale and with participants who—while proficient in their respective fields of interactive and industrial design—had little experience in somatic methods, performance, or martial arts (Lee et al., 2014, p. 1057). The ability to sustain somatic reflection alongside designerly thinking is one that I developed in the course of approximately 20 months of research; was supported by the "experiential acuity" (Schiphorst, 2011) that I have cultivated over the past decade in various aspects as a movement researcher, dance artist, and somatic practitioner; and was additionally developed through extensive participation in a portion of an FM training programme (section 3.2.1). Thus, the timescales and skill sets of this study and Lee et al.'s are not comparable—this is the second difference. A third and final distinction can be made between the aims of the

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[6] The relationship of sensing the self with sensing the environment is an important one and will be taken up again in section 3.3.2.1.

prototypes generated through the somaesthetic reflection process. In this research, I sought specifically to build a learning tool to support somatic exploration and enhance the existing sensory capabilities of the user. In the KAIST workshops, the end goal was to prototype "an interactive product" that generally related to the theme of "cooperative movements" (Lee et al., 2014, p. 1057).

1.5.2. Prototype: Sketching, soldering, and sewing

My methodology embeds *making* within a process of inquiry on how technological artefacts can support somatic learning. The process of making enriched the theoretical orientation of the research (and vice versa), as did the results of the evaluation studies, the "technical opportunities" presented by available technologies, and the "unanticipated effects" that the prototypes elicited (Zimmerman, Forlizzi, & Evenson, 2007, p. 6).

I kept a design research diary, which took on two forms: a paper-based journal with sketches and notes; and digital archives of audio, video, images, diagrams, and typed text that documented the design research process (see Appendix 4). Some design insights (for instance, the organisation of the wires and electronic components) were achieved through the process of diagramming and visual sketching; others, through more hands-on activities such as soldering, sewing, and coding. I elaborate on the prototyping process in more detail in Chapter 5.

1.5.3. Evaluate: Conducting prototype studies and workshops

Prototypes were evaluated against the aim of creating a somatic learning experience in users. To do so, I used ISRD principles to design workshops, public events, continual prototype trials, and controlled studies. Taken together, these studies form the evaluative strand of this methodology, as mentioned in Table 1. Each succeeding evaluation generated both theoretical and design insights, which were in turn woven back into the immersion and prototyping strands of the inquiry. Immersive explorations and evaluative investigations both probed the content of participants' somatic experiences; in the case of evaluative investigations, these somatic experiences were mediated by an artefact generated from prototyping activities.

1.6. Chapter summary and thesis outline

In this chapter, I reviewed the motivation behind the research reported in this thesis. The theory of embodied cognition, the theme of body awareness, and approaches from somatic practices form the background against which I conducted this practice-led investigation into how technology can facilitate somatic learning. I outlined three strands of inquiry—immersion, prototype creation, and prototype evaluation—that variously contributed to the aims of this research.

In Chapter 2, I deepen the discussion on specific contexts for this research by outlining related concepts theories and prior work related to body awareness and design approaches that place embodied experience and somatic learning at their core. I briefly review the neurophysiology of vibrotactile stimuli and existing uses of vibrotactile stimuli in new media art and technology design.

Chapter 3 constructs a conceptual framework for FM as an educational system for body awareness. The framework is largely informed by a practice-led immersion I took in the FM that centred on my participation in part of a FM practitioner training programme and extended to somatic explorations and studies that I conducted as part and outside of the training.

Through the iterative process of reflection and making, I mapped the FM conceptual framework onto design decisions for the material components of Haplós. I elaborate on this in Chapter 4 and report on my engagement with an existing work, Sally Dean's Somatic Costumes™, that further spurred the prototype creation process.

In Chapter 5, I develop a set of principles, schemes, and heuristics for using the prototype I developed in Chapter 4. I report on three studies I conducted to evaluate the prototype. In addition, I describe exploratory and speculative applications of vibrotactile stimuli that were explored in considerable depth in parallel with the main thread of this research.

Chapter 6 concludes the thesis with a review of the research context, aims, questions, and methods, as well as a summary of the main developments and contributions of this research. Finally, I outline further research and development directions for Haplós.

Chapter 2: Related concepts and prior work

2.1. Introduction

In this chapter, I review aspects of Shusterman's framework of somaesthetics, technology design using somatic and somaesthetic principles, the effects of vibrotactile stimulation on the body and nervous system, and vibrotactile stimuli in new media art and technology design.

While this research additionally draws on other perspectives and practices, I weave throughout the thesis the relevant theoretical threads from other knowledge formations as the need arises. In addition, I devote most of Chapter 3 to the aims, theories, and epistemology of the somatic practice, the FM, from which my research crucially draws.

2.2. Somaesthetics

Philosopher Richard Shusterman laid out his framework of somaesthetics in its most complete form in his book, *Body Consciousness: A Philosophy of Mindfulness and*

Somaesthetics.[7] (2008) Somaesthetics is "concerned with the critical study and meliorative cultivation" (BC, p. 19) of the soma (previously discussed in section 1.4.3). Within the framework, "aesthetic" refers to both the process of sensing as well as stylising and remaking (BC, p. 19). Somaesthetics proceeds from the embodied cognition stance (reviewed in section 1.4.1) that the body "constitutes an essential, fundamental dimension of our identity… [and] forms our primal perspective or mode of engagement with the world." (BC, p.20) Shusterman responds to criticism that cultivating body consciousness is tantamount to "trivial narcissistic hedonism" (BC, p.40) in at least two ways. First, he distinguishes the kind of bodily attentiveness that somaesthetics cultivates from the kind of "excessive attention" that contemporary culture "lavishes" on the body (BC, p. 6). Second, he reviews the central aims of philosophy of knowledge, self-knowledge, right action, happiness, and justice (BC, p. 19) and draws out the importance of the body in each aim (BC, pp. 19-22). "If embodied experience is so formative to our being and our connection with the world," Shusterman argues, "body consciousness surely warrants cultivating." (BC, p. 3) I share Shusterman's position, which forms an important standpoint within this research on technology-facilitated somatic learning.

Somaesthetics draws from a number of philosophical positions, including those of Simone de Beauvoir, who exposed the ways that power "shape[s] our somatic experience" (BC, p.77) as inflected by sex and age, but who nevertheless excluded reflective somatic introspection as a strategy for resisting power (BC, p.10); and Ludwig Wittgenstein, who demonstrated an attention to his somatic feelings and the aesthetic experiences they produce (BC, p. 124), yet rejected "the use of somatic

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[7] In this section, I will be citing from Shusterman's book, *Body Consciousness: A Philosophy of Mindfulness and Somaesthetics* (Cambridge: Cambridge University Press, 2008) by abbreviating it hereafter as BC.

feelings for explaining crucial mental concepts like emotion and will." (BC, p. 116) Somaesthetics also builds on the ideas of pragmatist philosophers such as William James, who contributed theories on the body's importance in "mental and moral life" (BC, p. 139), including a theory of emotion (the James-Lange theory) that is predicated on the primacy of interoceptive sensations (Craig, 2009). Another pragmatist philosopher who has influenced somaesthetics is John Dewey, who articulated the role that the sensate, biological body plays in "the roots of the esthetic in experience" (Dewey, 1934, p. 14). However, in this review of the philosophical precedents of somaesthetics, I reference in particular Michel Foucault (section 2.2.2), whom Shusterman credits for providing a large portion of the foundation of somaesthetics (BC, p. 9), and Maurice Merleau-Ponty, whose theories on phenomenological states are the basis for Shusterman's typology of body consciousness (section 2.2.3).

In addition, somaesthetics has been shaped by the theoretical and practice-based contributions of somatic practitioners such as Frederick Alexander, who developed the Alexander Technique, an approach which focuses on the inhibition of undesirable habitual patterns for better "use of the self." (F. M. Alexander, 2001) However, I focus in this thesis on the practice and theories developed by another somatic practitioner, Moshe Feldenkrais, which Shusterman draws upon (and quite significantly),[8] and whose eponymous Method I present in a conceptual framework in section 3.3.

[8] It is worth noting that Richard Shusterman is a certified Feldenkrais practitioner.

2.2.1. The three branches of somaesthetics

Somaesthetics has three branches, which Shusterman notes were "all powerfully present in Foucault." (BC, p. 41)

Analytic somaesthetics is a descriptive and theoretical account of the nature of somatic perception and sensation, and how these influence the construction of knowledge about the self in relation to the world. It draws upon discursive traditions of mind, ontology, and epistemology, but also on sociological and cultural analyses (BC, p.23).

Pragmatic somaesthetics, on the other hand, is a normative set of guidelines that builds on the ontologies and epistemologies laid down in analytic somaesthetics facilitating individual well-being. Pragmatic somaesthetics is prescriptive, guides action, and can be captured by language.

While pragmatic somaesthetics is representational, it is *practical somaesthetics* that covers the experiential dimension and that is concerned "not with saying but with doing" (BC, p. 29). Practical somaesthetics captures what might be called "tacit" knowledge (Polanyi, 2009), and must be enacted to be apprehended:[9]

> [Practical somaesthetics] is not a matter of producing texts, not even texts that offer pragmatic methods of somatic care; it is instead about actually pursuing such care through intelligently disciplined practice aimed at somatic self-improvement… [T]his practical dimension is the most neglected by academic body philosophers, whose commitment to the discursive logos typically ends in textualizing the body. (BC, p, 29)

One of the main contributions of my research is an articulation of a technology-based, sensory modality-specific framework that inherits from

[9] It is worth noting how practical somaesthetics' commitment to direct experience—combined with somatic techniques' shared goal to foster well-being—thus aligns it with the ethos of action research (Swantz, 2008).

somaesthetics and is similarly organised along these three branches. I present this framework—vibrotactile somaesthetics—in section 6.3.1.1.

2.2.2. The body as the site for self-fashioning: Foucault and somaesthetics

While Foucault is most cited for his theories on power, knowledge, and social control—collectively known as "technologies of power" (Foucault, 1978)—he also in his later years wrote and lectured on "technologies of the self" (Foucault, 1988), which are individual practices for regulating thinking and action:

> Technologies of the self … permit individuals to effect by their own means or with the help of others a certain number of operations on their own bodies and souls, thoughts, conduct, and way of being, so as to transform themselves in order to attain a certain state of happiness, purity, wisdom, perfection, or immortality. (Foucault, 1988, p. 17)

Shusterman proceeds from Foucault's position of "transfiguring one's inner sense of self (and thereby one's attitude, character, or ethos) through transformative experiences." (BC, p.9) However, while Foucault advocated technologies of the self-transfiguration that pushed the limits of sensory experience—notably "strong drugs and transgressive sex" (BC, p. 9)— Shusterman calls for "less violent" and "tranquil practices" (BC, p. 9) in order to cultivate better habits for responding to the world at large (BC, p. 205). Shusterman acknowledges that Foucault importantly "confronts us (even affronts us) with…attend[ing] more closely to cultivating the sentient body" (BC, p. 48) by way of developing body consciousness. Nevertheless, Shusterman delivers a strong verdict on Foucault, whom he chastises for "presuming that such consciousness is best heightened through maximized intensity of stimulation." (BC, p. 48) Instead, somaesthetics is positioned as a response to an increasingly stimulus-driven and stimulus-laden contemporary society (BC, pp. 6, 48):

> Somatic reflection's cultivation of more refined somatic self-consciousness can address these problems by providing more rapid and reliable awareness of when we are overstimulated by a surfeit of sensory excitements so that we know when to turn them down or switch them off to avoid their damage. (BC, p. 7)

While I do not necessarily partake in Shusterman's censure of Foucault's methods, I do support the importance of attending to and savouring sensory experiences that are confined within a smaller range of intensity—a subject to which I return in my discussion of FM learning strategies in section 3.3.3.3.

2.2.3. A taxonomy of body consciousness

Shusterman's typology of body consciousness serves as a useful framework and a starting point for discussion on what I mean precisely by body awareness in this thesis. Shusterman proposes four increasingly sophisticated modes of body consciousness (BC, p. 54 ff.): non-wakeful, wakeful but non-attentive, attentive, and meta-attentive. These are terms I have attributed—for clarity and brevity—to Shusterman's categories, since Shusterman refrains from attaching singular labels to these modes. These terms also reference distinctions made by cognitive neuroscientists to distinguish features of consciousness. For instance, distinctions can be made between *vigilance* ("the state of wakefulness"), *attention* ("the focusing of our mental resources onto a specific piece of information"), and *conscious access* (the reportability of attended information that comes into our awareness) (Dehaene, 2014, sec. "Cracking Consciousness").

2.2.3.1. Body awareness, body consciousness, body attentiveness: a taxonomy of body awareness

The first two of Shusterman's proposed states of body consciousness parallel the phenomenological states that Merleau-Ponty describes in the *Phenomenology of Perception (1962)*:

- **Non-wakeful.** A "primitive mode of grasping" is evidenced in situations when we are unconscious but physically functioning and responsive to the environment, and which Merleau-Ponty would call *corporeal* or *motor intentionality* (Gallagher, 2011, p. 310; Merleau-Ponty, 1962, p. 127). Shusterman gives the example of pushing away a pillow that blocks my breathing while continuing to remain asleep.
- **Wakeful but non-attentive.** A "basic" body consciousness involves "perception without explicit awareness" and forms the background of what Merleau-Ponty calls *primary consciousness* (Merleau-Ponty, 1962, p. xvii; BC, p. 55). That is to say, some aspect of my body (for example, my left shoulder) and its sensations would be accessible to awareness should I wish to direct my attention to it.[10] This perception also facilitates a response to the environment. Shusterman gives the example of walking through an open door and how people normally can do this successfully without noticing *precisely how* they do it, even if the door is new and its opening narrow.

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[10] Gallagher (2011, p. 310) notes that "phenomenologists would call this pre-reflective consciousness; analytic philosophers would call it first-order, nonobservational consciousness… [and] Gibsonian psychologists would call it ecological consciousness that provides information about both the environment and my bodily position."

The other two modes are reflective modes that, Shusterman argues, have been widely neglected by analytic philosophers of the body—including Merleau-Ponty, whose work, while having advanced the primacy of the body immeasurably in philosophical discourse, nevertheless suffers from "somatic attention deficit" (BC, p. 49).[11] He collectively calls these reflective modes "lived somaesthetic reflection" or "reflective body consciousness" (BC, p. 63):

- **Attentive.** A third level of body consciousness actually attends to the state of some aspect of the body. Returning to the example of my left shoulder, what I simply call an 'attentive' body consciousness to my shoulder implies that I possess "conscious access to sensory information" (Dehaene, 2014, Chapter 1, footnote 11)about it. Moreover, I have actually directed my attention to my shoulder. In doing so, I can thus sense that it is there in the first place and that its most distal bony landmark lies at a certain distance from, say, my left ear.[12] Shusterman refers to this variously as "explicitly conscious somatic perception," "conscious somatic perception with explicit awareness," "somaesthetic observation," and "somaesthetic perception" (BC, pp. 55-56).
- **Meta-attentive.** Shusterman suggests a fourth level of body consciousness in which one not only attends to the body but also to the very process of attending to the body. Shusterman refers to this as "self-conscious or reflective somatic perception with explicit awareness" or "somaesthetic self-consciousness or reflection." It is worth quoting Shusterman at length for an example of meta-attentive body consciousness (BC, p. 56):

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[11] Neglect does not necessarily mean rejection; see Gallagher (2011, p. 311), and Jordan (2010) for a rebuttal of Shusterman's criticism of Merleau-Ponty.

[12] A bony landmark is a feature of the skeleton that is easily distinguishable to a third-person observer.

> On this level, we will be aware not simply that our breath is short or even precisely how we are breathing (say, rapidly and shallowly from the throat or in stifled snorts through the nose, rather than deeply from the diaphragm); we will also be aware of how our self-consciousness of breathing influences our ongoing breathing and attentive awareness and related feelings. We will be focused on our self-awareness of how our fists are clenched not only in terms of specific attention to explicit feelings of tightness and orientation of thumb and fingers in the clenching but further to the feelings of that mindful attention itself and the ways such somatic self-consciousness influences our experience of fist-clenching and other experiences.

Close parallels can be seen in this example to what psychologists would call *metacognition*, which broadly speaking pertains to "any knowledge or cognitive process that refers to, monitors, or controls any aspect of cognition" (R. A. Wilson & Keil, 1999, p. 533). Shusterman's proposed fourth level of body consciousness would appear to involve two metacognitive constructs. The first is the activity of *monitoring*, a cognitive skill that aids in learning (Francis, 2013). The other is a proposed process in which awareness of a given aspect of your body changes both the functioning of that bodily aspect as well as the nature of that awareness in a feedback loop. This cleaves closely to the notion of a "second-order cybernetic process" (Von Foerster, 2003, p. 285) that is embedded in the human organism, which is "a self-observing system that generates the domain of self-consciousness as a domain of self-observation" (Maturana & Varela, 1980, p. 41).[13]

It is unclear to what extent this meta-attentive process happens automatically in the observer or to what extent it requires conscious effort on their part.[14] I discuss in section 3.3.2.3 an epistemological approach in the FM that I propose maps to somaesthetic meta-attentiveness. Nevertheless, the possible mechanisms, outcomes, and implications of this mode of body consciousness appear to be open issues across

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[13] Norbert Wiener coined the term cybernetics in his 1948 book, *Cybernetics or Control and Communication in the Animal and the Machine* (Wiener, 1948) to refer to the study of self-regulating systems, which includes human individuals as well as human social systems. First-order cybernetics is the study of "observed systems," while second-order cybernetics is that of "observing systems" (Von Foerster, 2003, p. 285).

[14] See Veenman et al. (2006, p. 6) for a summary of a related debate between conscious versus automatic metacognitive processes.

the study of body awareness;[15] addressing them is similarly beyond the scope of this research. Thus, in this thesis, I narrow the scope of "body awareness" to refer particularly to third-mode, attentive body consciousness.

2.2.3.2. What can you attend to? The content of body awareness

Although Shusterman advances the value of attention to the body, he does not enumerate clearly what precisely about the body one can attend to, though he mentions at various points breathing (p. 121), posture (p. 167), muscle volume (p. 71), movement (p. 25), muscle "tension" (pp. 68 and 71), and muscular tonus (pp. 20), which is the continuous and passive contraction of a muscle that is "long-lasting and fatigue resistant" (Gurfinkel et al., 2006).

What properties of the body, then, can one bring to one's attention? Taxonomies of attendable somatic phenomena can be found from different clusters in the embodied cognition studies network. Within the neurosciences, Sherrington first classified senses as "teloreceptive (vision and hearing), proprioceptive (limb position), exteroceptive (touch), chemoreceptive (smell and taste) and interoceptive (visceral)." (Craig, 2002, p. 655) Interoceptive sensations include but are not limited to hunger, thirst, dyspnoea (feeling of shortness of breath), sexual arousal, "air hunger," coolness, warmth, heartbeat awareness, distension of internal organs, pain, and itch (Craig, 2002; Craig, 2009).

Proprioceptive sensations, on the other hand, originate from the musculoskeletal system (Damasio, 2010), and include the sense of effort, sense of

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[15] For instance, while there has been increasing interest in recent studies of body awareness in the cognitive sciences—see for instance Schmalzl and Kerr (2016), Payne and Crane-Godreau (2015), Kerr et al. (2013), Mattes (2016), Rosenkranz et al. (2009), Rosenkranz and Rothwell (2004)—they focus on Shusterman's third mode of attentive body consciousness.

tension or force, the sense of heaviness, and the sense of balance (which is provided by the vestibular system). Proske and Gandevia (2012) note that kinesthesia is a sub-category of proprioception and refers specifically to the sense of position and sense of movement of the trunk and limbs. They also note that it is possible to induce an "artificial proprioceptive signal" using vibration (Proske & Gandevia, 2012, p. 1651). I discuss some of the unique properties of vibration as a sensory modality and how it might influence body awareness in Chapter 3.

As will become apparent in my discussion of the evolution of Haplós in Chapters 4 and 5, I take particular interest in proprioceptive sensations. I thus take body awareness for the purposes of this research to be "the subjective, phenomenological aspect of proprioception [...] that enters conscious awareness" (Mehling et al., 2011, p. 2). Cohen (1993) evocatively and accurately summarises this view of body awareness as "experiential anatomy." However, taxonomies carve (the) nature (of sensory experience) at its joints in different ways. By no means do I suggest my enumerations of sensory phenomena to be complete. In section 4.5.1.2.3, for instance, I develop a notion of "structured somaesthetic phenomena," an example of which is the perception of the internal connectedness of the body in movement that I call "anatomical relatedness."

2.2.4. Sensing the self, sensing the environment

In anticipation of criticism that somaesthetic awareness is license for self-absorption, Shusterman argues that "intensified body consciousness need not disrupt but rather can improve our perception of and engagement with the outside world." (BC, p. 8) The development of somatic knowledge is a situated process contingent on the properties of the physical environment that enfolds the self. Sensing one's contact on the ground, for instance, involves sensing both one's self *and* the ground:

> To focus on feeling one's body is to foreground it against its environmental background, which must be somehow felt in order to constitute that experienced background. One cannot feel oneself sitting or standing without feeling that part of the environment upon which one sits or stands. Nor can one feel oneself breathing without feeling the surrounding air we inhale. (BC, p. 8)

One consequence of the situated nature of the development of somatic knowledge is that the materiality of tools, technologies, and environments that are outside the "natural" order of things—that is, design—can create new felt experiences of the self. Thus, design can facilitate the development of somatic knowledge in ways that the world-as-it-is does not. Designing tools and environments, therefore, can develop new types of bodily awareness. I build on this concept in section 3.3.2.1.1 where I discuss the notion of somatic learning affordances.

2.3. Technology design using somatic and somaesthetic principles

Responding to the creativity of self-fashioning inherent in somaesthetics, Jerold Abrams (2004) points out that the malleability of the soma can be furthered through new and emerging technologies. "Why not extend pragmatist aesthetics into the future, creatively redescribing the self?" asks Abrams (2004, p. 246). While the main contributions of this thesis are neither specifically futurist nor speculative (Dunne & Raby, 2014) (except in one notable application, which I describe in section 5.7.2), Abrams' provocation sets the stage for a review of existing technologies and technology design approaches that are inspired by or facilitate somatic awareness.

2.3.1. Human-computer interaction design and the soma

A number of researchers and artists have used somatic epistemologies as an organising principle for the design and evaluation of new tools and technologies. In the field of human-computer interaction (HCI) design, for instance, somatics and somaesthetics have inspired critical reimagining of distributed and "ubiquitous" (Weiser, 1999) computing, and have led to increasing interest in embedding embodied and movement-based perspectives in computing technologies (Levisohn & Schiphorst, 2011). Building on the paradigm of *embodied interaction* proposed by Dourish (2001), Thecla Schiphorst (2007) has argued that as a computer is increasingly understood less "as an object but a set of invisible distributed processes" (p. 4), the need for new interaction metaphors might be met by looking towards somatics as an "experience tradition" (Schiphorst, 2007, p. 10). Schiphorst expands on her framework with three case studies involving digital sensors: exploratory workshops involving "experience modelling" of interoceptive and proprioceptive phenomena (*whisper[s]*); an interactive art installation wherein breath data is mapped to vibrating motors and small fans that generate air currents (*exhale*); and pillow-like "tactile networked objects" that respond to human gestures (*soft^n*) (Schiphorst, 2007). Liam Loke and Robertson's *Making Strange* framework (2013) incorporates the felt experience of a technology user's actions in movement-based interaction design, in which other strategies (such as design representations of movement, interaction maps, and machine sensor readings) are used to evaluate the quality of user interaction. Negotiating the tension between invisibility and palpability in interaction, as well as drawing from Shusterman's somaesthetics theory, Nunez-Pacheco and Loke (2014) have refashioned Heidegger's notion of *ready-to-hand*—wherein familiarity and skilful manipulation of a tool causes the tool to "disappear" (e.g., the awareness of a carpenter is focused on the act of hammering and not the hammer itself)—to apply it to the space of wearable biofeedback-based technologies through a design framework they call "body-to-hand" (Nunez-Pacheco & Loke, 2014). Here, the states of the body and of the device are mutually visible and responsive to each other in a "cycle of body-tool visibility" in which "the body and device presence moves constantly between the foreground and the background" (Nunez-Pacheco & Loke, 2014, p. 558). They illustrate their framework using the case of *Eloquent Robes,* a wearable art installation that "projects visualisations of heartbeat data on the body to communicate and make evident intimate physiological data." (Nunez-Pacheco & Loke, 2014, p. 559) Users alternately attend to state of their own bodies and to the state of the technology as made legible by the visualisation in order to modulate their physiological state. Finally, and as previously discussed in section 1.5.1.2, Wonjun Lee, Youn-kyung Lim, and Richard Shusterman have incorporated somaesthetic reflective methods derived from the FM to prime the ideation process in an exploratory workshop involving industrial designers and robotic engineers (Lee et al., 2014).

Altogether, these examples illustrate the growth of a community of designers who wish to place embodied experience at the core of technology-based design. This trend is most recently evidenced in a call for proposals for an upcoming workshop in "Soma-based design theory" (Höök et al., 2017) at the 2017 ACM Conference on Human Factors in Computing Systems.[16] While my goal in this research is not to propose new human-computer interaction metaphors or paradigms, the research reviewed here has advanced the role that somatic experience can play in technology design and thus provide a critical foundation for this research.

What is crucial to note here—and what distinguishes my work from a growing trend of using digital sensors to infer not only user behaviour but somatic experience—is that despite helpful frameworks for integrating quantitative measures of physiological state with qualitative experience of well-being, as proposed for

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[16] https://chi2017.acm.org

example by Nunez-Pacheco and Loke (2014), Haplós does not incorporate sensors. This is by design, and for two reasons. First, somatic practices in general (and the FM in particular) already provide a useful set of strategies for rendering bodily states or processes that may be imperceptible, perceptible. The second reason relates to fidelity in data capture and representation: there is a deep gap between felt experience and the current technologies for capturing and representing physiological states from which the experience emanates. As Smith and Vonthethoff note in their discussion of data proxies for sensory experience: "their existence and content create a disconnect between how someone should feel, and how they actually feel." (Smith & Vonthethoff, 2017, p. 18) In this regard, my current research is aligned with the critical stance that Nuñez-Pacheco (2015) takes against "self-knowledge through numbers" (Wolf, 2009). Instead, I set out to create a tool for differentially stimulating the body, not for reading, reinterpreting, or representing it.[17] I thus find no need to represent embodied phenomenal experience "as" something else when it can stand (and be used) as its own best and lossless representation. As Shusterman notes, "we cannot simply rely on further technological instruments to do our somatic monitoring for us, because we need our own body sensitivity to monitor the performance of those devices whose functioning and fit are always fallible." (BC, p. 13)

2.3.2. Designing for somatic transformation

Shusterman's warning is particularly timely given recent intensified interest in devices and garments ostensibly aimed to improve posture. Two such devices were

[17] For a comprehensive review of biofeedback in technologically-mediated performance, see Donnarumma (Donnarumma, 2016, pp. 42–51).

launched on the crowdfunding website Kickstarter[18] one month prior to the completion of this thesis: a "posture monitoring" (Wang, 2016) device that alerts its user when they "slouch" (Upright Technologies, 2017), and a "posture transformer" that promises to deliver "perfect posture instantly." (Perfectore Corp., 2017) The first campaign raised over twenty-five times its funding target, while the second raised over one hundred fifty times its target. While it is laudable that a portion of the general public recognises the value of optimal neuromuscular organisation, it is nonetheless problematic that the most readily available options develop it by outsourcing, instead of refining, their capacity for self-sensing.

The approach I have taken in this research is instead more closely reflected in the works discussed in this section, which specifically focus on transforming users' felt experience of their body. For instance, Ståhl et al. designed two prototypes that aim to use "a somaesthetic approach to support a meditative bodily introspection" (2016, p. 305). The *Breathing Light* is a lamp that dims and brightens to the rhythm of your breathing, with the intent to act as a "reflection aid on your breathing and body" (Ståhl et al., 2016, p. 306). The *Soma Mat*, on the other hand, is a mat made with memory foam with embedded heating elements, which provide "heat stimuli to guide your attention to different body parts." (Ståhl et al., 2016, p. 306) Sensorless, neither prototype seeks to capture nor represent bodily states through data proxies, much like Haplós. The creation of both prototypes was guided by a design framework that Höök et al. (2016) call *Somaesthetic Appreciation*, which is characterised by subtleness in sensory cues and guidance, an intimate correspondence with the rhythm of the body, an approach to warding off external distractions through the designs' form

[18] https://www.kickstarter.com

factors, and user articulation of their experience to deepen the somatic learning process.

Haplós is similar to the *Soma Mat* in its use of directed stimuli to direct attention to specific regions of the body, as well as in its intent to create a comfortable learning environment to facilitate somatic learning (as I later discuss in section 5.2). The *Soma Mat* is also notable in its creators' considered attention to the material qualities of the mat's surface for affording somatic introspection, a subject I take up in section 3.3.2.1.1. Unlike the *Soma Mat*, however, Haplós is portable, wearable, and can be incorporated into a variety of clothing and surfaces. In addition, the vibrotactile somatic learning principles that I develop in section 5.2 share an affinity with Somaesthetic Appreciation, particularly in its approach to warding off external distractions and encouraging user externalisation of their somatic experience, particularly through drawing (Höök et al., 2016, p. 7). The vibrotactile somatic learning principles have additional aspects, however, that are particular to the somatic insights that patterned vibrotactile stimuli can uniquely afford. I also note that for many individuals who live in significantly warmer climates, heat stimuli would not necessarily bring with it the same positive, affective response that it might bring when experienced in a more temperate climate.[19]

The *Sonic Cradle* is an installation that "comfortably suspends users in complete darkness" (Vidyarthi & Riecke, 2013, p. 2306) and uses "respiratory biofeedback" (Vidyarthi & Riecke, 2013, p. 2311) to create a soundscape based on the user's breathing. The goal of the work is to introduce non-practitioners of meditation to mindfulness practice through "heightened and compelling breath

[19] I make this observation as someone who was born, raised, and is currently based in a tropical country where temperatures rarely fall below 26°C and can rise to 34°C, and rising (Cinco, de Guzman, Hilario, & Wilson, 2014).

awareness" (Vidyarthi & Riecke, 2013, p. 2307). While attaining a meditative state is not the goal of Haplós, nor does Haplós use any computationally-mediated biofeedback, Haplós shares with the Sonic Cradle the goal of encouraging users to tune into their embodied experience, and the use of a mechanism for reducing *postural tone* (which I define in section 4.5.2.2) as a way to provide a calm learning environment. In addition, its creators describe the *Sonic Cradle* as the mindfulness equivalent of "training wheels for children's bicycle" (Vidyarthi & Riecke, 2013, p. 2306), much like I intend Haplós to be used as a learning scaffold for facilitating somatic insight.

Surging verticality is an installation that used FM principles to "translate the subtle shifts in attention and nuances of felt sensation" to guide the design of "sensor-based interactive artworks" (Loke et al., 2013, p. 340). *Surging verticality* is composed of a suspended cloth apparatus which enfolds its user, to create a fabric-based "body extension" that altered the "morphology of the body through costume" (Loke et al., 2013, p. 346) and a balance board that is wired to detect the distribution of the user's weight, which determines a sound score that is heard as part of the installation experience. An initial version of the installation proved to be challenging to some users, and was subsequently modified in order to accommodate a wider range of physical abilities. The modifications were made with the goal of reducing initial stimuli, a strategy that was derived from FM (Loke et al., 2013, p. 346). The installation is intended to be experienced in two parts, the first being an artwork-specific guided FM lesson that precedes the second, installation-specific experience. In Haplós, I take a similar approach in sourcing strategies from the FM for focusing attention through an initial reduction of proprioceptive stimuli, and in the explicit use of FM-based instruction to guide user experience. Again, however, *surging verticality* is a sensor-based installation, whose interactive components and intended context of use differ significantly from that of Haplós.

Indeed, all of the examples discussed so far have been interactive installations, pointing to an absence of more wearable, portable form factors. In addition, while the works discussed above have been concerned with facilitating an awareness of the body, few have yielded cases of users reporting a change in the way they proprioceptively perceive a neuromuscular reorganisation, except in the case of *surging verticality* wherein some users were reported to "reevaluate their habitual posture and ways of moving." (Loke et al., 2013, p. 353) In a fascinating example of how sensory stimuli can alter perception of one's own physiological structure, Tajadura-Jiménez et al. (2015) designed and tested a wearable technology that synchronised a user's footsteps with modified footstep sounds that were intended to change the user's "perceived body." (Tajadura-Jiménez et al., 2015, p. 2950) In particular, increasing the perceived pitch of the footsteps "caused participants to feel as having a thinner body." (Tajadura-Jiménez et al., 2015, p. 2947)

The ability to create a somatically transformative experience is, I argue, best exemplified in independent dance/theatre artist Sally Dean's Somatic costumes™. Observing that "costumes have been underutilized as a tool in somatic practices" (Dean, 2012, p. 167), Dean uses costuming to defamiliarise one's own experience of the body:

> What we wear affects the way we move and how we are perceived. If I wear high heels, for example, I walk in an entirely different way than if I wear boots. My experience of my feet, and indeed of my whole body, is different; I create a quite different 'character', and the basis for my interactions with my environment and with others around me also changes. (Dean, 2012, p. 168)

For instance, the *Balloon Hat* costume is composed of six to eight balloons encased in stretchy fabric and worn on the head, and was influenced by imagery sourced from somatic techniques such as "the Skinner Releasing image of 'floating skull' and 'buoyancy' as well as the word 'volume' from [Scaravelli] yoga classes." (Dean, 2012, p. 173) The *Lentil Socks* costume was influenced by Dean's experience of the ground while practising Amerta Movement in Java (Dean, 2014), and is composed of socks with an inside layer of nylon, creating a sock-shaped compartment that was filled with dried lentils (Dean, 2012, p. 173). Dean recounts how her experience of wearing a traditional Javanese dance costume—composed of "a sarong tightly wrapped around my legs and pelvis, held in place by a *stagen* (sash)" (Dean, 2012, p. 168)—helped her "find an experiential understanding" (Dean, 2012, p. 168) of the sense of "containment" that she felt in the movement of people around her (Dean, 2015). Her experience recalls Lakoff and Johnson's (1999) theories around the embodied basis of more abstract thought, and point to Dean's assertion that costumes can be "portals of perception." (Dean, 2015, p. 158) My interest in this research was to investigate whether it was possible to create a reportable difference in how one perceives oneself somatically, and not in the way one is perceived by others. As such, Haplós is not explicitly or intentionally performative. However, in section 4.4.3, I recount a transformative encounter that I had with one of Dean's costumes, the *Balloon Spine-Leg* costume, which spurred the prototyping and evaluation process that eventually led to Haplós, while section 4.5.1 elaborates on a workshop that I held using a modified version of this costume.

2.4. Effects of vibrotactile stimulation on the body and nervous system

As I establish in section 4.5.2.1, Haplós uses vibratory motors to apply vibrotactile stimuli to the human body. In that section, I discuss how I chose vibrotactile stimuli as an alternative (though not a substitute) for pressure-based tactile stimulation. In this section, I describe the effects of vibrotactile stimulation on the body and the nervous system.

Vibrotactile motors do not provide the same tactile stimuli as the pressure-based stimuli that hands or material objects do when brought in contact with the skin. For one, they do not stimulate the same tactile receptors. A type of receptor known as Pacinian corpuscles pick up high-frequency vibrations, whereas other types of receptors—such as Merkel's disks and free nerve endings—respond to contact, pressure, and stretching (Gallace & Spence, 2014, p. 22; Karam, Wilde, & Langdon, 2017, p. 119).

However, neither is the mapping so unequivocal between receptor type and stimulation type. For instance, while hair follicle receptors are sensitive to stroking (Gallace & Spence, 2014, p. 22), they also detect vibrotactile stimuli at low frequencies (Mahns, Perkins, Sahai, Robinson, & Rowe, 2006). In addition, different tactile receptors are absent or present to varying degrees depending on whether the skin is *glabrous* (the type present on the palms of the hand, soles of the feet, and some parts of the genitals) or *hairy* (the skin found everywhere else on the body except on the lips, which is classified as being somewhere in-between glabrous and hairy) (Gallace & Spence, 2014, p. 22).[20] Thus, different receptors respond to tactile stimulus depending on where it is being applied. To further complicate matters, Pacinian corpuscles are not present in the superficial regions of hair skin, but they *are* present in "the deeper underlying tissue surrounding joints and bone" (Mahns, Perkins, Sahai, Robinson, & Rowe, 2006, p. 1442). Indeed, the tactile sense is—unsurprisingly—a complex phenomenon that arises from the integration of

[20] The human back is covered by hairy, not glabrous skin, but while glabrous skin may have more receptors and are more sensitive to vibratactile stimuli (Gunther et al. 2002:3), pleasantness is more highly rated on hairy skin (Etzi, Spence, & Gallace, 2014).

information from multiple types of receptors (Gallace & Spence, 2014, p. 34). No form of tactile stimulation can really substitute for another on a neurophysiological substrate level.

However, this does not mean that tactile stimulus from a non-human source has no somatic learning value. I argued in section 3.3.2.1.1 that the properties of an artefact can be tuned to the human organism's sensory capacities to afford somatic insights. Similarly, I sought to explore whether a physical technology using vibratory motors can create a novel (though not necessarily "better") somatic learning experience that perhaps not even a human teacher alone could provide.

Vibrotactile stimuli create sometimes contradictory responses in human tissue. On the one hand, plantar fascia becomes more pliable when subjected to vibrotactile stimuli at 8-10 Hz (Frenzel, Schleip, & Geyer, 2015). Indeed, Usuki and Tohyama (2016) reported a case study of three patients with Minamata disease (which causes cerebral palsy-like spasticity) where handheld vibration massagers, applied to plantar fascia at 90 hz for 15 minutes, over one year, improved their range of motion. On the other hand, vibrotactile stimuli can increase the tonus of muscles when applied to tendons, due to a neurophysiological response called the *tonic vibration reflex* (Park & Martin, 1993). For instance, vibration of the hand tendons can increase muscular tonus of the associated muscles due to the tonic vibration reflex, particularly in those who suffer from a condition known as writer's cramp (Kaji et al., 1995); the increase in muscular tonus rises if the muscle is already voluntarily contracted (Park & Martin, 1993).[21]

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[21] A similar increase in muscular tonus can be observed in *whole body vibration* (WBV), in which the entire body is vibrated using, for instance, a large vibrating metal plate. However, the increase in tonus occurs only during the period during which the WBV is applied and not after (McBride et al., 2010). While WBV uses much lower vibration frequencies (5-45 Hz) (though Petit (2010) reports that 50 Hz

Like many sensory modalities (Squire, 2008), vibrotactile perception is susceptible to perceptual illusions. Consider two points on an individual's skin—point A and point B—on which a vibrotactile stimulus can potentially be applied. If A and B are stimulated one after the other within a particular time frame, the individual can perceive the vibrotactile sensation moving—or indeed, hopping—from point A to point B; this is known as the *saltation* or *cutaneous rabbit* illusion (Tan, Gray, Young, & Taylor, 2003). If point A and B are stimulated simultaneously at different intensities, the individual perceive a vibrotactile sensation at a third point somewhere in-between A and B; this is known as *funnelling* (Barghout, Cha, Saddik, Kammerl, & Steinbach, 2009). Vibrotactile perception also appears to follow at least one of the Gestalt perceptual properties (Lidwell, Butler, & Holden, 2003, p. 44), that of *closure* (Kitagawa, Igarashi, & Kashino, 2009). Gallace and Spence note that "people can complete the gaps between two separate sequentially-presented vibrotactile stimuli when these gaps are filled with tactile noise." (2014, p. 66)

For this research, the most interesting and pertinent effect of vibrotactile stimuli on neurophysiology comes from a series of studies by neuroscientists Karin Rosenkranz and John Rothwell who showed how vibrotactile stimulation can reorganise cortical representations of sensation and motor function. I defer further discussion on this subject until section 4.5.2.1.1 because I wish to emphasise its place in the chronology of the research process, as I discovered this work (which provides considerable justification for what I do from a neuroscience perspective) after I had already started conducting my studies.

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is optimal) than the kind of vibration that is known to induce the tonic vibration reflex (100-150 Hz) and are administered indirectly as opposed to directly onto a specific area of the body (Cochrane, 2011), the tonic vibration reflex may account for the effects seen in WBV (Zaidell, Mileva, Sumners, & Bowtell, 2013).

2.5. Vibrotactile stimuli in new media art and technology design

While a large portion of research in and design using vibrotactile stimulation has focused on sensory substitution or augmentation (Collins, 1970; Bach-y-Rita, 1972; Bach-y-Rita & Kercel, 2003; Bird et al., 2008; Matt & Junge Symphoniker Hamburg, 2016; Morrow, 2016), or more generally as an information medium (Jones, 2011; Novich & Eagleman, 2015; Spence, 2014), it is the use of vibrotactile stimuli for artistic, ameliorative, and affective purposes that concerns my research.

Vibrotactile stimulation is often associated with massage and relaxation (Gunther & O'Modhrain, 2003). Indeed, a number of patents have been filed for portable devices intended to induce relaxation or provide a massage-like experience using vibrotactile stimuli (Blue, 2002; Brueckmann & Whittinghill, 2008; Hajianpour, 1996; Muggenthaler, 2009; Omandam & Spector, 1994; Stark & Stark, 2008). In all of these cases, the vibrotactile stimuli are arranged in fixed arrangements that do not permit redistribution. Nor do these devices explicitly support reprogramming the vibrotactile patterns along user-specified parameters. A particularly interesting use of vibrotactile stimuli for relaxation and pleasure is represented by *Massagebot,* a small climbing robot which uses computational methods to locate and stimulate acupuncture points (Chen, Wu, Feng, Xu, & He, 2016). Several devices claim medical or therapeutic value. One patent is aimed at pain reduction using a combination of "vibration, cold and distractive elements" (Baxter & Calderon, 2008), while a device meant to be strapped on the forearm is intended to treat repetitive trauma syndrome (W. M. Davis & Yanke, 2000). A clinically-established use of vibration is high-frequency chest wall oscillation (Lange et al., 2006), although this involves indirect vibration as opposed to localised vibrotactile stimulation.

One artwork, *TapTap*, is described as an "affectionate scarf… that can record, distribute, and play back affectionate touch for emotional therapy." (Regine, 2006) The emulation of expressive human touch using continuously varying vibrotactile feedback is reminiscent of Manfred Clynes' notion of *sentics*, a theory that affective information can be modelled using contours of intensity that he called "essentic forms" (Clynes, 1980). While recording, distribution, and playback of vibrotactile patterns is also a feature of Haplós, *TapTap*'s playback capabilities appear to be limited to only "three kinds of touch… the pressure of touch, the warmth contact and the percussion of a friendly scarf." (Regine, 2006) *TapTap* represents what appears to be a rare use of vibrotactile stimuli as the sole sensory modality in artistic work. Most uses of vibrotactility are part of a multimodal sensory experience. For example, Israr et al. (2014) use vibrotactile stimuli to enhance visual imagery presented during storytelling; similarly, Ozcan (2004) proposes the use of vibration to prompt imaginative thinking in interactive artwork that involves visual and auditory imagery.

Indeed, vibrotactile stimuli in artistic and design work are often coupled with auditory stimuli. As sensory phenomena, vibrotactile stimuli and auditory stimuli are fundamentally similar in that they enter the field of awareness through mechanotransduction (Suslak, McKay-Fletcher, Armstrong, Jarman, & Bewick, 2013), the biological process of converting mechanical energy into electrical impulses in the nervous system, which are eventually experienced as tactile or auditory phenomena. The relationship between vibration and sound is well articulated by Lawrence Kramer, who writes that "music is matter rudely awakened—matter that quivers as a result." (2015, p. 151) Interestingly, sound can heighten the experience of tactile stimulation (Merchel & Altinsoy, 2014), and vice-versa (Huang, Gamble, Sarnlertsophon, Wang, & Hsiao, 2013). This close correspondence between mechanical vibration and audible sound has motivated artistic and design practices that bring these two sensory modalities together. This has been exploited in commercial products such as the SubPac[22] and the SpinalTAD[23] which play audio directly onto a user's torso, and is particularly evidenced in the body of work of Eric Gunther, who has coupled vibration with sound in a number of different pieces, including *Organ Organ* (Gunther, 2007) and *Vibravive-VL12* (Gunther, 2005). Both works involve a user reclining or lying prone on a soft surface through which they experience a multimodal composition for sound and vibration.

Significantly, Donnarumma (2016) has used vibration as effected through sound and whole-body vibration to create unusual physiological experiences in his artwork, *Nigredo*. There are notable parallels but also diametric oppositions between Haplós and Nigredo. Both aim to create "altered self-perception" (Donnarumma, 2016, p. 149) of the body through vibration. Both works can be tuned to the user, which in Nigredo involves the use of biofeedback through sonification of the user's physiological data, whereas in Haplós, it involves the user's ability to configure their vibrotactile experience (as I describe in section 5.3.5). Technical differences between the systems include Nigredo's use of indirect or diffuse vibration through sound, while Haplós uses point-like vibrotactile stimulation delivered using motors. However, the most important differences between the two works lie in their intended experience for the user. Nigredo uses "intense vibrational stimuli" (Donnarumma, 2016, p. 131) to create a disconcerting experience in order "to produce the visitors' bodies as new hybrid, corporeal entities through the experience of threshold phenomena." (Donnarumma, 2016, p. 151) In contrast, Haplós uses comfortable, perceptible vibrotactile stimuli to allow users to feel more of themselves through attention to just noticeable differences in sensory cues.

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[22] http://subpac.com/
[23] http://www.tadsinc.com/products/spinaltad/

A precedent to Haplós that comes close to its use of vibrotactile stimuli is the body of work on what has been variously called *tactile composition* (Gunther, Davenport, & O'Modhrain, 2002), *vibrotactile music* (Baijal, Kim, Branje, Russo, & Fels, 2012), *vibrotactile composition* (Nam & Fels, 2016), or *mechanotransductive composition* (Kokoras, 2014). However, with the exception of the work of Nam and Fels (whose contribution is on an authoring tool for vibrotactile patterns), all these works rely on a multimodal coupling of vibrotactile or vibration stimuli with sound. For instance, Baijal et al. (2012) created twenty pre-composed vibrotactile "tune blocks" and asked Deaf film-makers to score a film score using these tune blocks; the score was experienced through a chair with voice coils (the essential component of sound speakers) embedded in them (Holland, 2015). In *Cutaneous Grooves* (Gunther et al., 2002), thirteen high-frequency transducers are placed on various locations of the users' body to provide vibrotactile stimuli. These are then used as part of a series of hybrid musical-vibrotactile "concert for the skin" (Gunther et al., 2002, p. 2) in which the vibrotactile and musical components function as "independent compositional strands [that] can coexist in any number of ways ranging from rhythmic unison to crossmodal counterpoint." (Gunther et al., 2002, p. 11)

I conclude this review with the work of Morrison et al. (2017), who have used vibrotactile stimuli in an interactive installation that has artistic and ameliorative aspects, much like Haplós does (as I discuss in sections and 5.7.1.1). In their work, *The Humming Wall,* a vest equipped with vibrotactile motors plays structured patterns based on a "vibrotactile language" (Morrison et al., 2017, p. 1) that work simultaneously as navigational guides and (similar to *TapTap*) sensory proxies for human touch. Notably, they emulated tactile gestures "such as stroking up or down the back to relax a person - providing sensations that produce a 'there, there, it's okay' effect." (Morrison et al., 2017, p. 3) The vest is used in conjunction with a vibroacoustic wall which produces calming sounds (Morrison et al., 2017, p. 3). *The Humming Wall* system represents a confluence of embodied aesthetics and a concern for well-being, an ethos that is shared in my research. Haplós extends this work by— among other ways— empowering the user to customise their own vibrotactile experience (as I explain in section 4.5.2.4).

2.6. Chapter summary

This research draws on multiple strands of inquiry and practice. Philosophically, it finds a home in Shusterman's somaesthetics, which positions the body as the site for self-fashioning, sensory appreciation, and improved perception of the self. I take these as the foundational principles of the entire research-through-design process, and weave throughout the thesis viewpoints that anchor my approach to the somaesthetic framework. I reviewed the three branches of somaesthetics— analytic, pragmatic, and practical—which I return to in Chapter 6 when I discuss one of the main contributions of this work, a proposal for vibrotactile somaesthetics that inherits from Shusterman's framework. Shusterman's four levels of body consciousness were reviewed and discussed, after which I clarified that this research is primarily concerned with the third level of body consciousness, which I named somaesthetic attentiveness. I also made explicit that I was interested in proprioceptive sensations, but that I also intend to develop a specific notion of structured somaesthetic phenomena.

Because of the role that material tools, technologies, and environments can play in facilitating somaesthetics attentiveness, somaesthetics opens a door for design interventions. After reviewing seminal work in HCI on designing with the soma in mind, as well as previous work in designing for somatic transformation, I noted an absence of wearable digital technologies that facilitated somatic learning in a consistent or systematic way. I also highlighted the somatics-inspired costume research of Sally Dean, which I further discuss in sections 4.4.3 and 4.5.1.

I then turned to address the other body of theoretical and practice-based research related to vibrotactile stimuli, and the particular effects that they have on the body and the nervous system. In particular, I referenced a body of work conducted in the neurosciences on the effects of vibrotactile stimuli on cortical representations of sensation and motor function, which I elaborate on at length in section 4.5.2.1.1.

Finally, I reviewed the use of vibrotactile stimuli in new media art and technology design and demonstrated a relative paucity of work that simultaneously incorporates the use of vibrotactile stimuli, an interest in embodied aesthetics, and a concern for well-being, with *The Humming Wall* being a notable exception.

In summary, this review of related concepts and prior work point to a gap in design-based research, one that can be filled with the creation of a wearable, portable, and easily customisable technology that seeks to cultivate somatic insight in a way that is supported by the unique neurophysiological properties afforded by vibrotactile stimuli, and by a structured method for developing somaesthetic attentiveness. This method—the FM—is the subject of Chapter 3.

Chapter 3: Somatic learning concepts from the Feldenkrais Method

3.1. Introduction

In Chapter 2, I reviewed the way in which somatic approaches and vibrotactile stimuli have previously been applied to the design of interactive technologies and wearable devices. While these works have significantly re-established the value of embodied, first-person experience in technology design, my review of the literature revealed a need for elaboration of embodied learning processes as a strategy for designing somatic technologies. In particular, there is a potential to render somatic methodologies more accessible to a wider audience through designing technologies that can function as learning "scaffolds" (Wood, Bruner, & Ross, 1976) through which somatic insight can be built. In this research, I thus seek to address the educational aspects of somatics more explicitly in technology design.

To this end, I chose to undertake a "deep dive" (Tischler, 2009) into the Feldenkrais Method (Moshe Feldenkrais, 1990; Rywerant, 2003) because of its emphasis on learning (Buchanan, 2012). Indeed, the Feldenkrais Method is usually positioned by its practitioners not as a therapeutic modality but as a movement-based learning system that facilitates "neuromuscular re-education" (Beringer, 2010). Russell and Schläfke suggest that during an FM "lesson," increased attentiveness to subtle changes in movement engages and regulates communication between brain areas related to planning, emotion, sensorimotor maps, and movement, which in turn leads to an "expansive perspective for effective action" (Russell & Schläfke, 2016). Others have additionally expressed the learning mechanisms using formal frameworks such as cybernetics (Rywerant, 2003) or dynamic systems theory (Kimmel, Irran, & Luger, 2014) to explain the efficacy of FM.

What are the principles of FM? In this chapter, I take up this question by describing the insights that emerged from my participation in an FM training programme. I discuss how the training motivated and provided the methodological tools I used for two other explorations that I conducted in parallel with the training: practice-teaching FM lessons, and phenomenological explorations of my embodied experience using ISRD, which I discussed in section 1.5.1.1. My insights from these explorations be braided with the theoretical and empirical literature on the Feldenkrais Method to form an *integrative review* (Whittemore & Knafl, 2005) that lays out a conceptual framework of FM that advances the practice-based aspects of this research.[24]

3.1.1. About Moshe Feldenkrais

[24] Like meta-analyses (Glass, 1976) and systematic reviews (Counsell, 1997), integrative reviews synthesize previous research. However, unlike meta-analyses and systematic reviews (which require the reviewed data to be the result of quantitative analysis), integrative reviews can take on a wider range of types of research results. Integrative reviews can not only present the state of the discipline, but also contribute to theory (Whittemore & Knafl, 2005) and build new concepts (Broome, 2000). Integrative reviews are particularly useful for conducting interdisciplinary reviews of research that cross more than one epistemological paradigms; see, for instance, Parker & Prechter (2005). For these reasons, the integrative review model is appropriate to the generation of a conceptual framework.

The Feldenkrais Method is named after its originator, Moshe Feldenkrais (1904-1984), who was an electrical engineer and physicist with an athletic inclination. He was active with soccer and, most notably, judo, a martial arts practice to which he made contributions. Drawing from a variety of fields—including but not limited to neurodevelopment, Eastern meditative practices, Hassidic philosophies, and theories on the cognitive unconscious and its influence on conscious action (Braude, 2016)—as well as his own experiences as an athlete, he developed what came to be known as the Feldenkrais Method (Smyth, 2016). His personal experiences are closely intertwined with the development of his philosophies and the Method (Braude, 2016). While a discussion of the confluences between his personal and professional activities is beyond the scope of this thesis, readers are referred to other sources (Newell, 1990; Reese, 2012) for a more comprehensive review of his life, work, and philosophy. What is relevant here is that Moshe Feldenkrais took what was then known in neurophysiology and developmental biology, continuously integrated it with his own epistemological and phenomenological frameworks, and evolved a pragmatic (in the somaesthetic sense of the word) system that drew upon the neurodevelopmental insights of the time.

3.1.2. Experimental research on the Feldenkrais Method

Indeed, of all the somatic practices I have encountered, FM is most consistent with scientific theories on motor learning, sensory-motor activity, and skill acquisition (Connors, Galea, Said, & Remedios, 2010). Studies from the cognitive and kinesiological sciences on people doing FM show sustained improvement in balance control and postural alignment (Connors et al., 2010; Ullmann & Williams, 2014). Yet other studies show a decrease in perceived pain (A. Alexander, 2006; Plastaras et al., 2011). A particularly dramatic example can be found in Doidge (2015), who documents a case in which FM lessons restored vision in a patient with serious eye impairment by facilitating awareness of the structure of the eyeball and the extraocular muscles connected to it. Doidge explains that the lessons provided the patient with the kind of awareness and control of these muscles in order to change not only the quality of eye movement, but also the cortical representation of his 'blind' eye:

> During the course of his blindness, [the blind eye] had disappeared from his body image. The body image has both a mental component (our subjective sensory awareness of our body) and a brain component (in the sensory neurons of our brain maps). [He] no longer had a sense of where the eye was in his head. (Doidge, 2015, sec. "Putting It All Together")

While ostensibly focused solely on improving the quality of physical movement and improved interoceptive awareness (Paolucci et al., 2016), FM can also enhance cognitive functioning through measures of cognitive flexibility and executive function (Ullmann & Williams, 2016), and affective states as measured in terms of anxiety (Kolt & McConville, 2000) and quality of life (Edgar, 2016).

3.1.3. Two ways of learning the Feldenkrais Method

In order to provide context for the review, it is worth introducing at this point the two ways of learning FM in practice: Awareness Through Movement (ATM) and Functional Integration (FI). ATMs often (but not always) begin with a student lying on their back, usually on a mat or a carpeted surface. The student listens to movement directions verbally delivered by the teacher, and enact the instructions within certain parameters: students can take a rest at any time, reduce the size of the movements, and do a movement in the imagination if the movement is too difficult. All movements are done gently, softly, within the range of ease and comfort.

FI lessons, on the other hand, involve the teacher performing gentle "manipulations" (Rywerant, 2003) with the student on a padded table. A successful

FI teacher is able to touch and move a student in such a way that the student feels themselves more clearly. It is a relational process where the teacher and student explore movement possibilities together. Kimmel et al. elegantly summarise Functional Integration lessons as processes which "enable somatic learning through continuous tactile coupling, a real-time interpersonal dynamic unfolding in a safe dyadic sphere" (2014, p. 14).

3.2. Primary sources: immersive explorations

To construct a conceptual framework for FM, I sample from three primary sources that I have generated: my experience of participating in the learning activities within an FM training programme; participant experiences of ATM and FI practice sessions that I conducted; and insights generated from self-exploration sessions I conducted throughout the entire duration of the research using the ISRD method (discussed in section 1.5.1.1). The activities which generated these data form the immersion strand of my methodology. In addition to generating primary data, these activities also contributed to refining my somatic analytical abilities in a process leading to increased "somatic connoisseurship." (Schiphorst, 2011) I expand on these three activities in following sections.

3.2.1. Participating in a portion of a FM training course

The foundation of my practical and theoretical appreciation of FM was generated through my participation in a portion of an FM practitioner training programme offered by the Feldenkrais International Training Centre (FITC) in

Sussex, which was the first training centre established in the UK (FITC, n.d.-b). I was enrolled for the equivalent of the first two of the four years of the training programme that started in October 2014, called "Sussex IX." As a late-entry student, my training period began on 20 May 2015 and ended on 3 September 2016. Of the 80 training days that comprised these two years, I attended 67.5 days.[25] As of this writing, the training continues to be led by the FITC's educational director, Garet Newell, who co-directed the first Feldenkrais professional training programme in the UK (FITC, n.d.-a). Figure 1 shows students participating in a FM class similar to the Sussex IX training.

Figure 1. Students participating in a typical FM class. Image from https://www.flickr.com/photos/divamover/3198517366. Licensed for reuse under a Creative Commons CC BY-SA 2.0 license.

The training was conducted in segments that lasted between four to six days every two months, and was led by either Newell or a guest teacher. A typical day began with students sharing insights on their experiences from the previous day or, if it was the first day of the segment, reflections about how the previous segment might have influenced the students' experiences of daily activity during the intervening period. The rest of the day would then be occupied with ATM lessons, discussions

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[25] Time and budget constraints on this research prevented my enrolment in the succeeding years. Absences were largely due to having joined the programme late and despite attending 'catch-up' segments.

and lectures on theoretical aspects of FM, practice-teaching ATM lessons, and practice-teaching FI lessons. At the end of the day, a subset of the students would get FI lessons from Newell and invited teachers; each student received several FI lessons from the teachers each training year. At the end of each segment, we were frequently given homework, such as preparing to teach a specific ATM or FI lesson to other students in the class for the following segment, or practice-teaching ATM or FI lessons in-between segments.

3.2.2. Practice FI and ATM explorations

I formalised the practice FI and ATM explorations I conducted as research studies in which I developed my understanding of somatic teaching and learning processes. I recruited participants from within my network of colleagues and acquaintances. They were briefed about the sessions and their participation prior to the start of the lessons, although in the information sheets and during pre-session conversations, I attempted not to bias the participants with specific descriptions of what they might experience. I merely stated that they were to experience "hands-on, touch-based manipulation" and that they might experience "unfamiliar sensations." Participant impressions of the lessons were gathered through structured interviews and written self-reports. I used questions from the ISRD framework both to guide my line of questioning and to analyse their verbal and written responses. Ethical approval for these sessions (and for all somatic investigations in this research that involved other participants) was granted by the Faculty of Arts & Humanities Ethics Committee.

3.2.3. Somatic self-exploration sessions using ISRD

The primary purpose of ISRD was to structure, record, and analyse the somatic explorations I conducted with myself in an "autobiographical" (Ellis & Bochner, 2000) manner. Embodied, critical reflection is a crucial part of postpositivist, somatic research processes (Green, 2015; Shear & Varela, 1999), in which the practitioner-as-researcher is simultaneously subject, observer, and observational instrument (Shusterman, 2008). Foregrounding the personal and the private does not wipe out the public and the theoretical; as Sparkes (2002) writes, "My subjectivity is filled with the voices of others." Similarly, I argue, my embodied experience finds echoes in those of others.

I employed ISRD in two types of self-explorations. The first type involves activities that were part of my daily routine, such as walking to work or doing household chores. Indeed, throughout the course of this research, somaesthetic reflection became a fixture in my phenomenological landscape, infusing nearly every moment of my waking life. As I type these words, for instance, I am paying attention to the way my ischial tuberosities (sit bones) are contacting the chair, how the weight of my torso is distributed across them, and how the different actions of my left and right arms re-organise my torso and, subsequently, the activity of my thoracolumbar muscles and the weight distribution across my pelvis.

The second type of activity in which I brought ISRD to bear involved dedicated somatic exploration sessions, lasting up to an hour, which I conducted at home or in a fitness centre. Many of my key insights happened when I was lying on the carpet (at home) or on a gymnastics mat (at the fitness centre). Indeed, lying on my back became foundational to my research process in that it seems to engender a form of 'embodied mind-wandering'.[26] In these somatic exploration sessions, I revisited and elaborated on ATMs that I have come to learn through the FM training programme. At the very beginning of the research, the intention of these sessions was vague and the insights generated from them wandered across related but distant themes. However, after building the first prototype of Haplós based on a speculative idea of using vibration as a body awareness cue (as I discuss in section 4.4.2), both my theoretical and designerly analysis began to come into clearer focus and in closer relationship with each other, and the sessions became more purposeful.

3.3. A conceptual framework for the Feldenkrais Method

In this section, I present a framework of FM as a collection of concepts that I have categorised as aims and theories, epistemological approaches, and methods. My categorisation borrows in part from Repko's (2008, pp. 83–114) collection of defining elements of a discipline. In presenting this conceptual framework, I do not mean to suggest that my codification is exhaustive or definitive.[27] The boundaries of the framework's elements are not fixed, and what might be an aim in my analysis is a methodological strategy in another's. Furthermore, my experience of the FM training programme was constrained by practical considerations around timing and funding.

Nevertheless, this integrative review serves two purposes. First, I wish to provide a more substantive foundation for the importance of FM and somatic methods for lived experience and in doing so, more clearly frame, scope, and warrant the arguments I advance for the value of designing technologies for somaesthetic

[26] For a discussion on how the somatic processes might play a role in creative process, see Krichman (2014).

[27] For an outstanding example of a formal reframing of a somatic practice, see Kimmel et al.'s (2014) analysis of FM and Shiatsu using dynamic systems theory.

experiences. Second, sampling from and organising the substantial practice and theory of FM into a set of components helps contextualise the somatic concepts which I map to—and further develop as—design features of Haplós, as I discuss in Chapter 4.

In weaving the conceptual framework for FM, the three primary sources collectively form the warp of my thinking process. Through these, I thread perspectives from the FM literature, which include writing and talks by Moshe Feldenkrais, publicly available resources (such as scholarly writing, lectures, and ATM lessons) created by FM practitioners, and perspectives from across the embodied cognitive studies network. In this section and throughout the remainder of this thesis, ideas generated from a note or memo are referenced as appropriate. For instance, "#P0.150213.SE.A3" and "#P08.160707.tFI.A3" refer respectively to a somatic exploration session from 2015 February 13 and to a practice FI session I conducted on 2016 July 7 with participant P08, both of which are documented in Appendix 3.[28] I also draw from notes and memos I kept of my experiences during the training, as well as quotes from the teachers who led the segments. The segments were audio recorded by the FITC and copies were provided to the students. While these recordings are proprietary and cannot be accessed by the general public, they are archived with the FITC and filed under a coding system. Quotes from instructors are thus referenced using the code of the associated audio file; for instance, "S9-016" refers to the sixteenth audio file in the Sussex IX training recording archive.

[28] Each participant in this studies for this research is assigned a code with the format "Px", where x is a unique integer. This code remains constant across studies, since some participants participated in multiple studies throughout the project. P0 refers to myself.

3.3.1. Aims and theories

FM has several interrelated aims and theories. To introduce them, it is worth quoting at length a portion of a talk by Newell, which was delivered at the start of the training programme and which deftly brings many key themes together:

> There's a capacity [afforded by the potential connections in the brain] for connecting, for learning, for putting things together, that's almost infinite. It's so large, mathematically, that it's hard to imagine the profundity of the human brain. That kind of respect for the human brain and the potential that's there—the potential for us to learn, the potential for us to be able to make our lives better, make our lives easier—is really the aim of what we're doing here. But we start in a very different place than [where] a lot of schools start. We start with the premise that until you know yourself, you can't really do much with this capacity. So many skills are taught with you learning immediately the skill, and before you learn the skill you don't learn anything about you. So the skill either fits you or it doesn't fit you; or you learn it easily or you struggle with it. So the basis of what we're doing here is [....] a continuation of what I think is [the process of] knowing yourself. "Know thyself" is something we know, philosophically, from the time of Socrates, [who] was a challenger of human experience. He went around and asked people, "How do you know what you know?" ....I really feel that Moshe Feldenkrais' project is like a continuation of the project that Socrates started. (S9-001)

In the following sections, I unpick and identify some of the aims and theories of FM that Newell touches on. Six are discussed: the body as constitutive of the self; the existence of a plastic self-representation; self-knowing as self-sensing; self-sensing as an improvable skill; the connectedness of the body; and improving action.

3.3.1.1. Having and being a body: reuniting the body with the self

Feldenkrais was concerned with "deciphering of the relationship between the self and the body" (Mansbach, 2016). As Shusterman observes, "When using my index finger to touch a bump on my knee, my bodily subjectivity is directed to feeling another body part as an object of exploration. I thus both *am* body and *have* a body" (2008, p. 3). However, though I can indeed turn my bodily subjectivity towards another part of my body, the relationship cannot be as simple as a subject-object one. Bodily self-perception as mediated by touch is a looping relationship. The question of what constitutes the self could invite further analysis into dualism and identity theory,[29] but would be beyond the scope of the present discussion.

What is relevant for this research is to illustrate how the body is treated in relation to the self pedagogically. In section 1.4.3, I raised the distinction between the body and the soma. This nomenclatural distinction between the two is important enough that it plays a role in FM instructional strategies: during the Sussex IX training, students were instructed not make a distinction between the person and their body. Instead of asking our prospective students to "feel their bodies," we were advised to instead simply direct them to feel *themselves*, thus avoiding any thorny problems of dualism that may arise from dissociating the self from the body.

3.3.1.2. The existence of a plastic self-representation

Kampe (2015, p. 204) notes that Moshe Feldenkrais was influenced by the work of neurologist and psychiatrist Paul Schilder and his work on the "body image." He further quotes Feldenkrais at length: "We act in accordance to our self-image. This self-image—which, in turn, governs our every act—is conditioned by varying degree by three factors, heritage, education and self-education." (Feldenkrais, 1974, p. 3) While a critical discussion of what precisely constitutes the self-image is beyond the scope of this thesis, a more delimited view of the self-image as the body image allows me to relate FM with the cognitive science literature on body representations. For instance, Gallagher (2011) refers to an individual's conscious and unconscious models of their physical self as the *body image* and *body schema*, respectively. The size, shape, and relative position of body parts is hypothesised to be a precept that is constructed and stored in a neural "implicit body representation" (Longo & Haggard,

[29] See, for example, Chalmers (2002).

2010) and updated based on proprioceptive, exteroceptive, and teloreceptive sensory information (Proske, 2015; McNeill, Quaeghebeur, & Duncan, 2010; Touzalin-Chretien, Ehrler, & Dufour, 2010; Tsay, Giummarra, Allen, & Proske, 2016). FM practitioners Roger Russell and Ulla Schläfke suggest that the "cascade" of neural signals triggered by an FM lesson help synchronise the "multiple sensory and motor homunculi—neurological maps of the body—in the brain" (Russell & Schläfke, 2016). The word 'homunculi' here refers not only to Penfield's well-known representations of the amount of cortex devoted to sensory and motor representations (Penfield & Boldrey, 1937)—also known as *somatotopic maps* (Squire, 2008)—but potentially other kinds of homunculi as well. For instance, Longo and Haggard (2010) suggest that cortical representations could exist that map the body's "underlying position sense"—i.e., a *proprioceptive* homunculus.[30] These cortical representations of the body can be altered (Ramachandran & Blakeslee, 1999; Blakeslee and Blakeslee, 2008; Rosenkranz & Rothwell, 2006); that is, the brain is plastic.

My own experience resonates with these theoretical positions. For instance, over the course of two years I have developed a more persistent and clearer perception of my pelvis (#P0.150529.SE.A3; #P0.150725.SE.A3) and ribcage (#P0.160331.SE.A3; #P0.170127.SE.A3). In the studies I conducted involving Haplós, participants reported an altered perception of their backs, as I discuss in sections 5.5.2 and 5.5.3. Because the difference between the body image and body

[30] In addition to these more 'structural' representations, I suggest that there might also be more functional representation of the self, consisting of cortical models of one's one own behaviour and responses both to the exteroceptively sense-able or "phenomenal" (Gibson, 1979, p. 61) environment as well as interoceptive and proprioceptive stimuli. This repertoire of functions thus forms a part of the organism's set of processes for self-organisation or "autopoiesis" (Maturana & Varela, 1980).

schema is a contested one (de Vignemont, 2010), and because the self is framed in FM within the context of the body, I henceforth use the more general term "self-representation" as a way to encapsulate—as well as park the debate on—the relationships between self-image, body image, body schema, and cortical homunculi.

3.3.1.3. Getting to know the self by improving the self-representation

Studies in the cognitive sciences have suggested that the proprioceptive and interoceptive senses are important mechanisms for how we understand or indeed construct the self (Tajadura-Jiménez & Tsakiris, 2014; Craig, 2009; Damasio, 2010). For instance, Gallagher suggests that the development of the sense of self in infants is linked not only to the ability to visually recognise oneself in the mirror, but also linked to the establishment of the "proprioceptive self—a sense of self that involves a sense of one's motor possibilities, body postures, and body powers, rather than one's visual features" (Gallagher, 2005, p. 83). It thus stands to reason that developing these sensory capabilities also serves to develop our capacity to "know the self."[31]

FM seeks to help individuals get to know themselves better by taking advantage of brain plasticity to increase the resolution and accuracy of the self-representation. By accuracy, I refer specifically to properties of the self that have both a subjective experience and an objective component, such as size and shape. Two examples illustrate this concept. In one activity during the training, the class was asked a series of questions about physical properties of regions of ourselves; for instance, we had to figure out which part of ourselves could typically fit comfortably in our forearm. The answer, somewhat surprisingly, was our foot. This activity was

[31] Knowing oneself, in turn, can be related to wellbeing, as Foucault did by insisting that "to take care of oneself consists of knowing oneself." (Foucault, 1988, pp. 24–25).

meant to draw attention to how our self-representations do not fully capture objectively observable or even measurable properties of the physical self. In another instance, while receiving an FI lesson, it was made suddenly obvious to me that my shoulders were actually broader than I thought they were because I kept lying on my side in a manner that suggested that I thought my shoulders were 1-2 inches narrower than they are. My internal representation of that part of myself was not consistent with its more objectively measurable properties. Indeed, when one looks at Penfield's sensory and motor homunculi, a surprisingly small amount of the somatosensory and motor cortex is devoted to the torso (Penfield & Boldrey, 1937), particularly given its physical size with respect to the rest of the body.

One of the ways that FM improves the self-representation is by clarifying body areas and motor functions that are poorly represented. A good example of this involves an ATM lesson taught in the training where, lying on my back with legs bent and my pelvis and back lifted away from the ground, I traced a precisely defined circle on the area between the shoulder blades by moving my pelvis and torso so that the circle was defined by which part of my upper back was in contact with the ground. This tracing was done several times, in both clockwise and counter-clockwise directions. When the lesson ended, that defined area between the shoulder blades felt much clearer and in contact with the ground.

3.3.1.4. Self-sensing is an improvable skill

FM assumes that self-sensing through body attentiveness and body meta-attentiveness (previously discussed in section 2.2.3.1) can be improved. Accounts of improved self-sensing have been reported in the FM literature (Kampe, 2015) testifying to this. A basis for this theory can be found in the *enactive* view of cognition, in which sensation is understood not as something which "just happens to us" but something we do; as Alva Noë argues, "what we perceive is determined by what we do (or what we know how to do); it is determined by what we are ready to do" (2006, p. 1). That is, *self-sensing is a skill*.

Nowhere perhaps is this more true than in proprioceptively and interoceptively sensing the self, a process that typically requires the allocation of attention when performed during the course of everyday activity. My experience over the course of two years of FM training bears testament to that, as do the testimonials by other people who have gone through an FM training programme (Hasler, n.d.). In the previous section, I recounted how I have found functional relationships between my torso, pelvis, and lower body through a process of self-sensing. In addition, I have found that I am able to more quickly "scan" (S9-077) myself and attend to the anatomical relationships present within my body (#P0.170228.SE.A3).

3.3.1.5. The body is connected and can be experienced as such

"The whole body," Hackney writes, "is connected [and] all parts are in relationship" (2004, p. 41). Yet though the body is anatomically connected—by different types of fascial tissues for instance (Schleip, Jäger, & Klingler, 2012)—it is neither consistently nor constantly experienced as such. One of the outcomes of a typical FM lesson—whether an ATM or an FI—is a feeling of *connectedness*. Through developing proprioceptive attentiveness, this feeling of connectedness can be discovered. As one participant reported after experiencing a practice FI lesson: "After the session, I felt more connected mind/body + soul… I felt calm before and after, and definitely felt more connected" (#P08.160707.tF1.A3).

Indeed, I use FM methods in everyday life to explore and reconcile more chronic feelings of anatomical disconnection. For instance, at the beginning of this research process two years ago, I recorded feeling a disconnect between my legs and my torso and expressed that I had little understanding of how the pelvis mediates the movement of these parts of myself (#P0.150706.SE.A3). Over time and through regular somatic explorations, I developed a greater experiential understanding of how the pelvis is connected to my feet (e.g., #P0.160611.SE.A3, #P0.160408.SE.A3) and to my torso and head (#P0.151005.SE.A3; #P0.160405.SE.A3).

A functional magnetic resonance imaging (fMRI) study by Verrel et al., (2015) shows neurological support for how FM facilitates this feeling of connectedness. In the study, when an FM practitioner moved a participant's foot in a way that isolated it from the movement of the rest of the participant's body, the part of the brain responsible for action of the foot lit up in the scan. However, when the practitioner moved the foot in such a way as to demonstrate to the participant how the foot was connected to the rest of themselves, the part of the brain that is more responsible for *global* action lit up.

3.3.1.6. Improving action: "the impossible possible; the possible easy; and the easy aesthetically pleasurable"

By improving cortical self-representation, refining the skill of self-sensing, and facilitating the ability to experience the body as an integrated system of interrelated subsystems, FM contributes to an improved ability to act. This is summarised in an often-cited dictum of Feldenkrais: "If you know what you're doing, you can do what you want." (Fraser, 2003, p. 23) That is, when one can sense themselves better, one can understand habits and preferences for action and be more likely to discern new choices for movement. Among these choices are those that present more efficient and easier ways to meet the intent of a movement. A simple yet striking corroboration of this principle can be found in the field of kinesiology with the case of flexibility: muscle length can be increased not (just) through mechanical means such as stretching—an activity that relies on a simplistic model of muscles as elastic bands—but also by heightening one's ability to sense and attend to one's own musculature (Weppler & Magnusson, 2010; Stephens, Davidson, DeRosa, Kriz, & Saltzman, 2006), which situates muscular activity as part of a neurally-based sensorimotor loop.

I have come to validate this myself in my own experience over the past two years of seeking improved hamstring length. By increasing my ability to feel what my extensor, gluteal, hamstring, calf, and foot muscles are doing when in action, I have developed the ability to coordinate their actions properly and achieve tasks such as touching my toes with my hands… or even touching my head to my knees. Even a commonplace activity such as slicing food has become much easier and more pleasurable when I realised that I need not grip the knife so hard or rely only on my trapezius muscles to stabilise the knife in my hand. Instead, I can direct my attention to standing as a whole-body activity and use the muscles of my hips, knees, and ankles as well to easily direct the knife into what would otherwise be a more resistant block of cheese (#P0.170308.2.SE.A3).

Slicing cheese with the "whole self" is very reminiscent of my experience training in and performing contemporary dance. It was an aesthetic (or, for that matter, somaesthetic) experience that required the mobilisation of all of one's being. I introduced this thesis with a story about a neuromuscular "aha" moment during a Pilates session 13 years ago. It was around the same time and in the same Pilates studio that I first glimpsed the idea that ease can be an aesthetic quality. A Pilates teacher who was enrolled in a Feldenkrais training programme gave a demonstration of classic Pilates exercises. There was something compelling about her movement that I could not name at the time. In retrospect, I have to come realise that she made the considerably complex movements look *effortless*. By improving the efficiency and ease of action, FM ultimately aims to "make the impossible possible; the possible easy; and the easy aesthetically pleasurable" (Feldenkrais, quoted in Sholl, 2007).

3.3.2. Epistemology

To apprehend the felt experience of the body, FM epistemology largely relies on three interrelated approaches: observing contact with the environment; observing movement; and observing the quality of one's attention.

3.3.2.1. Observing contact with a horizontal surface

Flat surfaces and their material qualities play an important role in FM epistemology. For instance, observing your contact with a horizontal surface—such as a mat, a table, or the floor—is a key part in the FM observational process. Horizontal surfaces are perpendicular to the direction of gravity, a force that plays a critical role in FM theory. Gravity acts on the body incessantly. Newell points out that, "you can live your whole life without ever sensing or being able to register [how gravity affects your muscles], or realising how important that is" (S9-005) to movement and function. Consequently, horizontal surfaces create a learning environment in which you can learn about your neuromuscular response to gravity.[32]

Three activities—standing up, walking, and lying on your back (i.e., supine)—illustrate this concept. Standing and walking are skills resulting from a complex learning process in the brain and the body, starting in early childhood

[32] Indeed, an implement called an "artificial floor", consisting of a small light plywood plank, is used on a student's foot and ankle while they are lying down during a Functional Integration lesson, as a substitute for a floor (Verrel et al., 2015). The artificial floor is used as a proxy for the ground to help the student feel how they might organise themselves in relation to a flat surface beneath them when they are in standing.

(Thelen & Smith, 1996), of coordinating the functioning of various "antigravity mechanisms" (Feldenkrais, 2005, p. 75). Indeed, Feldenkrais argues that posture is better seen as an active process that could be called "acture" (Feldenkrais, 2003, p. 108), in that even merely standing upright consists of continual neuromuscular activity against gravity, rather than the static position it is often thought to be. After an FM lesson, students are often asked to feel themselves in standing, first on two feet and then by shifting their weight to the left and to the right to see if they organise themselves differently in supporting themselves—and resisting the pull of gravity—on one leg compared to the other.

In walking, on the other hand, you can attend both to the sound and the kinaesthetic sensations of the impact that the floor has on your body as the floor contacts your heel (Collins & Whittle, 1989) and creates a "shock wave [that] is transmitted along the skeletal system" (Adderson, Parker, Macleod, Kirby, & McPhail, 2007). Through attending to these sensations created by your contact with the ground, both before and after an FM lesson, you develop somatic insight into how your neuromuscular system organises your functional response to gravity.

On the other hand, when supine, you can use the horizontal surface of a mat or table to sense how much of yourself is in contact with the mat. The muscles of the neck, trunk, and hips are the primary postural muscles in humans and normally possess a baseline level of muscular tonus, called postural tone (Gurfinkel et al., 2006). Along with the architecture of the skeleton, postural tone determines how much the surface of one's back is in contact with the floor. For instance, in most people, there are curves in their neck and lower back that prevent these areas from fully touching the floor. Many of the lessons I encountered during my time in the training programme aimed at reducing the tonus of postural muscles so that the muscles "return" closer to their resting length, which often creates the sensation of a change in size (S9-009), resulting in self-reports of feeling wider or more spread out on the mat. It is both a pleasurable and instructive experience (#P0.170105.SE.A3, #P0.161014.SE.A3). Indeed, a horizontal surface can serve as a "kinaesthetic mirror" (Wildman, 2006a, p. 64).[33] As in the case of standing, sensing one's contact with the ground while supine reveals something about one's neuromuscular organisation. By attending to one's contact with the ground, one can clarify the self-representation. Indeed, our ability to be aware of the self depends on our ability to sense the environment, as I had previously discussed in section 2.2.4.

3.3.2.1.1. Surfaces and somatic learning affordances

The relationality of the self to surfaces present in the environment is captured by the notion of *affordance*. Psychologist James Gibson first used the term in 1977 to refer to "a specific combination of [anything's] substance and its surfaces taken with reference to an animal" (Warren, 1984), a combination which subsequently supports a particular activity of that animal. For instance, a horizontal, flat, sufficiently large, and sufficiently rigid surface affords support for an animal within a particular size and weight range. A pool of still water affords support for a water bug, but not for heavier terrestrial animals (Gibson, 1979). An affordance is a relational property; it arises as a result of the properties of the thing in the environment and the properties of the animal. The mechanism by which these affordances are made legible to the animal is through visual perception of *surfaces*. Surfaces can be human-made. Indeed, Gibson writes, "man [sic] change[s] the shapes and substances of his environment … to change what it affords him" (Gibson, 1979, p. 130). A surface thus creates an

[33] Although perhaps the more accurate term would be *proprioceptive* mirror.

interface, by which I mean a physical field of contact, interaction, and possibility between the external surfaces and the (surfaces of the) organism.

New interfaces create new sensorimotor experiences in humans. Whereas Gibson's focused on the motoric, behavioural aspects of these experiences, I wish to highlight the sensory experiences that new affordances invite. With respect to the present discussion, I suggest that the notions of surfaces, interfaces, and affordances can be applied to somatic learning. The use of the mat in FM provides a clear example of how surfaces afford somatic learning. Just as the type of motor activity that can be afforded (in the classic Gibsonian sense) by a surface is dependent on the surface's material properties, the types of somatic knowledge that can be afforded by a floor, mat, or table is similarly contingent on the material properties of that surface. Indeed, the firmness of the mat or table in FM is carefully chosen to be able optimally to *afford somatic inspection*: the "firm cushion needed by the Feldenkrais practitioner" (Feldenkrais Resources, 2017) allows one to feel themselves in a way that softer massage table surfaces do not. In the Sussex IX training, we used a particular gymnastic mat sourced from one supplier not only because it was light and portable, but it also had a good *and uniform* thickness, firmness, springiness, and grip that allowed us to attend to the changes in muscular tonus and contact between bony landmarks and the mat in a way that was not uncomfortable. The particular material properties of a surface—its thickness, firmness, springiness, and traction, in addition to its orientation with respect to gravity—can be specifically "tuned" to the neurophysiological properties and sensory capabilities of the human organism. Thus these *somatic learning affordances* are relational ones, much like Gibson's affordances.

Thus, in FM, a flat, horizontal, and uniformly textured mat uniquely *creates an interface that facilitates the refinement of the proprioceptive self-representation* by *affording proprioceptive distinction-making.* If the mat is not completely flat, or completely horizontal, or completely uniform in texture, then any differences in sensation that an FM student may sense cannot be adequately attributed to a change in their neuromuscular organisation.

3.3.2.2. Observing movement (Somaesthetic attentiveness)

The experience of your own movement is the primary target of somaesthetic attentiveness, and attending to movement experience is the primary preoccupation of ATM and FI lessons. FM practitioner Larry Goldfarb has developed a system for movement description called "SPIFFER" that borrows in part from Laban Movement Analysis (Laban & Lawrence, 1974). SPIFFER stands for seven interrelated aspects of movement (McCaw, 2015): the sequence of movements through the skeleton (*Sequence)*; the shape of the movement through three-dimensional space (*Path*); where and how movement is started (*Initiation*); the distribution of weight over the base of support (*Foundation*); tempo and attitude towards time (*Flow*); the experience of exertion (*Effort*); and the dimensions and rhythms of breathing (*Respiration*). Throughout my training, I found Effort and its relationship to the notion of "ease" was given particular importance, though ease is a qualitative and highly personal assessment. As Newell explains, one individual might view a movement to be easy because their breathing can continue without interruption, whereas another individual might consider movement easy only when it's not painful to do (Newell, S9-013). While other systems for movement observations could be applied to structuring somaesthetic attention to movement,[34]

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[34] Goldfarb's system, while immensely useful, does not capture all aspects of movement experience. For instance, an interesting phenomenon that was often present in my movement explorations were clicks and snapping sensations or sounds that I could feel/hear in my feet various part of my anatomy, and helped me become aware of the connectedness of my body (#A3.ISRD.160408; #A3.ISRD.170107;

what is important for this research is that movement experience can be systematically observed and mined for insights.

3.3.2.3. Observing quality of attention (Somaesthetic meta-attentiveness)

During my somatic explorations, I discovered that when there was a "hiccup" in my ability to attend to what I was doing, there was an associated glitch in the smoothness of my movement. For instance, in one exploration where I was reviewing an ATM lesson involving lying on my back and allowing my legs to tilt to one side, I recorded the following observations:

> I realise that as my legs tilt to the side, there's a point when the movement becomes harder and not as easy[…] Something [then] happens to the quality of my attention. It just becomes blurry or jagged; I don't exactly know what it is [or how to describe it] but it just isn't as clear. And then as I get past this point, when my legs are closer to the floor, it becomes clearer again. And [the range when my attention isn't as clear] is the [same] range [as] when I begin to make an effort. (#P0.170303.SE.A3)

The ability to notice a change in the quality of attention is related to Shusterman's fourth level of body consciousness, which I termed somaesthetic meta-attentiveness in section 2.2.3.1, and it is a metacognitive ability (Kerr et al., 2013; R. A. Wilson & Keil, 1999). In FM, somaesthetic meta-attentiveness is achieved by a teacher through directing the student to not only attend to their sensations, but to notice *how* they are attending to it. During an ATM lesson, an FM teacher will sometimes not only asks what it is that students are experiencing, but also *how* they are experiencing it.[35]

#A3.ISRD.170124; #A3.ISRD.160410). These clicks do not neatly fit into any of the SPIFFER categories, although it could be argued that they related to Effort.

[35] Somaesthetic meta-attentiveness has interesting similarities to Petitmengin's (2006) interview method, which follows a similar approach of using "metacognitive probes" (Hacker, 2009, p. 22) to systematically build a metacognitive awareness of subjective experiences.

3.3.3. Teaching and learning strategies

While ATM or FI lessons vary enormously in their content, they share many common high-level characteristics which can be understood as teaching and learning strategies for facilitating FM's epistemology. I describe seven in this section: creating a learning environment that affords safe, distraction-free somaesthetic attentiveness; facilitating curiosity and not correcting errors; moving gently and within the range of comfort in order to make differentiations; exploring proprioceptive experiences through variation, complexity, and temporary restriction; using oscillation to explore movement reversibility and refine the self-representation; providing opportunities for comparison of experience by leveraging bilateral symmetry; and resting.

3.3.3.1. Creating a learning environment that affords safe, distraction-free somaesthetic attentiveness

Recalling her first training day with Moshe Feldenkrais, Newell described to our class how Feldenkrais explained his role as a teacher, which was to "create circumstances… [and] situations for you to learn" so that you can become "a self-learner" (S9-001).[36] In order to support the epistemological approaches of FM, the teacher must create an optimal learning environment. It is instructive to quote in full Feldenkrais' description of what he did in the case of one particular student:

> I had Nora lie on her on back on a couch-table so that there would be easy access from all sides. I put a wooden roller with a soft spongy cover behind her nape, thus raising her face to where it would be relative to the body when the person was standing. I put another roller under her knees and moved each leg until the feet were lying toes out, heels close together. I wanted to make her comfortable and more at ease so that she could detect and recognize very gentle movements. The body arranged thus is supported everywhere and relieved of the usual necessity to react to the pull of gravity. The nervous system gradually stops maintaining the muscles at a

[36] As neurologist and FM practitioner Barbara Morgan remarked, "you learn how to learn in a Feldenkrais class" (Giroux, 2016, p. 172).

> normal high level of contraction where they are ready to move at the slightest of intentions. (Feldenkrais, 1993, p. 24)

Three properties of an effective learning environment in FM can be discerned from this example. First, Feldenkrais created a situation in which the student, Nora, could proprioceptively sense and observe herself. This often (but not always) involves lying on the back. In FM theory, if the student is organised in some way so that they do not have to support themselves with muscular effort, the tonic activity of the muscles that would normally be activated to support their postural organisation is lessened considerably. Lying down is precisely such an organisation. Another example is sitting in such a way that the torso is kept upright not by the activity of the extensor muscles, for example, but by a chair's back rest if sitting in a chair, or by leaning on your arms so that you can use your limbs' skeletal structure to support the weight of your torso.

For some individuals, lying supine, prone, or on one's side may not necessarily be comfortable, so a variety of implements can be used, such as in Nora's case. That is to say, the physical environment must be tuned to the individual needs until it can best afford proprioceptive self-observation. This often requires a variety of props, including boosters, pillows, and foam padding to be put under the student or between their limbs.

Finally, a learning environment filters out unnecessary and distracting stimuli in order to "[ward] off competing interests to what we are trying to attend to and feel" (Lee et al., 2014, p. 1056). From a neuroscientific perspective, it can be said that lying on the back activates the parasympathetic system and modulates inhibitory and excitatory responses (Clark, Schumann, & Mostofsky, 2015), reduces the neuromuscular system's need to work against gravity, and filters out extraneous sensory stimuli. The learning environment should feel not just comfortable, but also *safe* (#P0.170216.SE.A3). In this state, the student can "settle, relax, and rest," enabling "the nervous system to rest and gather energy that will be necessary for learning and differentiation" (Doidge, 2015, Chapter 6, section "Putting It All Together").

3.3.3.2. Facilitating curiosity and not 'correcting errors'

Part of creating an effective learning environment involves the facilitation of a curiosity of the self. In one practice teaching session during the training, I was leading fellow students through an ATM. After observing the way I conducted the lesson, the guest instructor at the time commented that while I had a grasp of the technical aspects of the lesson, what was lacking in my instruction were verbal cues that encouraged students' curiosity in what they were doing and how they were doing it.

Even during an FI, which is significantly less verbal than an ATM, a teacher can facilitate curiosity in a student. For instance, in one practice FI that I was conducting with a participant, I began to understand how I can direct my attention in a way that my touch can 'ask the student a question.' As I was moving two different areas of the student together, I found myself mentally asking a series of inquiries: "Can you do this very subtle movement? No? Ok, let's make it subtler. Even subtler still. Ok, I feel you responding to that smaller movement. Let's expand it now. Was that too big a leap? Let's go back and increase the movement in smaller increments." (#P47.160727.tFI.A3) Indeed, a trained FM practitioner conducting an FI lesson will often first look for what movement patterns the student finds easy and familiar before finding those that are more challenging and less familiar (Rywerant, 2003). Conversely, as a student, one can feel the teacher's inquiry if the intention and the line of questioning behind the manipulation is clear. In FM, touch is a strategy for inquiry. Touch is a teacher. As Juhan notes, "Touching hands are not like pharmaceuticals or scalpels. They are like flashlights in a darkened room. The medicine they administer is self-awareness." (Juhan, 1998, p. xxix)

However, it is important to stress that the type of curiosity in the self-encouraged in FM is meant to be value-neutral. Beginner FM students often feel the need to correct themselves when, for example, they are not lying symmetrical on the ground. But the FM learning process is one of "getting to know yourself, not getting to judge yourself," as Newell points out (S9-002). In section 1.4.3.2, I mentioned that in my training, students were asked to avoid terms such as "blocked" or even "tension." This is because these are loaded terms that discredit and obscure what might simply be the neurophysiological system's best attempt at dealing with the restrictions that an individual has faced throughout their development and given the endowments that they have. FM practitioner Sheryl Field summarises this point eloquently:

> "A person moves always the best way that they can. They're recruiting and doing things in a way that, while it may not be pleasing to see on the outside, and it might not even feel good to them, it is the best solution to the task at hand, given their history, given their experiences, and given what they have to use at that given moment." (Field, 2010)

Revealing options is thus seen as the best route to learning in the FM epistemology. The ethos is summed up in the oft-repeated Feldenkrais aphorism, "to correct is incorrect" (Field, 2010).[37]

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[37] Field is articulate on this matter, and I find it worth citing the rest of her statement in full: "Our primarily role… is to allow an individual regardless of what age the opportunity to sense and feel themselves as they are in that present moment, and offer them some alternatives, offer them other possibilities of ease, of organisation, of effectiveness, of expedience … And so within the context of functional integration, we meet a person where they are, as they are, without making that type of evaluation or value judgement, and saying 'we know what you feel to yourself, and the thing you feel really doesn't fit, it really needs to be corrected.' We

3.3.3.3. Moving gently and within the range of comfort in order to perceive just noticeable differences

Most movement in FM is done gently and within the range of comfort and ease, in order to reduce the muscular tonus of the student as much as possible and allow them to register "just noticeable differences" (Goldstein, 2010, pp. 15 & 20). The term comes from the study of psychophysics, and it describes the relationship between the perceptibility of a change in stimulus. If the initial stimulus is low, then a small change (call it ∂) in the stimulus level will be detected; if the initial stimulus is high, then a change by the same amount ∂ will not be as perceptible. For instance, in a very dark room, an observer would notice a change in the luminance of the room if a single candle was lit, whereas they would hardly notice the difference if the room were initially flooded with sunlight. The same largely holds true for other sensory modalities (Stevens, 1957). In the Sussex IX training as well in other writings about FM (for example, Myers, 2016), this relationship is attributed to a pair of closely-related psychophysical laws, Weber's Law and Fechner's Law, which are often referred to together as Weber-Fechner Law (Dehaene, 2003).[38]

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don't think this way. We rather think, 'Wow, you are making do with you as you are, and look at all that you are that you haven't yet discovered.' And then offering that person the time… to make those discoveries, to go slow enough to meet them where they are so that the sensations can register and integrate with where they are in the moment." (Field, 2010)

[38] The mathematics that governs the relationship between the objective strength of a stimulus and its perceived strength has been debated extensively (Krueger, 1989). Fechner's Law (Fechner, 1987) was devised in 1851 and describes the relationship as logarithmic; Stevens (1957), on the other hand, describes the relationship as a power law. Though it has been argued that a power law is the more correct approximation of psychophysical functions than a logarithmic law (Krueger, 1989), it has also been argued that Weber's Law and Stevens' power law produce similar curves in certain conditions, such as with respect proprioceptive sensations like heaviness (Wagenaar, 1975). What matters for the purpose of the present

Applying this principle to the observation of proprioceptive stimuli during movement, it is easier for a student to discern differences in structure and function during movement if the movement is small and gentle, creating what is known in FM as a *differentiation*. Cortical representations of body parts correspond to how intensely, complexly, and finely differentiated those body parts are used (Doidge, 2015; Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995). Hence, strategic application of the psychophysical laws to sensory-motor action (through gentle and slow motion) facilitates increased and more finely differentiated cortical self-representations. Indeed, I suggest that through the application of the psychophysical principle of just noticeable differences, FM takes the key task in philosophy of "making distinctions" (Sokolowski, 1998; Szostak, 2008, p. 110) and systematically applies it to sensory experience.

It is often surprising to those new to FM how bringing their attention to these just noticeable differences can create a large impact on their bodily experience and self perception (e.g., #P33.160828.tATM.A3; #P42.170325.tFI.A3). However, the subtle differences in sensation *must be attended to* in order for them to have these noticeable after-effects. In other words, a student can move slowly and gently, but if they are not attending to the experience of the movement—i.e., applying somaesthetic attentiveness—the somatic insight that would have followed from the movement is considerably lessened.

3.3.3.4. Experiencing ease after variation, complexity, and temporary restriction

Once an optimal learning environment has been put into place, the quality of movement established, and attention directed towards the self, then movement

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discussion is the basic fact that fine proprioceptive distinctions can be made only when the initial proprioceptive stimulus is low.

exploration can begin. This exploration is typically characterised by a number of sub-strategies that are aimed to make the experience of any particular movement easier. Three of these sub-strategies are *creating variation*, *adding complexity*, and *placing restrictions*.

Variation can be created, for example, by exploring different pathways that arrive in the same final position. For instance, one way to raise your hand over your head is to let the hand and arm arc away from your midline; alternatively, you can bring your hand through your midline, passing in front of the sternum, chin, nose, and forehead. Variations create opportunities to identify easier versions of a movement; in this example, the second pathway for raising the hand over the head is usually perceived to be easier than the first. Some variations may be easier or more habitual for the student than others, and it is instructive to draw the student's attention first to those variations of movement that are easy or habitual for them, and then to those that may be new and as yet unfamiliar. Indeed, many FM lessons begin by drawing attention to what the student already knows as the basis for learning (Fraleigh, 2016).

Complexity is introduced by, for instance, layering movements that typically do not feel natural when performed together. As an example, to experience the action of rolling the pelvis to the right while lying on your back, try the following. Lie on your back. After sufficiently feeling yourself in lying, roll your pelvis to the right, and then back to where you started. Repeat this movement a few times before taking a rest. After resting, resume the movement of rolling the pelvis to the right, but at the same time *turn your head to the left*, and at the same time *directing your eyes to the right*. Do this complex, layered movement a few times before taking a brief rest. Then try the original movement of rolling the pelvis to the right on its own. You will most likely find that the movement suddenly feels easier than the first time it was done, as I have in a previous exploration (#P0.170118.SE.A3).

Finally, you can temporarily place a restriction on a movement in order to make feel it subsequently easier. For instance, lie on your back and notice your breathing. Then increase the arch in your lower back by bring your belly towards the ceiling. Does this changes the pattern and intensity of your breathing? If it does, how? Is it harder or easier? After keeping this position—which creates a restriction on the movements associated with respiration—for a few seconds, let your lower back return towards the floor again. How does breathing feel? You may find it easier or fuller.

A common structure in a lesson is to start a simple, basic form of a movement first; then adding variation, complexity, or restriction; and finally returning to the first movement so that the student can experience performing it with greater ease.

3.3.3.5. Using oscillation to explore movement reversibility and refine the self-representation

In order to fully observe a movement in FM, it is almost always repeated at least a few times, creating what is essentially an oscillatory movement. These oscillatory movements start small and slow, and as they become more familiar, students are often encouraged to play with the amplitude and frequency; for example, trying out movements that are bigger and faster. As the student plays around with oscillation amplitude and frequency, they monitor whether there are gaps, bumps, or "glitches" in two things: one's attention to the movement, and one's physical experience of the smoothness and continuity of the movement. Oscillatory movement provides a framework for both cognitive *and* physical self-monitoring. Three reasons account for this: exploring movement reversibility, ensuring observation validity, and refining the self-representation.

First, oscillation is the cornerstone for exploring how *reversible* a movement is, which is critical to developing what in FM would be considered aesthetically pleasing movement. As Newell (S9-013) suggests, "A well-organised movement is one that can be reversed and stop any time at will. It also looks graceful." Going from lying down to sitting to standing up, for example, is not often performed in reverse nor gracefully, but it can be, as my class experienced during our training. Second, through repetition, the student can clarify and ensure the validity of their observations of the movement. Finally, repetition through oscillation refines the student's self-representation. For instance, in one lesson from his book, *Awareness Through Movement*, Feldenkrais instructs the reader to keep track of the movement of the left earlobe while tilting the head to the left: "Repeat this many times, always more and more quietly. Try to keep track of the ear lobe by feeling only: Simply pay attention *until you can feel clearly where the ear lobe is* in relationship to the edge of the shoulder." (Feldenkrais, 1972, p. 140, emphasis added) That is to say, oscillatory movement clarifies structural relationships in your self-representation by allowing you to experience the parts of your body in relationship to each other throughout a movement, both forward and in reverse. Furthermore, changes to the size and speed of the oscillatory movement allow you experience the connections within your body at different scales. For example, gently rocking your pelvis back and forth in a small way while lying on your back might allow you to feel the connection of the pelvis to the femur and to your lumbar spine, whereas rocking your pelvis in a larger, more sweeping manner might alert you to structural connections that go all the way down to your feet and all the way up to your head.

3.3.3.6. Providing opportunities for making distinctions by leveraging bilateral symmetry

Comparing and contrasting sensations in one part of the self to another is fundamental to FM (Lee et al., 2014, p. 1056). FM makes extensive use (more than other somatic practices that I have encountered so far) of the bilateral symmetry across the mid-sagittal plane in humans as a strategy to create observable differences. Lessons are often designed to create movement that itself creates differences in movement and sensation between the left and right sides. Before switching sides, students are often asked to lie down on their backs to see how this asymmetry has affected their self-representation. Indeed, during my training, FM lessons were sometimes taught "one-sided"; students left the training hall for the day, tasked with registering their experience of everyday activity in the world after an asymmetrical lesson. Some reported finding it easier to turn in one direction more than another or reported a temporary preference for sitting in one part of the room instead of another. The following day's "one-sided" lesson often focused on the other side of the body. I have found bilateral symmetry to be a powerful tool for observing, comparing, and making sense of my proprioceptive experiences, and for designing my own explorations that attempt to refine my self-representation (#P0.170107.SE.A3, #P0.170207.SE.A3, #P0.170217.SE.A3, #P0.170303.SE.A3).

3.3.3.7. Resting

Finally, rest is a vital strategy in FM learning. Within a lesson, taking a rest from the movement is encouraged. "You cannot rest too much. Relax and let the movement settle in, enjoy the feeling," writes Wildman (2006, p. 6). Rest during a lesson allows the learning in the neuromuscular system to integrate. It also provides an opportunity for the student to compare sensations and make distinctions. These comparisons may be of proprioceptive sensations across the sagittal plane after having moved in an asymmetrical way. The comparisons might also be between how they felt before a lesson and how they feel after it—a comparison across time.

I suggest that rest can also be thought of on a larger timescale. In chapter 1, I observed that revisiting previously experienced lessons after not doing them for some time often yielded new insight about my movement function and self-representations. For instance, I first did the "pelvic clock" ATM (Feldenkrais, 1972, Lesson 6) many years ago, and while I cannot recall precisely how it felt then, I know that how I experience my pelvis and my lower back (indeed, my whole self) when doing that lesson is very different now.

3.4. Chapter summary

FM is a movement-based somatic learning system that aims to improve the organisation of movement and function by creating finely differentiated and integrated cortical self-representations. By developing attentive and meta-attentive observation of the self in action—for the ultimate goal of making life easy and pleasurable—FM can profoundly and positively contribute to many aspects of everyday, lived experience. In this chapter, I presented a conceptual framework of FM. The framework was constructed from my experiences of participating in a portion of an FM training programme, the application of ISRD to conducting practice FM lessons and self-explorations, the research literature, and knowledge generated by the FM community of practice. As part of this framework, I developed the notion of somatic learning affordances, which can be applied to the analysis and development of both new and existing somatic learning implements. I used the FM mat as an example of how a surface can afford somatic knowledge. The ideal FM mat is perfectly flat, horizontal, and possessing of a uniform and particular thickness, firmness, springiness, and traction. Taken together, these mutually exclusive properties of the mat afford proprioceptive distinction-making. From the perspective of the Gestalt principle of the figure-ground relationship (Lidwell, Butler, & Holden, 2003, p. 96), an optimal, material somatic learning environment that enfolds the user must be able to guarantee as perfectly uniform a perceptual ground as possible in order for the nature of the somatic experience (the figure) to be perceived.

The conceptual framework presented in this chapter is not an exhaustive codification. For instance, I left out the use of "mental imagery" (May et al., 2011) and its role in movement in FM, as exercises are sometimes performed only in the imagination and not acted out based on the theory that imagining a movement partially activates the same neuromuscular pathways as actually performing the movement (Mulder, 2007). I also did not elaborate on the precise use of language by FM practitioners, such as the way that students are directed to observe and sense themselves as a human organism, not as anything else. For example, a somatic practice called the Franklin Method occasionally uses imagery like imagining gluteal muscles as sponges when activating them for the external rotation of the legs, in order to affect the quality of movement (Franklin, 2004, p. 60). A non-human reference to human action is rarely, if at all, used in FM.

Nevertheless, this framework was constructed from elements of FM that I found most compelling during the course of my involvement in an FM training programme. This framework, along with the notion of creating a uniform perceptual ground for affording proprioceptive distinction-making, have thus guided the design-based activities of this research, as I discuss in Chapter 4.

Chapter 4: From somatic techniques to somatic technologies: Designing the Haplós physical prototype

4.1. Introduction

In this chapter, I present an account of the design process for the physical component of Haplós and the major developments that emerged through the design-based activities involved in prototyping and evaluating the physical component for the purposes of somatic learning.[39] *How can somatic learning principles inform the physical design of a somatic learning technology?* To answer this, and throughout this account, I weave elements from the conceptual framework of FM I developed in section 3.3, insights from neurophysiology and somaesthetic philosophy (reviewed in sections 2.4 and 2.2), and primary sources that document somatic experience (discussed in section 3.2) in order to contextualise and support the various activities embedded within the design process, thereby connecting the design methodology to the FM conceptual framework.

[39] I expand on its other existing and potential uses in Chapter 6.

To begin, I provide a brief technical overview of the most current version of Haplós, after which I present a timeline of milestones that marked the development process. The development and evaluation of Haplós can be discussed chronologically in three phases. These three phases largely correspond to the three-stranded braid of the research methodology (immerse-create-evaluate), even as smaller braids were embedded in fractal-like manner within each research strand. In this chapter, I discuss the first two phases, while the third phase is taken up in Chapter 5. The first two phases are linked by the work of somatic researcher Sally Dean, whose work inspired the initial design explorations documented in this chapter.

4.2. Technical overview of the current prototype

The heart of the physical component of Haplós is a set of coin vibration motors (3.3-volt, 0.1-ampere, Assisi brand) on which male snap fasteners are affixed. These motors can be attached to female snap fasteners sewn onto a piece of ribbon (Fig. 2), allowing for easy repositioning, overcoming limitations in most existing vibrotactile garments reviewed in Chapter 2.

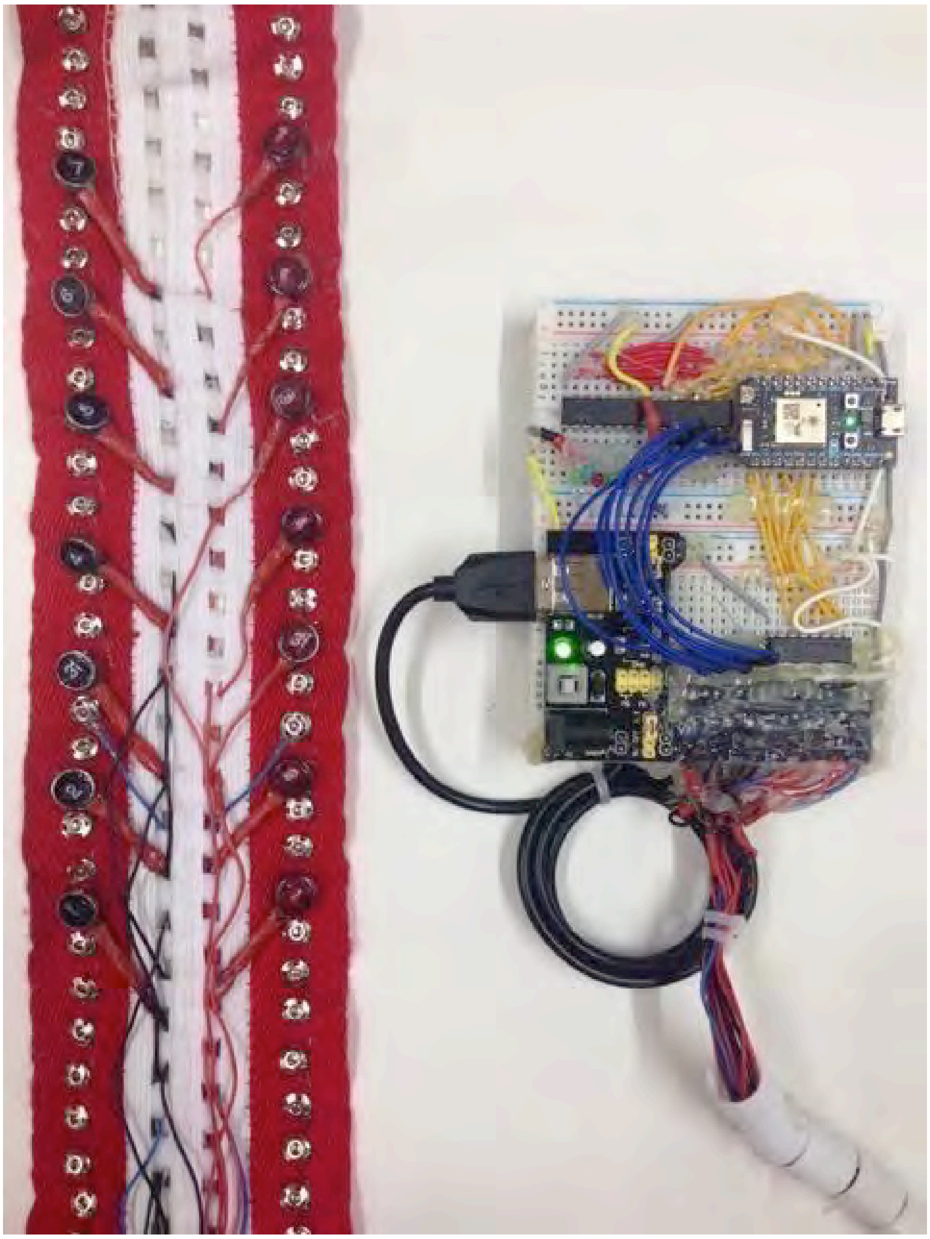

Figure 2. The physical components of the Haplós prototype

To maximise user comfort and ease of handling, I devised a system to reduce the amount of wiring trailing from Haplós by close to 50%: the female fasteners on the ribbon are connected to each other with conductive thread, while the male fasteners are wired to each of the motors' lead wire; snapping the motor onto the ribbon completes the circuit. The ribbon can then be attached to a wide variety of existing clothing and implements, and formed into any shape, again making Haplós more flexible than most vibrotactile garments. Fig. 3 shows Haplós attached to a commercially available back support garment. The motors are powered by a battery pack and controlled by a WiFi-enabled Particle Photon microcontroller. Haplós can thus be controlled and reprogrammed over a local network or even the Internet. The current circuitry has been assembled on a breadboard for ease of prototyping, but can be shrunk down in size significantly.

Figure 3. Haplós attached to a commercially available back support garment

The Haplós software's graphical user interface (GUI) (Fig. 4) is a Processing-based programme that can create, save, and transmit vibrotactile patterns that are played by the motors. My prototype used a step sequencer akin to software-based music sequencers (Arar & Kapur, 2013) to compose tactile patterns. The GUI can be run on desktop and mobile devices. Tempo and motor intensity can be controlled from the GUI. Users can generate and send patterns on the fly, as well as save and play previously saved patterns. A single instance of the GUI can control multiple Haplós devices and mass broadcast the patterns (which was done during the Manufactory workshops, which I discuss in section 5.5.2.3).

Figure 4. The Haplós graphical user interface

4.3. Timeline of milestones and activities

The road that led to the most current version of the prototype was marked by incremental discoveries. As with many design research projects, the research questions were initially both "ill-defined" and "ill-structured" (Cross, 2006, p. 7), bounded at the outset only by the institutional and conceptual contexts of the project, and motivated by a conviction that somatic aims, epistemologies, and methods are of value to the embodied cognitive studies network. Haplós emerged as the result of a gradual process of braiding together the three strands of immersing (in somatic experience and expertise development), prototyping (designs for somatic learning), and evaluating (the prototypes). It is worth noting that even a simple sketch was a prototype in that it was still a materialisation of an otherwise abstract idea. Indeed, some of the very initial immerse-prototype-evaluate loops were small in scale and scope. For instance, a simple design loop might involve attending to the experience of touching my right shoulder with my left finger; wiring together a single motor and powering it; and then placing it on the spot on my shoulder that I had previously touched and attending to how that experience compared to that of touching my shoulder with my finger. These small explorations eventually contributed to larger-scale investigations.

Figure 5 visually summarises design activity milestones and additionally serves as a visual guide for the remainder of this chapter. This abbreviated guide is intended as a wayfinding tool for the chapter, not an exhaustive summary of all activities related to this research. For instance, I started recording somatic reflections as early as February 2015 (#P0.150213.SE.a3), as noted in section 1.5. Prior to that, considerable work was spent through training workshops, seminars, and conference attendance in developing the conceptual connections between somatics, art and design, and other disciplines from which I draw in this research, particularly experimental psychology, cognitive neuroscience, and computer science.

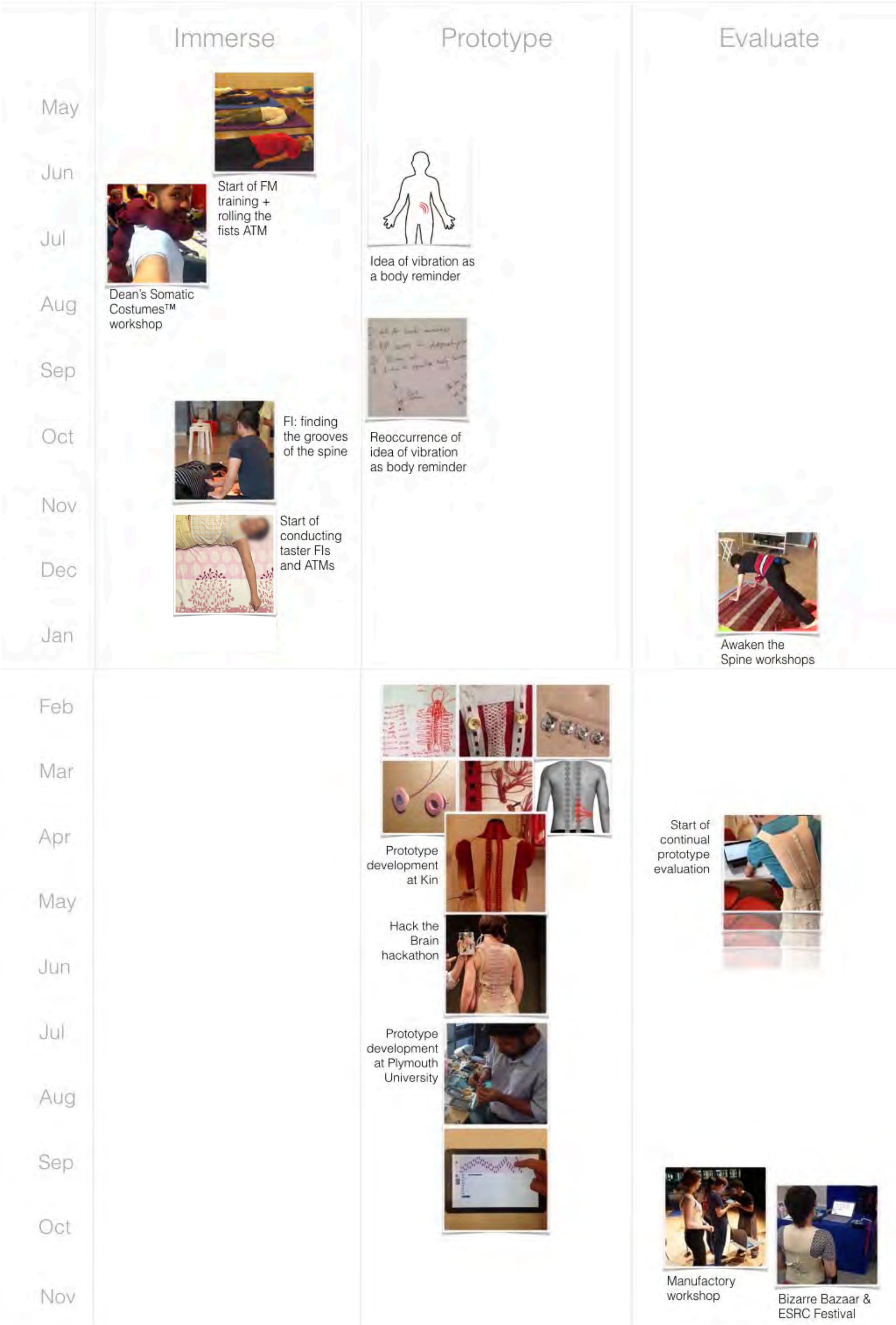

Figure 5. Design activity milestones

4.4. Phase 1: Immersing in and developing somatic insights

The first phase largely involved immersing in and developing somatic insights. In addition, it was during this phase that the idea of using vibrotactile stimuli first emerged, and my attention was drawn to the significance of the spine and the area between the shoulder blades, to which the Haplós prototypes would first be applied. The phase concluded with my attendance at a workshop by Sally Dean on the Skinner Releasing Technique in which I first experienced Dean's costumes, which became a turning point for the research.

4.4.1. Attention to the spine and the thoracic area

As mentioned in Chapter 3, I joined the FM training programme in May 2015. During the training, I found two aspects of the Method particularly compelling: the aim of clarifying areas that are poorly represented in the self-representation (as defined in section 3.3.1.3), and the epistemological approach of attending to contact with a surface as a kind of proprioceptive mirror. In addition, three FM experiences from the training made a particularly significant impression on me and subsequently influenced the development of the Haplós usage scenarios: two ATM lessons that brought my awareness to the area between the shoulder blades (where the thoracic spine is located), and a series of practice FI studies that facilitated awareness of the spine and its relationship to movements of the torso.

The first ATM involves lying on your back, hands gently closed into soft fists, and gently rolling the fists on the floor in a series of different variations (Figure 6).[40] The net result for me (and indeed for some other members of the class) was an increased awareness of the area between the shoulder blades, which I felt to be contacting the mat more clearly. This ATM also illustrates how the movement of one part of the body can influence movement and sensation in parts distal (further away from the midline of the body) or proximal (closer towards the midline) to it. Indeed, I have found that after doing this ATM, I am able to use my hands and fingers with more ease and refinement, such as in playing the piano. In fact, I conducted a practice session of this ATM with a professional musician (participant P33), who remarked after the lesson that he experienced "an increasing body consciousness" that changed the way he experienced playing the piano: "Usually I mainly *listen* to how does it sound […] I don't feel so much what it *feels* for me, like, 'is it a pleasant movement?'" (#P33.160828.tATM.a3)

Figure 6: A participant being led through a practice session of the 'rolling the fists' ATM

The second ATM involved using the contact between the ground and your back to trace precisely the outline of a circle on that area between the shoulder

[40] A version of this lesson is available on http://www.kinesophics.ca/rolling-arms.

blades. The exactness of this activity clarified my perception of the shape and size of my back's contact with the mat. In addition, I noticed after the ATM that the movement of my arms and hands were more fluid; this is yet another example of how proximal-distal relationships can be used to create more ease in one part of the body by intentionally moving not that part but another that is more proximal or distal to it.[41]

The third FM experience that influenced the development of Haplós was a series of practice FI studies (S9-168, S9-172) where participants of the training used their fingers to do a series of explorations involving a prospective student's spine: first finding and tracing the spinous processes of the vertebrae;[42] then finding and tracing the grooves along either side of the spine, each of which is the conjunction of the surfaces on either side of each vertebral spinous process; and finally doing a series of gentle manipulations that encourage lateral flexion in the vertebral column. Viewed objectively, this exploration involved very little movement in the spine, but the sensory experience can be quite profound, as evidenced in remarks by two participants of practice sessions that I conducted of this study. One participant, P42, said that this FI was "the best one yet" of the practice FIs I've conducted with him, and felt "subtle but amazing" (#P42.170325.tFI.a3). Another (participant P52) was an 86-year old woman with a noticeable asymmetrical and exaggerated kyphosis.[43] After exploring her spine through this practice FI, she stood up. Remarkably, her kyphosis had noticeably diminished and was more symmetrical. She then raised her arms overhead repeatedly, indicating that the activity was more possible now than

[41] In hindsight, I now see that my interest in this area is also clearly echoed in that embodied Eureka moment with which I introduced this thesis.

[42] For a review of the bony landmarks of the spine, the reader is referred to any standard anatomy textbook. See for example Calais-Germain (2007, pp. 36–86).

[43] Kyphosis refers to the convex curvature of the thoracic spine (Calais-Germain, 2007, p. 35).

before. She had a smile on her face, indicating that the movement was also pleasurable. (#P52.151219.tFI.a3)

Figure 7: Practice FI study of finding and moving the spinous processes of the vertebrae

I suggest that increased awareness of the thoracic portion of the back is interesting and significant for two reasons. First, the area between our shoulder blades is one that is difficult both to see and touch ourselves; as such, I suggest that it can be poorly defined in the self-representation. As one participant of a Haplós prototype trial, P49, would remark, the thoracic area is a part of him that he "normally wouldn't think of." (#P49.170205.ProtoTrial.a5) Another participant. P39, had observed that described the area between the shoulder blades "is hard to focus on it, to bring attention to it, to find its proper way of feeling, because of its location." (#A3.tFI.161230.P39) Touching that area with your hands is difficult though not impossible, but P39 further observes that "even if you do, your body [would be] too contorted to relax." (#A3.tFI.161230.P39) Second, it can influence the experience of skilled movement of the arms, hands, and fingers, which are essential to a great deal of daily activity. I further suggest that providing tactile stimulation and even the smallest movements to the grooves located on either side of the array of spinous processes can create remarkable somatic experiences. It is for these reasons that the first usage scenario for Haplós was the vibrotactile stimulation of the grooves of the thoracic spine, as I describe in section 4.5.2.

4.4.2. The emergence of the idea to use vibration as a body awareness cue

In section 3.2.3 I described how I employed ISRD in dedicated somatic exploration sessions but also in my everyday activities. After going for a jog on 6 July 2015, the idea of using vibrating motors as an awareness prompt came to mind:

> I was lying down and I decided to put my hands on my lower abdominal muscles, just where they're about to insert on my pubic bone [...] and I realised (again? or more than ever? with shocking clarity?) how little I know about that area. AND THEN I realised what I meant by that phrase "how little I knew about that area." I could feel it moving up and down with my breath and I realised that I've never really recognised what that moving was like. and I realised that this was one of the disconnects in my body, one of the bridges between upper and lower halves that just seemed to be missing. and I'm wondering what would happen as I increasingly make the connections between my upper and lower halves [... A] tech tool idea: what about a phone or device that just constantly or occasionally vibrates? to just remind you of a body part? (#P0.150706.SE.a3)

In the previous section (4.4.1), I suggested that the thoracic area of the back between the scapulae might be poorly represented in the self-image because it was difficult to touch it with the kind of precision and dexterity possible with one's own hands and fingers. Vibratory motors could function as a kind of "exosomatic" (Innis, 2002) approximation of the fingers. Four and half a months later, the idea reoccurred in a sketch that I drew during an FM training segment (#P0.150929.Training.a3), reproduced in Figure 8.

Figure 8. Left: Abstract representation of the initial idea from #P0.150706.SE.a3. Right: Reoccurrence of the idea in #P0.150929.Training.a3

The idea of using vibrotactile stimuli as an awareness tool was just one of several prototype ideas I was considering; however, it was the one I ultimately chose to pursue largely because of my experience of Dean's costumes.

4.4.3. Experiencing the Balloon Spine-Legs Somatic Costume™

Somatic Costumes™ are educational tools intended to bring awareness to different body areas as well as generate different movement qualities and experiences in the "body-mind" (Dean, 2014). They are meant to be used as a playful resource for instigating new relationships between self, others and the environment.[44] Dean has explored the creation of somatic costumes in non-Western contexts, engaging with Javanese philosophies and embodied practices in her analysis of felt phenomena (Dean, 2012).

I first encountered what Dean calls the "Balloon Spine-Leg" costume (Dean, 2016) during a workshop that she ran at the Dance and Somatic Practices Conference at Coventry University on 12 July 2015, six days after I noted down the

[44] The project website is http://www.sallyedean.com/publicationsresearch/somatic-movement-costume.

idea of using vibrotactile stimuli as an awareness prompt. Figure 9 shows the costume as I had worn it during the workshop.

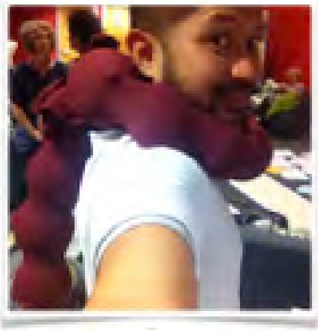

Figure 9: The author participating in Sally Dean's workshop at the 2015 Dance and Somatic Practices Conference.

The costume consists of a number of elements:

- Inflated balloons stuffed into a nylon stocking, which is then tied into a shape that allows the stocking to cradle the neck and then run down the length of the wearer's back;
- A tight shirt that fits over the balloon-stuffed nylon stocking;
- Two wide strips of latex resistance bands that loop over the top of either shoulder and around the respective inguinal areas; and
- A long, thick, and wide band of cloth that wraps over the preceding costume elements and around the abdominal area.

Pressed against the wearer's back by both the t-shirt and the abdominal wrap, the balloons placed constant but gentle pressure against the midline of the wearer's back. The elastic loops and the band of cloth created support for the torso. I found the workshop profoundly transformative and felt the balloons along my spine long after the workshop was done. The costume and the workshop's setup allowed me to experience a body that was very different from mine, so much so that I sensed a connection to my evolutionary animal ancestors and moved in ways that were not quite mammalian or bipedal, perhaps because of the heightened awareness that the costume facilitated of my sacrum and coccyx—the evolutionary remnants of the tail. While this thesis is not primarily concerned with subject matters of physiological empathy (Levenson & Ruef, 1992), empathy with non-human living entities (Gruen, 2009), or non-human consciousness (Low et al., 2012; Nagel, 1974), I report this encounter with animal-like consciousness while wearing the costume because it was a profoundly moving and surprising experience. Moreover, in a workshop that I subsequently held (discussed in section 4.5.1), at least one participant reported a similar experience. For now, I set aside further discussion on the matter. What is important to state at this juncture is that the costume heightened my physiological awareness of—and suggested new neurophysiological relationships within—myself. I wrote to Dean, shared my experiences, and expressed my interest in designing a form factor that might allow these kinds of phenomena to become part of everyday experience.

4.5. Phase 2: Creating the first prototypes of the physical components

The second phase of the process started about three months after Dean's workshop and was marked by the beginning of an eight-month secondment with Kin, which I had introduced in section 1.3. The secondment initiated the prototyping process. The phase ended with the realisation of a physical prototype that was functional enough to be used at a neuroscience-inspired hackathon in Amsterdam in June of the following year. Within this timeframe, I conducted my first evaluation workshop in the Philippines and began creating the first prototypes for Haplós while at Kin. I discuss these activities in this section, starting with the evaluation workshop I conducted.

4.5.1. Awaken the Spine workshops

In Chapter 1, I noted my concerns about the applicability of somatic practices that were initially developed in the West to non-Western contexts. Though I have found my experiences of somatic practices in general and Dean's costumes in particular compelling, I thought it essential to verify whether they would be shared by other individuals, particularly those from a non-Western public. My concern around this is summarised articulately by contemporary choreographer and somatics researcher Isabelle Ginot, who argues that there is an implicit corporeal ontology embedded in many somatic practices and research:

> Somatic discourses are mobilized by thoughts of the universal. They are freighted with innumerable ideologies: the natural…, the transcendent …, the biological difference of the sexes, and cultural hierarchies. … Behind the insistence on the singularity of each corporeality, most somatic methods have as a backdrop a homogenous, universal, ahistorical, and occidental body… Is the somatic body so universal that it transcends this issue? Thought to respond to culturally and historically determined ills, somatics has not conceptualized the social changes that accompanied its development; instead, it has remained fixated on the concepts of body and culture current at the time of its advent. How can somatics respond to the needs of a non-Western public, in a time of globalization and massive immigration? Is Shusterman's hypothesis that somatic techniques will help 'us' to surmount our visceral fears of the unfamiliar really adequate to this context? Can somatics help us understand the unique corporality of migrant peoples and contribute to reducing their suffering? In other words, what would somatic knowledge look like when applied to issues of postcolonialism? (Ginot, 2010)

This criticism continues to confront (Western) somatic practice and research, and it is one that has unsettled me—an immigrant to the West and a student of somatic practices—over the past fifteen or so years. Dance professor Jill Green (2015) expressed similar concerns in negotiating the tension between the social construction of the body and somatic theory, while the relationship of somatics to culture and the postcolonial condition were taken up in two panels at the 2015 Conference on Dance and Somatic Practices held at Coventry University.[46]

Yet precisely because I *am* an immigrant of colour who confronts the issue of migration and race, who is permanently based in a non-Western country, *and* who has found value in somatic practice, particularly the FM, I offer a response to some of Ginot's questions with a strategy I have developed for myself over the years. My strategy is to align with somatic theory and practice that is consistent with and widely supported by neurophysiological research, such as theories on sensorimotor learning and the psychophysics of 'just noticeable differences'…much, indeed, as the FM has (Connors et al., 2010; Edgar, 2016; Ernst, 2015; Hillier & Worley, 2015; Mattes, 2016; Myers, 2016; Teixeira-Machado et al., 2015; Verrel et al., 2015). Moreover, other somatic techniques may also have wide cultural applicability. A recent case study studied the efficacy of the Basic Body Awareness Technique (BBAT) for refugees suffering from post-traumatic stress disorder. The study found that BBAT relieved pain and tension and brought "peace of mind and body," and overall facilitated "positive changes in the contact to oneself and others" (Madsen, Carlsson, Nordbrandt, & Jensen, 2016).

In this section, I further support my response to Ginot by reporting on a pilot workshop I held involving Dean's costumes in Quezon City, Philippines, during the weekend of the 10th and 11th of January 2016. This evaluative workshop instigated the prototyping process, which I describe in section 4.5.2. The workshop—which I called "Awaken the Spine"—was conducted in collaboration with Curiosity, a design

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[46] The two panels were on "Cultural Dialogues" and on "Exploring the Feldenkrais Method in its understanding of Ethics" (C-DaRE (Centre for Dance Research), 2015).

strategy firm I co-founded, which provided the workshop space and advertising for the event.[47]

With Dean's permission, I replicated part of the balloon-spine costumes with the participants. In my workshop, I did not use the latex resistance bands that looped around the groin and the shoulders because of the difficulty in locally sourcing the appropriate material. I also did not use the loop of balloons around the neck. During my participation in Dean's workshop, while the balloons down the spine provided a tactile, pressure-based reminder of my spine, I felt that the balloons around the neck served a different purpose altogether, which I felt was to structurally guide me in "finding length" in my neck. Finding length in the neck is a principle I found inconsistent with my understanding and experiences of FM. One of the primary functions of the neck is to support the head so that it can move freely and allow the human organism to scan the environment; thus, I was more interested in enhancing that function than in finding an experience of neck length *per se*.

The workshop was taught in a mixture of English and Filipino. A morning and an afternoon session was held on each of the two days, for which twelve participants signed up. The morning sessions had two participants each, while the first afternoon session had three participants and the final afternoon session, five. While three of the participants had heard of somatic practices before, none save for one (a contemporary dancer) had any previous experience with somatic practices.[48] Because this was the first evaluative investigation involving groups of people, the workshop was highly exploratory; its format evolved and differed slightly across the

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[47] Curiosity's company website is http://www.curiosity.ph

[48] The examples for somatic practices given were the Feldenkrais Method, the Alexander Technique (because of its shared interest with Feldenkrais Method in awareness during action and use of the self), and Skinner Releasing and Amerta Movement (because of their role in Dean's development of the costumes). However, three of the participants had indicated having previously practised yoga.

four sessions. However, the logic of each session was essentially the same and had three stages:

1) First, I asked participants to notice themselves in sitting, standing, and walking. Initially, I did not ask them to pay attention to a specific part of their experience in order to see what would emerge. Instead, I asked them open-ended questions, such as "What do you notice (as you're walking/standing/sitting)?" or its equivalent in Filipino. They were invited to say out loud any responses that they felt like sharing. I then asked them to pay attention specifically to their experience of their body in action. For instance, I asked them what walking felt like. I occasionally probed for specific bodily aspects of their experience, such as asking what their foot felt like, or whether they noticed which part of their foot would touch the ground first in walking.
2) After turning their attention towards their experience of their bodies in action, participants assembled a balloon-spine costume for themselves, sometimes helping one another get into the costumes. I then asked the participants to do different activities while wearing the costumes, including standing, walking, lying down, and sitting.
3) Finally they would take off their costumes and again explore how they felt in standing, walking, and sitting.

At each stage, I asked each participant to record what they were experiencing in writing. The written records of their experience are thus divided into pre-costume, wearing the costume, and post-costume stages.[49] These records are archived and

[49] All responses were written in English, but verbal feedback was also often given in Filipino that was consistent with the written reports.

analysed in greater detail in Appendix 5.[50] I organised and coded the reports in NVivo, a qualitative software programme, to aid my analysis, coding for themes that addressed or were related to the following questions:

- What somatic insights were generated through the costumes?
- What properties of the costume contributed to these insights? What properties of the costumes hindered these insights?
- At what point these insights were generated—that is, were they generated while wearing the costumes or after?
- To what prototype design directions do the workshop results point?

Participant observations about their experience of the workshop fell under two general categories. These categories are observations about the costume and how it made them feel; and observations about themselves (that is, their sensations, mood, thinking, and behaviour).

4.5.1.1. Observations about the costume and how it made them feel

Most of the participants' impressions about the costumes can be divided into three broad categories: feeling supported and experiencing comfort; feeling restricted; and metaphoric descriptions of the costume. The balloons, however, were well-received across the board (with the exception of the balloon near the base of the neck) and clearly facilitated some of the most interesting and memorable experiences.

Feeling supported and experiencing comfort. The garment had three components: the shirt, the wrap, and the balloon spine. Some participants felt that the

[50] For brevity in citing participant feedback in this chapter, I will only cite the participant code; the full citation has been referenced in Appendix 3.

combination of all three components made them feel "snug" and provided them with support, often linking the experience to a feeling of comfort:

> P20: *After applying and securing the balloon strip against my spine, while walking, standing and sitting there was a general feeling of comfort […] my spine has greater support*
>
> P18: *Feels like a comforting experience*
>
> P17: *It feels snug.*
>
> P19: *Like snug feeling*
>
> P03: *supported like a corset (but not painful =)*

Feeling Restricted. On the other hand, some felt that aspects of the costume created an uncomfortable or restricting sensation, particularly around the neck:

> P19: *disturbed with the one at my nape tight collar […] felt better, more relaxed when adjusted*
>
> P06: *the stockings were somehow putting pressure on my neck*
>
> P05: *one at the top should be small, big balloon pushes head forward*
>
> P04: *I feel like I was restricted to move/break my back bone; conscious of that feeling of keeping it straight*

The feeling of simultaneously being supported *and* restricted was also reported by two participants who noted that it was comfortable to do one activity (such as sitting or standing), but not to do other activities while wearing the costume:

> P04: *I'm more comfortable sitting up straight*
>
> P03: *can't sit down […] supported nice feeling [only] when standing up*

These comments suggest that the supportiveness and restriction are closely related experiences that are dependent on the activity of the user and their postural organisation in relation to gravity. It is also worth noting that a feeling of restriction is not inherently undesirable, especially if it is a temporary condition. In FM, temporary restrictions are often used to create an environment in which somatic learning can proceed, as discussed in section 3.3.3.4.

As the reports note, most of the feeling of restriction was centred on the area around the neck. I had decided that any prototype I built based on the Balloon Spine-Leg costume should not restrict the movement of the neck in any way, which led me to remove the balloon ring around the neck for the Awaken the Spine Workshop. However, by removing the loop around the neck but retaining one of the balloons touching the cervical spine, the costume still created a feeling of restriction around the neck.

Metaphors. Participants described the costume in metaphoric terms as well. Four metaphors emerged from their reports: body extension, exoskeleton, protection, and proxy for human touch. Feeling like the costume had become a part of the body was evidenced by reports of feeling like the participants were "missing" the costume:

> P20: *After removing the balloon spine […and] after taking a walk and standing still it seemed as if my body missed the […] support*
>
> P06: *feels like something is missing*

One participant reported feeling like they were settling into the costume, as if it were an exoskeleton:

> P03: *starts to feel nice while sitting down as I 'settle' more into it*

Another participant felt that the costume had a protective quality to it:

> P06: *the balloon also felt like an entity that protected me from the elements*

Some participants felt that it approximated some actions generally associated with human touch, such as being hugged or massaged:

> P04: *I feel like it can be a substitute for human touch*
>
> P53: *Cross between massage and a hug*
>
> P18: *it 'massages' your back*
>
> P03: *hugged tight*

4.5.1.2. Self-observations

For the following discussion, I organise participant self-observations into three general themes: cognitive, affective, and behavioural self-observations; observations of proprioceptive sensations; and what I suggest should be regarded as observations of structured somaesthetic phenomena. As I argue shortly in section 4.5.1.2.3, structured somaesthetic phenomena do not fit neatly under any existing sensory categories and arise only when the participants exercise somaesthetic attentiveness.

4.5.1.2.1. Self-observations of mood, thinking, and behaviour

Participants noted experiences related to several aspects of their mood, thinking, and behaviour. These included playfulness, curiosity, vulnerability, distractibility, awareness of the physical and social environment, generally positive feelings, acceptance of the present situation, and ability to attend to sensory experience.[51] Of these themes, playfulness and awareness of the physical and social environment were the ones most shared by the participants; I discuss these two themes in this section.

Playfulness. Playfulness was only experienced while wearing the costume, and not before or after. Playfulness was also accompanied by a change in the way participants moved. Not only did they note this in their self-reports, but I also observed some of the participants swaying from side to side and bouncing gently on their heels, much as I had done myself when I first wore the costume.

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[51] The last two aspects are notable in that they have been identified in psychology as components of "mindfulness" (Baer, 2004).

P18: *it's like a toy, makes you feel playful*

P06: *i feel more playful*

P53: *Round, bouncy*

One participant reported a sense of freedom and a curiosity to explore the costume:

P05: *feels freer, bouncy, like play […] really curious to lie down on it*

After taking off her costume, P06 noted the loss of her sense of playfulness:

P06: *by shedding off the costume it meant shedding off the playful mindset*

Awareness of and relation to the physical and social environment. While participants were aware of the physical space in which the workshop was being conducted and of the presence of other people, their relationship to the physical and social environment seemed neutral before putting on the costume:

P18: my companions

P19: Look at everything in the room. Didn't pay attention to how i was walking or to body parts

P04: The floor is cold

However, while wearing the costume, two participants noted that their perception of and relationship to the environment seemed to have shifted:

P18: *invites me to experience my environment differently […] i feel my companions look different and balance differently*

P07: *Lying down: Earth below. outer space above […] Walking: The environment around me […] I became more aware of my surroundings, and how my body reacts to it*

After taking off the costume, one participant felt that she was inexplicably more aware of the environment, while another linked the material properties of the costume with how he related to his surroundings after:

P06: *Can't explain it. I was more conscious of the floor.*

P18: *the snugness of the 'costume' made me less aware of the discomforts of my surroundings, but also made more accepting of them after*

In general, participant experience of their mood, thinking, and behaviour while wearing the costume and after taking it off were quite positive:

P18: *makes me smile*

P06: *smiling more while walking*

P04: *I feel less conscious with my posture and more confident [...] I feel great!*

4.5.1.2.2. Self-observations of physiological sensations

Reports of physiological sensations could be grouped into proprioceptive, interoceptive, and tactile sensations. Proprioceptive self-observations included experiences of weight, bodily structure (shape, size, symmetry), muscular tonus, and movement (kinaesthesia). Other types of physiological self-observation were that of interoceptive sensations sensations. In this section, I focus on the most commonly reported physiological experiences, which were proprioceptive in nature; that is, reports related to feelings of weight and of structure. I argue that experiences of both are fundamentally observations related to muscular tonus. In addition, I discuss two themes that, while not widely shared by participants, were notable: a phantomsensation of the balloons, and the feeling of being like an animal.

"Heaviness" and "lightness". Some participants reported feeling "heavy" in walking and standing, before they put on the costume:

P17: *I was having cramps on my back, and it felt really heavy [...] I was also leaning on my right side more so it felt uneven and heavier to walk*

P03: *after noticing heaviness of arms while standing still, it's hard NOT to notice heaviness of arms while walking*

In P17's account, two things are worth noting. She related her experience of feeling her back "heavy" to experiencing cramps, suggesting that her use of the word pertained not so much to the sensation of gravity acting on her body as it did to the effort involved in keeping herself upright. Second, she related the other use of the concept of heaviness to asymmetry in the distribution of her upper body's mass across the base of support. On the other hand, participant P03's account of experiencing the weight of her arms appears to relate to experiencing the sensation of the mass of her limbs.

While no participant used words related to weight to describe their experience while wearing the costume, some participants reported feeling "lighter" after wearing the costume, except for one who felt walking to be "heavier":

> P20: *After removing the balloon spine i immediately felt 'lighter' and felt that i had a much smaller frame.*
>
> P17: *My shoulder feels lighter. In general, my whole body feels lighter.*
>
> P19: *feel lighter*
>
> P04: *I feel lighter when I walk, I used to feel heavy-headed and feel like I have lazy neck and pelvis support*
>
> P06: *Footsteps felt heavier. Less springy.*

I suggest that in reporting that they "feel lighter," what the first four participants are experiencing is the activity of walking and standing with less "superfluous" (Feldenkrais, 2005, p. 141) muscular tonus that might have been present in their torso prior to wearing the costume. What they might have experienced is how they can keep upright with less muscular effort because of better alignment of their head, torso, pelvis, and legs with respect to gravity (Feldenkrais, 2005, pp. 140–143). I suggest that participant P06's report of feeling her footsteps to be "heavier" might be similarly explained in that the weight of her head, torso, pelvis, and legs were being supported in a different way by her feet.

Experience of structure. Participants also noted a change in their experience of their structure, by which I mean their perception of the size, shape, and organisation around the midline (that is, across the mid-sagittal plane) of their body.

For instance, one participant reported her self-assessment of her organisation in a way that can be interpreted as asymmetrical and not "centred" before putting on the costume:

> P05: *Feet turned out/ left move than right […] shoulders tilted forward […] head tilts down […] pelvis wobbly […] walking inside of feet not stable […] right side feels more stabl*e

After wearing the costume and taking it off, her description of her organisation suggests a more efficient "mechanical use" (Feldenkrais, 2005, p. 143) of her body:

> P05: *feet point more inwards; shoulders pull back; head tilts up slightly; right shoulder/arm feels relaxed; while walking less wobbly; feel taller*

Note how the participant felt taller after taking off the costume. Two other participants similarly reported a shift in their experience of their size. One noted that while wearing the costume they felt taller; the other, interestingly, reported the opposite experience after taking the costume off:

> P04: *it somehow gives me the image that I am very tall*
>
> P20: *felt that i had much smaller frame.*

One participant noted that after taking off the costume, her pelvis, torso, and head felt as if they were in a different relationship to each other in standing, and illustrated her experience visually (Figure 10):

> P17: I feel like my pelvis is thrusted/forward more. I feel like something is supporting my back, and I can lean back.

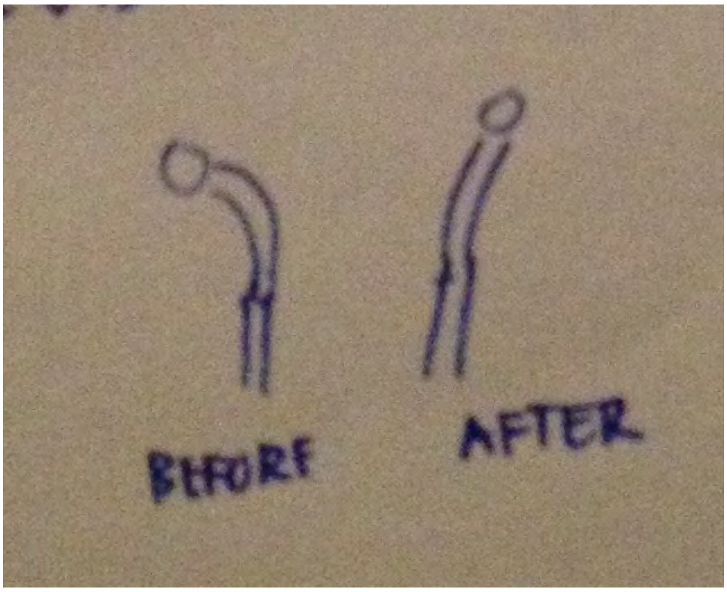

Figure 10. Participant P17's illustration of how she felt her body was organised before and after wearing the costume.

Feeling an echo of the experience. As I mentioned in section 4.4.3, I felt the presence of balloons on my back long after I had taken off the costume during Dean's workshop. Two participants reported very similar experiences:

P19: *sometimes still have the sensations of the balls*

P03: *i can feel the curve of my spine like i was still wearing the balloons*

Animal imagery. It is worth noting that the experience of feeling like an animal, while not widely experienced among the participants, came up again in the second session. It is particularly intriguing that their experiences echoed mine in Dean's workshop. While wearing her costume, participant P06 reported the following: "i feel animal-like […] i feel like i have a tail I'm thinking of my dog and what it must feel like to have a tail and communicate with another species." Interestingly, despite the fact that P06 did not share this imagery out loud, participant P07 spontaneously went down on his hands and feet reminiscent of a quadrupedal mammal at one point while wearing his costume (Figure 11).

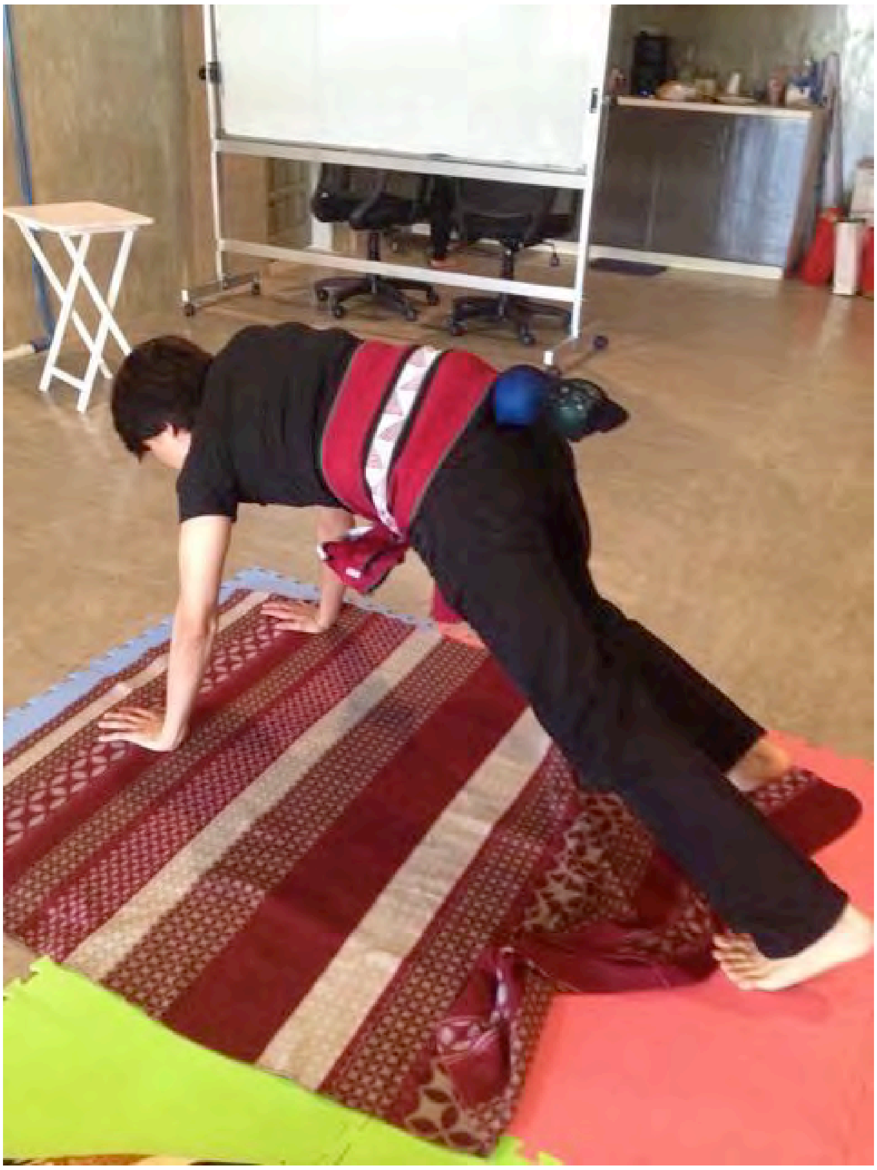

Figure 11. A participant exploring the costume on all fours.

4.5.1.2.3. Observations of structured somaesthetic phenomena

This last sub-category of physiological self-observations, which I call structured somaesthetic phenomena, is concerned not only with proprioceptive or interoceptive sensation, or even the awareness of these sensations, but the awareness of the *features and relationships within* the sensations. I suggest that *structured somaesthetic phenomena are observable, reportable sensory experiences that have been phenomenologically structured through the process of attending to them*. I call these experiences "phenomena" and not "sensations" because I believe that they are not exclusively sensory in nature;

I regard them as "higher-order" cognitive phenomena that do not fit easily within taxonomies of basic sensory experiences as discussed in section 2.2.3.2.

In section 3.3.1.5, I discussed how the body's internal connectivity can be experienced through FM. I suggested that the experiencing of the connectedness of the body is precisely an example of a somaesthetic phenomenon. I call this particular somaesthetic phenomenon *anatomical relatedness,* and define it as *the perception of the relations between the structures and functions of the body in movement.* Four reports from participants, made while wearing the costume or after taking them off, represent the experience of anatomical relatedness:

> P05: *More mindful of how body parts move in relation to my spine*
>
> P03: *can really feel the curve of my spine while walking*
>
> P04: *I feel aware of every bone in the spine*
>
> P07: *my right shoulder feels mobile [...] It is like is a ball that makes it rotate or move.*

4.5.1.3. Discussion and next design and research directions

In this section, I offer an analysis of the participants' reports using the conceptual framework of FM that I developed, citing the sections in Chapter 3 where the relevant concepts are discussed. I suggest that the costume facilitated the sensory, cognitive, and affective experiences that were reported by the participants, in part because of two neurophysiological processes that are central to FM. First, if muscles for postural organisation do not need to work because something else is maintaining the organisation, they will not (section 3.3.3.1). The shirt, waist band, and the balloon-spine provided a supportive structure that allowed the muscles normally involved in maintaining the individual's upright position to be less activated. I suggest that this was what led to reported sensations of comfort but also restriction whenever the costume hindered movement. Second, the decrease in tonus subsequently increases sensitivity to small changes to proprioceptive and tactile stimuli, which facilitates somatic learning through expanding the resolution of cortical self-representations (though only if the stimuli are being attended to in the first place) (section 3.3.3.3). The contact of the balloons against the midline of the back provided novel tactile stimuli that directed the user's attention to parts of themselves to which they may not usually attend.

It was also important to enable participants to attend to proprioceptive stimuli and ward off competing interests for attention. This was made possible during the workshop because (1) participants had voluntarily set aside time to participate, and (2) the sessions were held in a quiet, comfortable space partitioned off from the rest of the urban environment. But I also propose that the costume—as "exoskeleton" and "protection"—afforded participants the opportunity to focus on their internal experience. Thus, the costume created a safe and affordance-rich somatic learning environment in which participants felt safe to play and explore, guided by the tactile prompts provided by the balloon-spine. This license to play was further abetted by the unusual, visually striking, performative quality of the costume.

By actively encouraging a curiosity about their own neuromuscular organisation and using carefully worded verbal guidance to facilitate somaesthetic attentiveness—both crucial teaching strategies in FM (section 3.3.3.2)—I sought to increase the likelihood that they would experience and report anatomical relatedness. Somatic insight was generated by exploring different activities (standing, walking, sitting) while their ability to attend to their back was enhanced by the tactile contact with balloons *and* temporarily restricted by the costume, since placing temporary restrictions to movement has instructional value (section 3.3.3.4). Finally, taking off the costume and doing the same activities that they had performed at the beginning of the workshop provided the participants a learning opportunity to compare their experiences (section 3.3.3.6).

The results of the Awaken the Spine workshop and my analysis thereof contribute to knowledge in two ways. First, they lend weight to the Dean's assertion that these costumes are "portals of perception" (Dean, 2015, p. 158). In section 3.3.2.1.1, I elaborated on the importance of the interface between the body and a (horizontal) surface for somatic learning. Dean has pointed out that between the skin and the environment, there is clothing, and that the interface of skin to fabric also contributes to somatic insight (Dean, personal communication). Second, the workshop provides evidence that somatic practices and technologies for somatic experience developed in the West can have efficacy and value for a non-Western public.

In addition, the Awaken the Spine workshop contributed to the aim of this research of developing a wearable technology for somatic learning in that it provided guidance for preliminary design explorations. In particular, the Balloon Spine-Leg costume had two aspects that are relatable to the FM conceptual framework: postural tone reduction and awareness through tactile contact. After the workshop, I thus turned my attention to a design problem that underpins this research: how can aspects of the costume and the somatic insights it provided be brought into part of everyday experience?

4.5.2. The evolution of the Haplós physical prototype

The Awaken the Spine workshop was conducted three months into a secondment to Kin, a research and design company in London. As mentioned in section 1.3, my secondment with Kin was part of the overarching institutional goal of the CogNovo programme to bridge academic research with industry needs. The secondment at Kin provided an immersion into design business culture and designerly thinking.[52] Kin has eight full-time employees who possess a range of skills, including interaction design, physical computing, visual communication, and software development. The studio has a workshop area equipped with physical computing and prototyping hardware that afforded a wide range of materials exploration and experimentation.

The continual making and evaluation process began in earnest when I started my secondment, during which I clarified how creative and design practice could be woven with my interest in somatic learning and to the institutional contexts and themes around art, sound, media, and embodied cognition. For instance, the fact that Kin often designs products used by a large number of people prompted my interest in using design to bring technology-facilitated somatic learning to everyday experience through design. Moreover, conversations at the studio often turned into informal design critiques sessions which supplemented more formal feedback sessions. For instance, while I was trying out the back support suit at Kin one day, one of the designers remarked in passing that the suit (when modified with motors, batteries, and Arduino boards) look like a suicide bomber's vest and may deter user acceptability. This has led me to place more consideration on exploring other form factors, as I discuss in section 4.5.2.3. The secondment at Kin culminated in a design

[52] One risk of being part of an interdisciplinary PhD programme such as CogNovo is that a researcher might be the sole representative of their discipline or, at the very least, the particular disciplinary intersections they represent. In a report submitted to the CogNovo funders, I reflected on this issue and how my time at Kin addressed it: "For the first year of CogNovo, while I was active in a variety of collaborative projects, I still felt like I was working alone. At Kin, I am among fellow makers, surrounded by a material and cultural environment that open possibilities but also focus and refine the creative process. They share the joy I have both for small discoveries—as when I realised that a snap fastener can double as a switch for an electric circuit—and for the bigger questions around how built environments and artefacts shape human identity and experience."

critique session at Kin (#P34-55.160624.ProtoTrial.a5), which also functioned as a prototype trial session. Figure 12 shows one of the designers at Kin wearing the Haplós suit and operating an early version of the GUI during the design critique session.

Figure 12. Experimenting with different materials—in this picture, corn plasters—to bring the motors close to the body.

The first prototypes for Haplós emerged right after the Awaken the Spine Workshops. In section 3.3.3.2, I discussed how being touched can be a learning experience in FM, while in section 4.4.1 I talked about the value of getting to know the spine through touch, particularly its thoracic region, which I suggested is poorly rendered in the self-representation. Building on these assumptions, my experience of the Balloon Spine-Leg costume, and the results of the Awaken the Spine Workshop, I began prototyping Haplós with a particular somatic learning activity in mind: enabling the user to "touch" their own thoracic spine *comfortably, selectively, with precision*, and in a way that can be integrated into everyday clothing. My aim was to design a vibrotactile technology that was easily configurable in order to give users as much agency over their own vibrotactile experience as possible, much in the same way the learning experience in the FM is entirely self-paced and self-directed.

As I proposed in section 4.5.1.3, the effects of the original Balloon Spine-Leg costume on the participants' experience can be parsed by the material affordances of the costume. Specifically, the supportive, exoskeleton-like property of the combined shirt, waistband, and balloon spine helped reduce the tonus of postural muscles and created a somatic learning environment in miniature. The shirt also played an important role in bringing the balloon spine against the wearer's torso. The balloon spine alone, on the other hand, provided novel, gentle, and perceptible tactile stimuli to the midline of the back. Therefore, in this section, I discuss the physical prototype as interrelated subsystems with at least four functions: providing tactile stimulation, reducing muscular tonus, bringing the stimuli-providing subsystem close to the skin, and customising properties of the tactile stimuli.

4.5.2.1. Providing tactile stimulation through vibratory motors

The very first ideas for the tactile stimulation subsystem are shown in Figure 13, which illustrates how I considered a system of small inflatable air packs to literally recreate the balloon-spine in miniature. I decided against exploring this direction further because of the amount of engineering work and specialised manufacturing techniques that I estimated would be required. Furthermore, I was interested in being able to quickly apply and remove tactile stimuli, which I reasoned an air compressor-based system would not be able to deliver quickly enough. Figure 13 also shows that I considered small transducers (like those found in audio speakers) that can produce sound. However, after consulting with Kin's physical computing specialist, who advised that an audio transducer of the size I wanted may not provide enough mechanical energy to stimulate the skin and subcutaneous soft tissue, I also abandoned this line of inquiry.

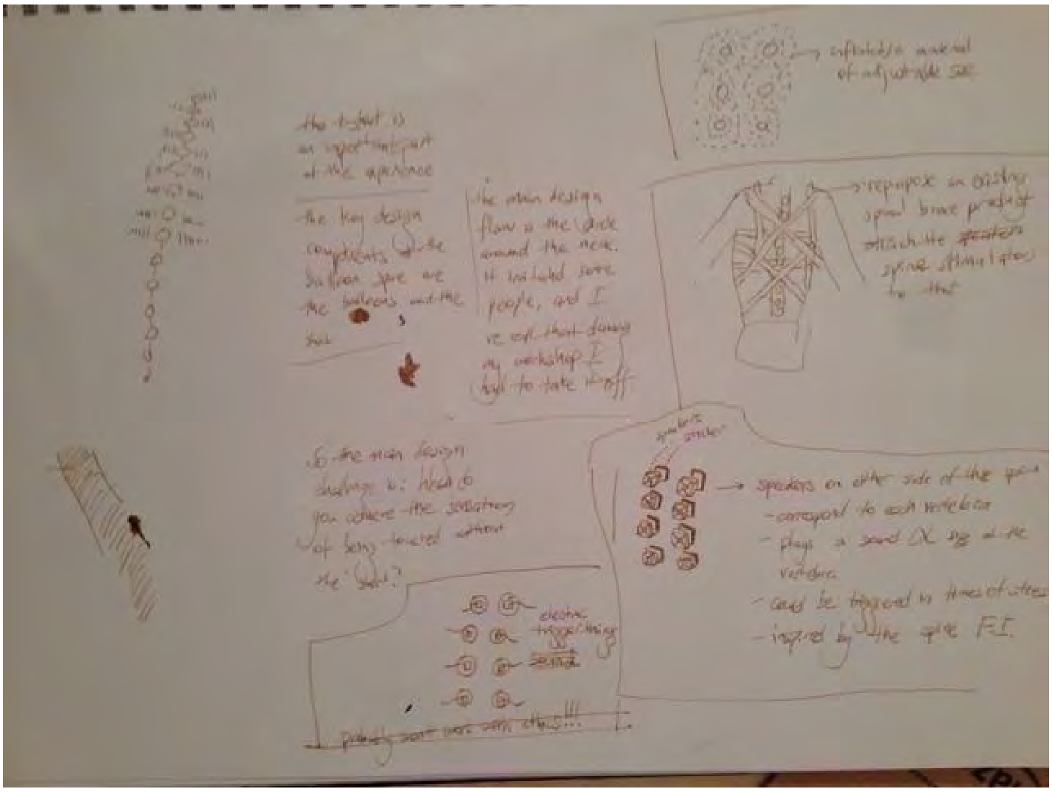

Figure 13. Page from the paper-based design journal on ideas for the physical prototype. A sketch speculating on repurposing an existing back garment is sketched on the middle right. Proposals for using small inflatable air cushions or audio transducers are also indicated.

Instead, I decided to use the brushless vibratory motors that remain part of the prototype to date. Vibrotactile stimuli provided the kind of spatially targeted stimulus whose properties, such as the stimulus envelope and intensity, could be controlled with precise timing (Marshall & Wanderley, 2006). I was also intrigued by the speculation that because performing movement in an oscillatory way is an FM learning strategy (section 3.3.3.5), perhaps oscillatory movement of vibratory motors might create body awareness in a way that has not been previously investigated. I did not discount scaling fallacy (Galilei, [1638] 2005; Lidwell et al., 2003, p. 214): oscillatory movement performed in an FM class is on a scale involving increments measured in centimetres at very low frequencies, while the oscillatory movements of vibratory motors are on the scale of millimetres at most and at frequencies at least one order of magnitude greater than the movement oscillations in an FM class. Nevertheless, I thought the proposition compelling enough to be worth exploring and to justify my choice of vibratory motors for the Haplós prototype. Figure 14 shows four individual motors being tested early in the prototyping phase.

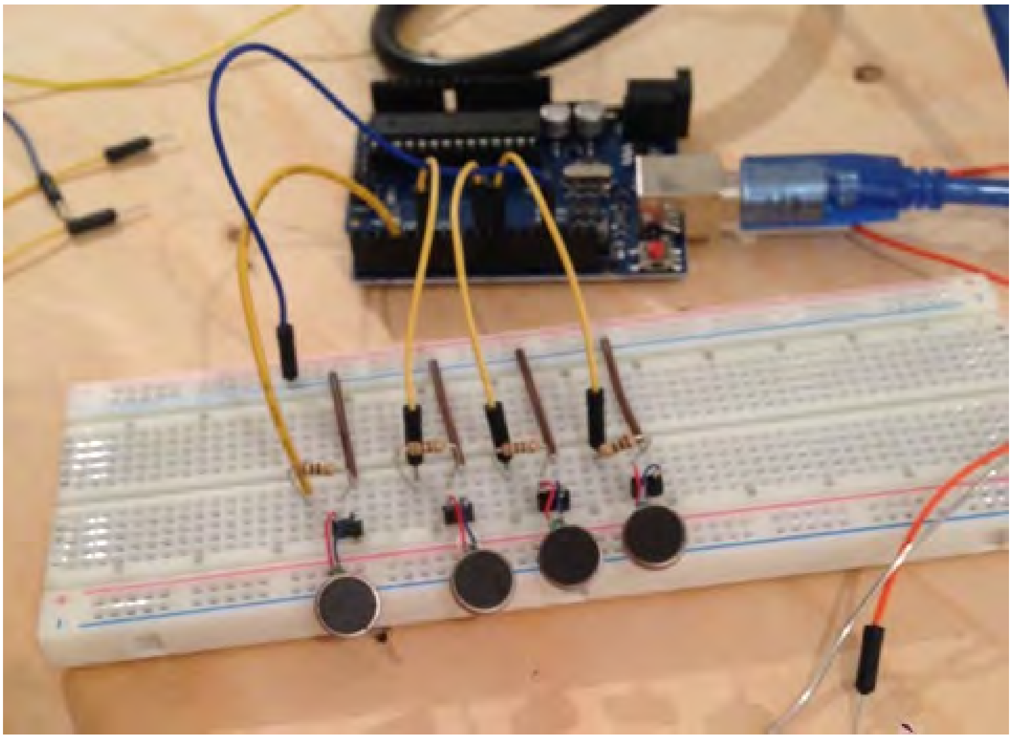

Figure 14. Four vibratory motors being tested

4.5.2.1.1. Neuroscientific evidence for vibrotactile stimuli's effects on cortical self-representations

Though my decision to use vibrotactile stimuli was largely motivated by instinct, my research into the neurophysiology of vibrotactile stimuli serendipitously revealed remarkable relationships between vibratory stimulation and sensorimotor learning that strongly affirmed my decision. Whereas it had been previously established that electrical nerve stimulation applied to an area of the body can reorganise the cortical representation of motor action for that area, e.g., (Tamburin, Manganotti, Zanette, & Fiaschi, 2001; Meesen, Cuypers, Rothwell, Swinnen, & Levin, 2011), Karin Rosenkranz and John Rothwell (2003) demonstrated that vibration stimuli can also "differentially modulate excitability in motor cortical circuits." Moreover, vibrotactile stimulus can target different parts of the motor cortex with more precision than electrical stimulation (Rosenkranz & Rothwell, 2003). In Rosenkranz and Rothwell's studies, they attached vibratory devices to specific areas of the hand and measured brain responses to vibrotactile stimuli using a brain measurement technique known as transcranial magnetic stimulation (Tamburin, Manganotti, Zanette, & Fiaschi, 2001). They found that applying an 80 Hz vibration stimulus for 15 minutes caused "long-term (>30 min) changes" in the brain (Rosenkranz & Rothwell, 2004). They called their protocol "proprioceptive training" (Rosenkranz & Rothwell, 2006). In a similar vein, (Christova, Rafolt, Golaszewski, & Gallasch, 2011) found that whole-hand stimulation of 25 Hz created "outlasting plastic changes in the primary motor cortex." It is theorised that vibrotactile stimulus affects the motor cortex by altering "the strength of sensory input to motor circuits" (Rosenkranz & Rothwell, 2006), and that somatosensory reorganisations based on proprioceptive training "can drive changes in motor behaviour" and motor learning (Rosenkranz & Rothwell, 2012). This is supported by prior work in experimental monkeys which has demonstrated that increasingly skilled used of the hands corresponded to "topographically expanded cortical sectors" of the skin of the fingers (Xerri, Coq, Merzenich, & Jenkins, 1996).

Two conditions help with proprioceptive training that are consistent with somatic learning strategies in FM: attending to the sensation and increasing the sensitivity by minimising distracting stimuli (section 3.3.3.1). First, proprioceptive training is more effective when the participant is attending to the sensations they are experiencing; the extent to which the motor cortex is reorganised by vibrotactile input is increased when the subject is asked to pay attention to changes in the vibrotactile stimuli (Rosenkranz & Rothwell, 2004). Attention must be directed to the particular area being stimulated; if the participants attend to a part next to (but not precisely) the area being stimulated, the reorganisation is not as strong (Rosenkranz & Rothwell, 2006). Second, immobilising the hand prior to doing the proprioceptive training increases the effectiveness of the training; the researchers theorise that this is because immobilisation creates a sensorimotor deprivation that "increases the sensitivity to remaining sensory inputs" (K. Rosenkranz, Seibel, Kacar, & Rothwell, 2014).

4.5.2.2. Reducing muscular tonus through clothing and posture

The feedback from the Awaken the Spine workshops on how Dean's costume evoked the feeling of being hugged reminded me both of animal science professor Temple Grandin's hug machine (Grandin, 1992) as well as artist Teun Vonk's installation, *The Physical Mind*, which squeezes audience members (Teun Vonk, 2016). Both were designed by their creators based on the realisation that applying pressure around the body creates a calming sensation that can reduce anxiety (Edelson, Edelson, Kerr, & Grandin, 1999). I submit that this phenomenon can be at least in part explained by the mechanism of reducing postural tone (see sections 3.3.2.1 and 3.3.3.1). In this section, I describe reducing muscular tonus through clothing and furniture.

4.5.2.2.1. Modifying an existing back support garment

After the workshop, I realised that I could repurpose existing, commercially available back support garments for the purpose of reducing muscular tonus, as noted in pages from my design journal in Figure 13. In addition to providing postural support, some back support garments also have the advantage of being explicitly designed to prevent constriction and movement restriction around the neck—a key design requirement that emerged from the Awaken the Spine worksop. These garments have the additional benefit of being easy to put on and take off.

For the purposes of prototyping, I chose the Deluxe Posture Corrector ELAST 0109-01 by Tonus Elast[53] because its abdominal support straps mimicked the waist band of the Balloon Spine-Leg costume and it also had arm straps that I could modify based on my original experience of the Balloon Spine-Leg costume and the Awaken the Spine Workshop results. I experimented with repurposing the arm straps, which are meant to go under the armpits, into vertical straps that loop under the pelvis in a manner similar to the elastic bands in the original Balloon Spine-Leg costume (Figure 15). This configuration is similar to how a ballet onesie enfolds the entire torso from shoulder to groin, my previous experience of which was pleasurable in that it proprioceptively reminded me of the full length of my torso. It was a sartorial analogue to an FM-like experience of the connectedness of the entire torso. However, the particular hack that I implemented did not work as well as I had anticipated because the strap was not uniformly elastic, occasionally creating an uncomfortable imbalance for many users who tried out the suit in informal tests (e.g., #P34-55.160624.ProtoTrial.a5). This prototype did not create the same pleasurable sensation that I had experienced in the Balloon Spine-Leg costume, and so was abandoned in later evaluation studies involving the suit. Another modification I made involved the removal of metal strips that were normally inserted in the garment to give it structural support. I removed them to provide the motors more contact with the skin and to recreate a more "hugging" sensation. Figure 16 illustrates some of these modifications.

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[53] Product website: https://www.itone.lv/en/belts-and-posture-correctors/58-elast-0109-01-comfort-tone-elast-elastic-medical-lower-back-posture-corrector-with-stiff-inserts-and-enhanced-comfort.html

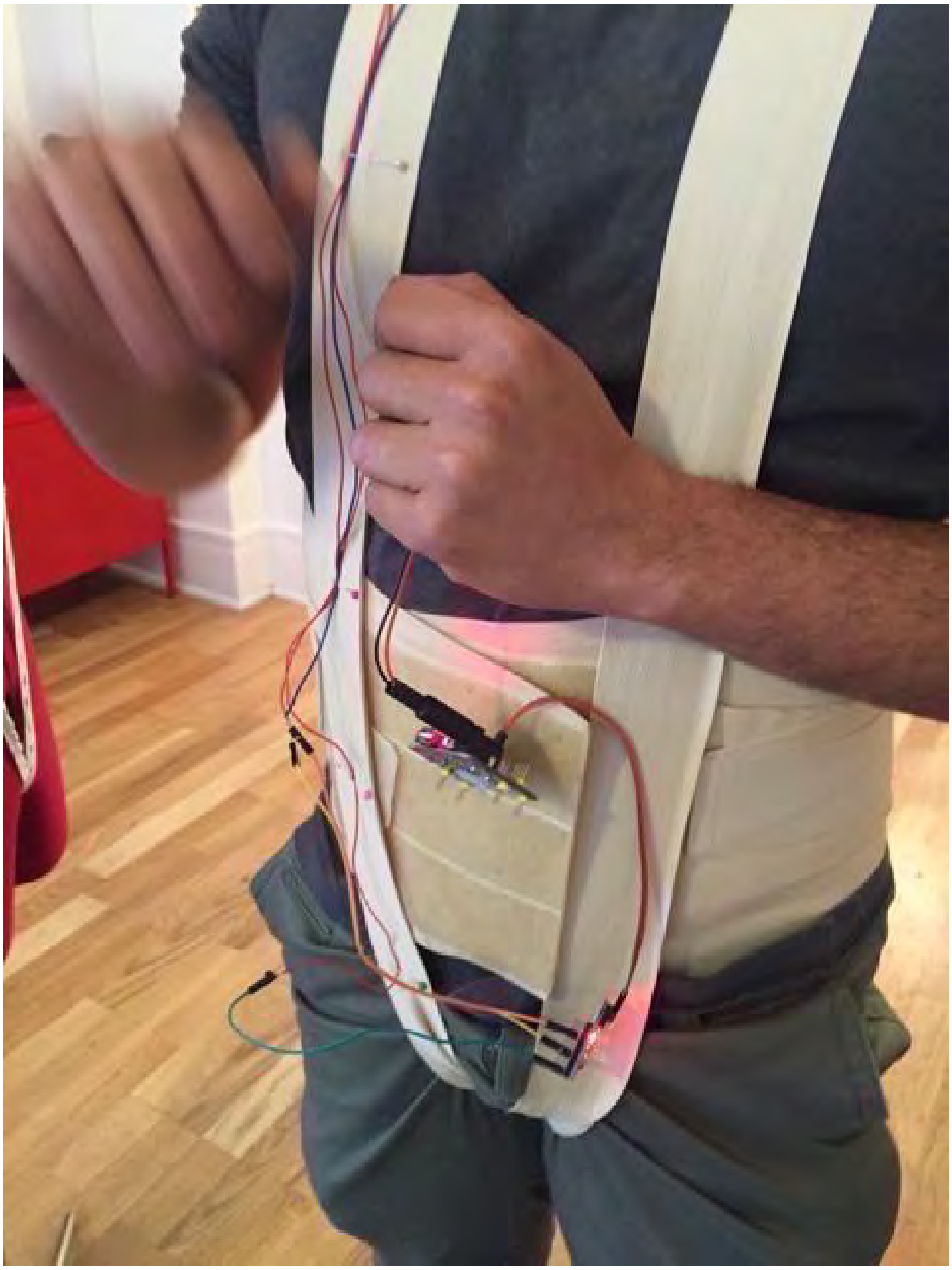

Figure 15. The arm straps repurposed into vertical torso bands. This feature was abandoned in later versions.

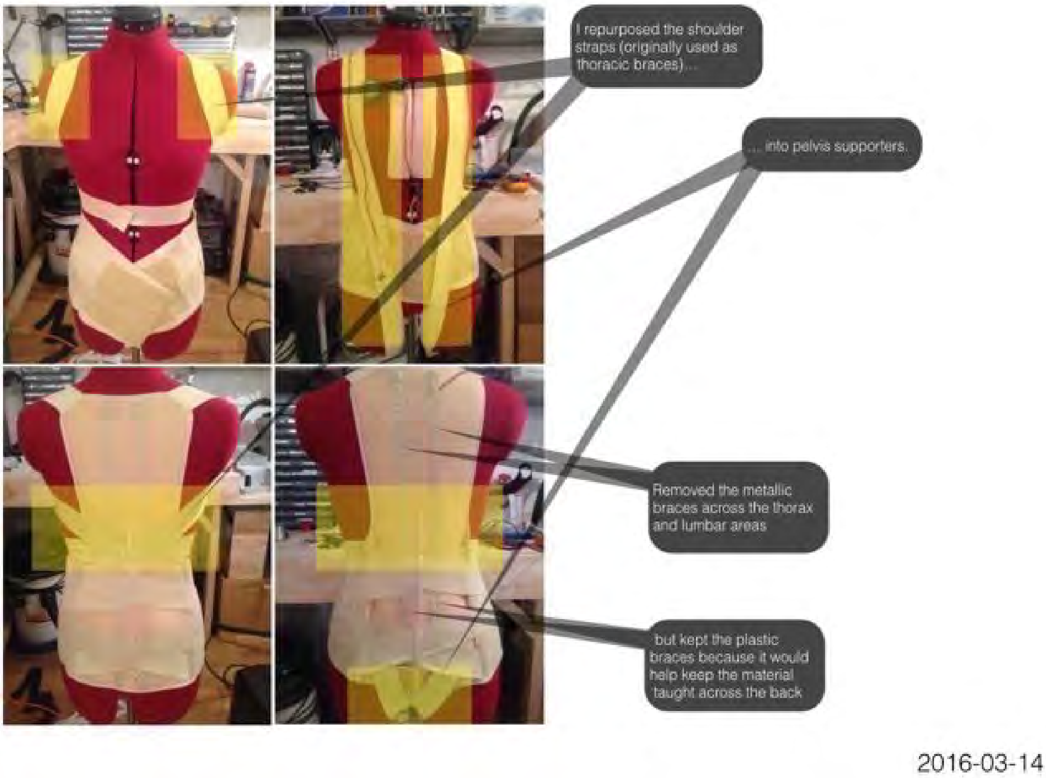

Figure 16. A section from my digital design journal showing modifications made to the back support garmen.t

4.5.2.2.2. Using furniture that afford postural support

In the evaluation studies I conducted (to be discussed in section 5.5), I continued to use the suit as the system for reducing postural tone and for bringing the motors closer to the user's body. However, the essential FM technique of lying down or leaning against something that can support one's torso (such as a chair back) works just as well. Figure 16 shows a participant experiencing a Haplós vibrotactile composition; while he is wearing a suit, it is only loosely fastened and mainly used to position the motors against his back. The weight of his torso against the soft cushioned surface brings the motor closer to his skin, while being in a prone position achieves the reduction in postural tone that renders him more sensitive to the vibrotactile stimuli. Other form factors that support the body's position, lessen postural tone, and allow the user to experience applied stimuli comfortably—such as a cradle (Vidyarthi & Riecke, 2013)—are possible. However, the combination of the softness and the horizontality of the surface of the couch in Figure 17 appears to press the motors in a generally consistent way against the body, affording the participant a uniform perceptual ground that can enable them to make sensory comparisons more effectively (as previously discussed in section 3.4).

Figure 17. The motors are pressed against this participant's back as he lies prone on the couch, a position which also reduces postural tone.

4.5.2.3. Bringing tactile stimuli close to the body

To bring the motors close to the user's body, I initially experimented with embedding the motors in corn plasters, which are foam pads with an adhesive back that can be attached to the skin; by coincidence, these pads also have a circular opening that perfectly fit the motors (Figure 18). I had also considered attaching the motors directly on the user using skin-safe glue or Kinesio Tape (González-Iglesias, Fernández-de-las-Peñas, Cleland, Huijbregts, & Gutiérrez-Vega, 2009). Kinesio Tape is a type of elastic fabric with an adhesive backing, used in orthopaedic and sports medicine and applied to body parts in such a way as to reduce pressure on a joint (Choi, Park, & Lee, 2016). However, I discarded these ideas as they would make it difficult to apply and remove the motors, rendering them inconvenient to use as part of everyday experience.

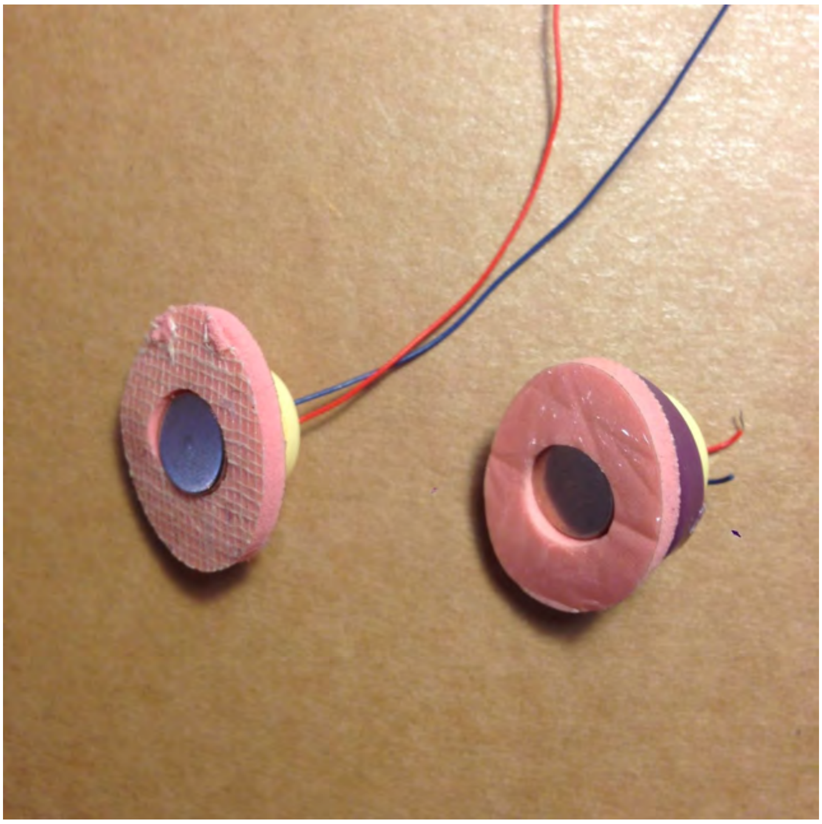

Figure 18. Experimenting with different materials — in this picture, corn plasters — to bring the motors close to the body.

Ultimately, the strategies I chose for bringing the motors closer to the skin were the same ones used for reducing muscular tonus: either using the fitted form of the back support garment (much like in the Balloon Spine-Leg costume), or using the user's weight to press the motors against their skin when lying down or leaning against a cushioned surface (as previously illustrated in Figure 17).

I had also experimented with putting the motors on other parts of myself, including the outer side of the leg where the tensor fascia latae is located

(#P0.170304.ProtoTrial.a5), the costal margin of the ribcage (#P0.170322.ProtoTrial.a5), and the region around the anterior superior iliac spine of the pelvis (#P0.170322.ProtoTrial.a5). In these cases, motors were brought closer to the skin through attaching them to a pair of leggings or a fitted shirt. Figure 19 shows the motors attached to a pair of thermal leggings as used in the prototype trial involving the tensor fascia latae.

Figure 19. Haplós incorporated in a pair of thermal leggings during a prototype trial focusing on the leg.

4.5.2.4. Customising the vibrotactile stimuli

To optimally direct the user's attention to the vibrotactile stimuli, I sought to customise four aspects of each vibratory motor's operation: its location, intensity, duration, and position within a sequence of vibrotactile patterns. In this section, I first discuss the system for placing motors on specific locations on the body and with respect to other motors. I then address the last three aspects by discussing the development of the Haplós software and hardware components.

4.5.2.4.1. Repositioning the motors

I explored different ways to position and reposition motors easily in order to enable the user to stimulate precise areas of their body. Figure 20 shows an early experiment in which the motors were attached to buttons and inserted into a buttonhole elastic band, which could then be sewn into a piece of clothing. This system proved to be infeasible as inserting and removing the buttons was a cumbersome process, and deformations in the elastic band meant that the spatial resolution would diminish over time. I also considered a more analog approach to repositioning the motors, such as using a strip of flexible magnetic material to which the motors could attach themselves. However, for the attachment to be secure enough, the magnetic strip would have to be so strong that it would affect the performance of the motors. A more compelling reason, however, against the use of a continuous repositioning system is based on my proposal of somatic learning affordances (as summarised in section 3.4): a material somatic learning environment must be as perfectly uniform a perceptual ground as possible.

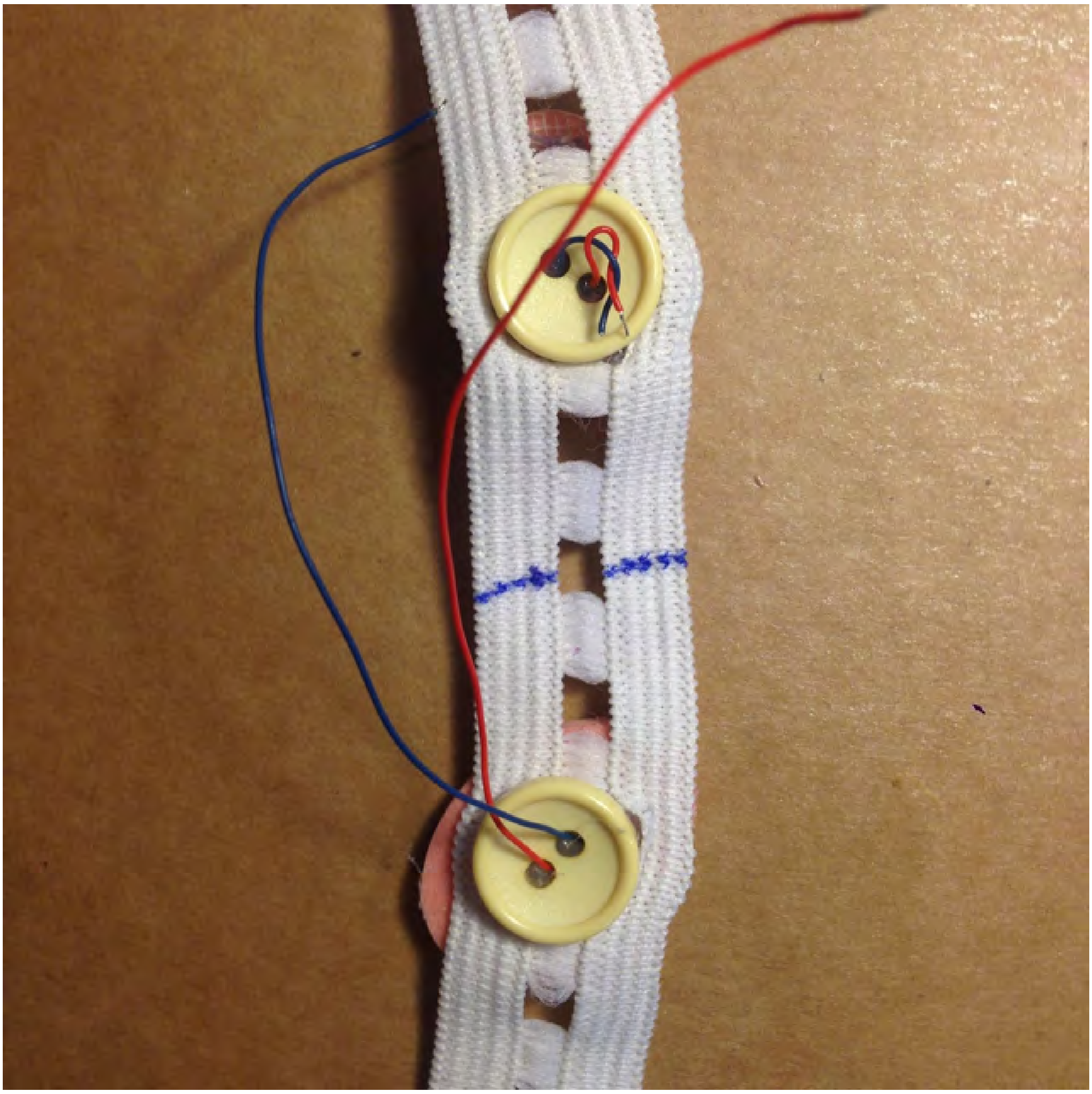

Figure 20. Experimenting with repositioning the motors.

Instead, I devised the system described in section 4.2 where female snap fasteners are sewn onto fabric, linked together with conductive thread, and connected in parallel to the power of a circuit. Male snap fasteners are glued to the motor and connected to the motor's anode wire. Motors simply need to be snapped on or off to be repositioned. Initially, the female snap fasteners were connected directly to the brace (Figure 21). However, because I was interested in being able to attach the motors to any kind of clothing or implement, I eventually decided to sew the female snap fasteners onto a non-elastic fabric ribbon (Figure 22), which can then be easily attached to any garment.

Figure 21: Conductive snaps were initially attached directly to the back support suit

Figure 22: Early version of snaps sewn onto non-elastic fabric ribbon

4.5.2.4.2. Software and hardware to customise vibrotactile intensity, duration, and sequencing

The motors were activated by the Photon microcontroller via a ULN2003A Darlington Transistor Array and powered by an MB102 Breadboard Power Supply Module. Figure 23 shows these hardware components as part of an early version of the Haplós circuit board. Light-emitting diodes are on the board for testing purposes.

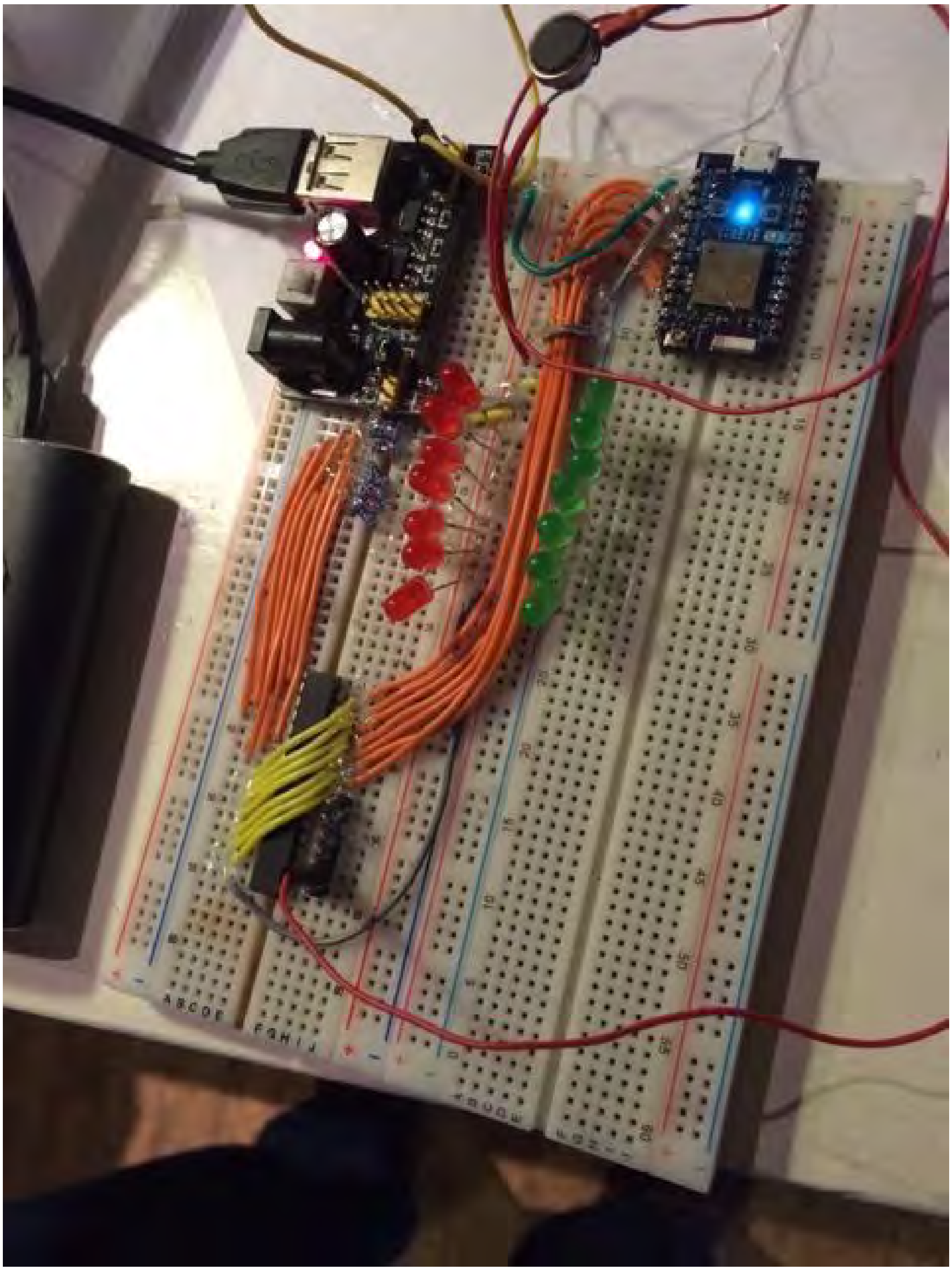

Figure 23: Close-up of early version of the Haplós circuit board. The green LEDs on the right were not being used when this photo was taken but were put there in anticipation of another seven motors being included in the board.

In the remainder of this section, I discuss the two codebases that I developed to customise the intensity and duration of each motor and use it as part of a sequence of vibrotactile patterns: the firmware embedded into the Photon microcontroller and the software for a graphical user interface.

4.5.2.4.2.1. The microcontroller firmware

The Photon microcontroller was programmed using firmware written in the Wiring programming language. The firmware wirelessly receives instruction from the GUI about which motors to turn on or off, for how long, and in what sequence. These instructions are then interpreted accordingly into voltage changes in the eighteen input/output pins of the Photon, to which the motors are connected. However, motor intensity can be controlled only on the seven pins which are capable of the "pulse width modulation" (PWM) required to create more subtle variations in intensity. Additional hardware can be used to expand the number of PWM-enabled motors, but early experiments with one such piece of hardware—the SunFounder PCA9685 servo driver—were not successful likely because of hardware compatibility issues.

4.5.2.4.2.2. The graphical user interface

Users can send instructions to the microcontroller firmware using a GUI previously shown in Figure 3. Figure 24 shows an early mockup of the GUI. In the mockup, three interaction modes are possible: manually toggling the motors on or off, programming the activity of the motors using a sequencer, and activating motors on the fly through gestures such as stroking or rubbing the screen. Note that the current version of the GUI (as previously illustrated in Figure 3) dispenses with the mockup's image of the back because the motors can be placed anywhere on the body, in any configuration; hence, I decided that a more abstract representation of the arrangement of the motors would be more appropriate.

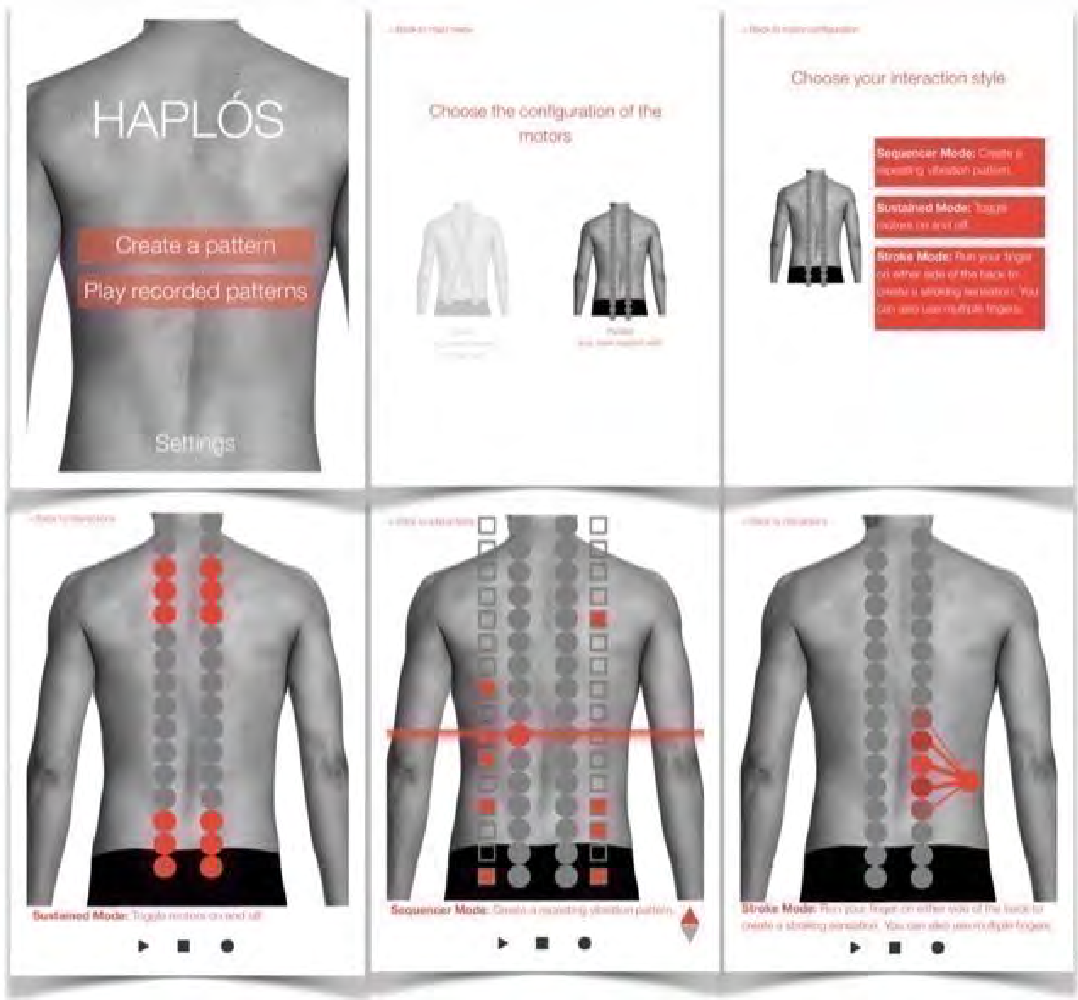

Figure 24: An early GUI mockup. Three interaction modes are illustrated (below, from left to right): manually toggling motors on or off, programming motors using a sequencer, and gesture-based interactions such as stroking or rubbing

An initial attempt to realise this mockup was implemented using Web-based technologies including HTML5, Javascript, a communication protocol known as Open Sound Control (OSC), and a toolkit for combining all three called NexusOSC.[54] While a purely browser-based GUI is possible to develop and would have allowed Haplós to be operated by any device with a modern browser installed, I chose instead to finalise the development of the GUI on the feature-rich Processing development platform due to time constraints. The GUI can still be run on a range of

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[54] http://nexusosc.com.

different operating systems, including the Microsoft Windows-based tablets that were used in later studies.

All three interaction modes were used in the Manufactory workshop and in public engagement events (to be discussed in section 5.5). However, because the Particle Photon microcontroller and the GUI communicated over a wireless network using OSC, information packets were occasionally dropped or delayed during transmission; gesture-based interactions were thus liable to occasional lags. Data packet transmission issues can be addressed in future work (section 6.4).

While it is possible to control the intensity in seven of the motors in the firmware, I deferred implementing the ability to set motor intensity in the GUI not only due to time constraints, but also because early experiments at Kin suggested that even at full power the motors still felt subtle (#P34-44.ProtoTrial.a5). I decided to settle for less nuance in the motor intensity but having at least twice as many motors—that is, because of the restrictions placed by the Photon microcontroller, I settled with having fourteen motors that could operate on full power instead of only seven that would be capable of more subtle vibratory behaviour.

The current version of both the firmware and the GUI allows between one to fourteen motors to be controlled and sequenced. Seven were used per suit in the Manufactory workshop and in public engagement events, while fourteen were used in the Cravings study (to be discussed in section 5.7.1). Figure 25 shows details of the GUI used in a seven-motor version of Haplós in sequencer mode. The GUI features the following:

1. A visualisation of which motors are currently on;
2. Choice of three interaction modes—stroke, toggle, and sequencer (here labelled "matrix".)

3. When in sequencer mode, a timeline of motor “slots” which can be filled or cleared on-the-fly to create a new pattern that can be sent to the microcontroller;
4. The ability to send the pattern to a particular Haplós device as identified by IP address;
5. The ability to broadcast the pattern to all Haplós devices on the network;
6. Controls for playback—clearing the vibrotactile scores, saving the score to disk, loading an existing score, generating a random score, play/pause, and stop; and
7. Controlling playback speed by setting the timestep duration (in milliseconds).

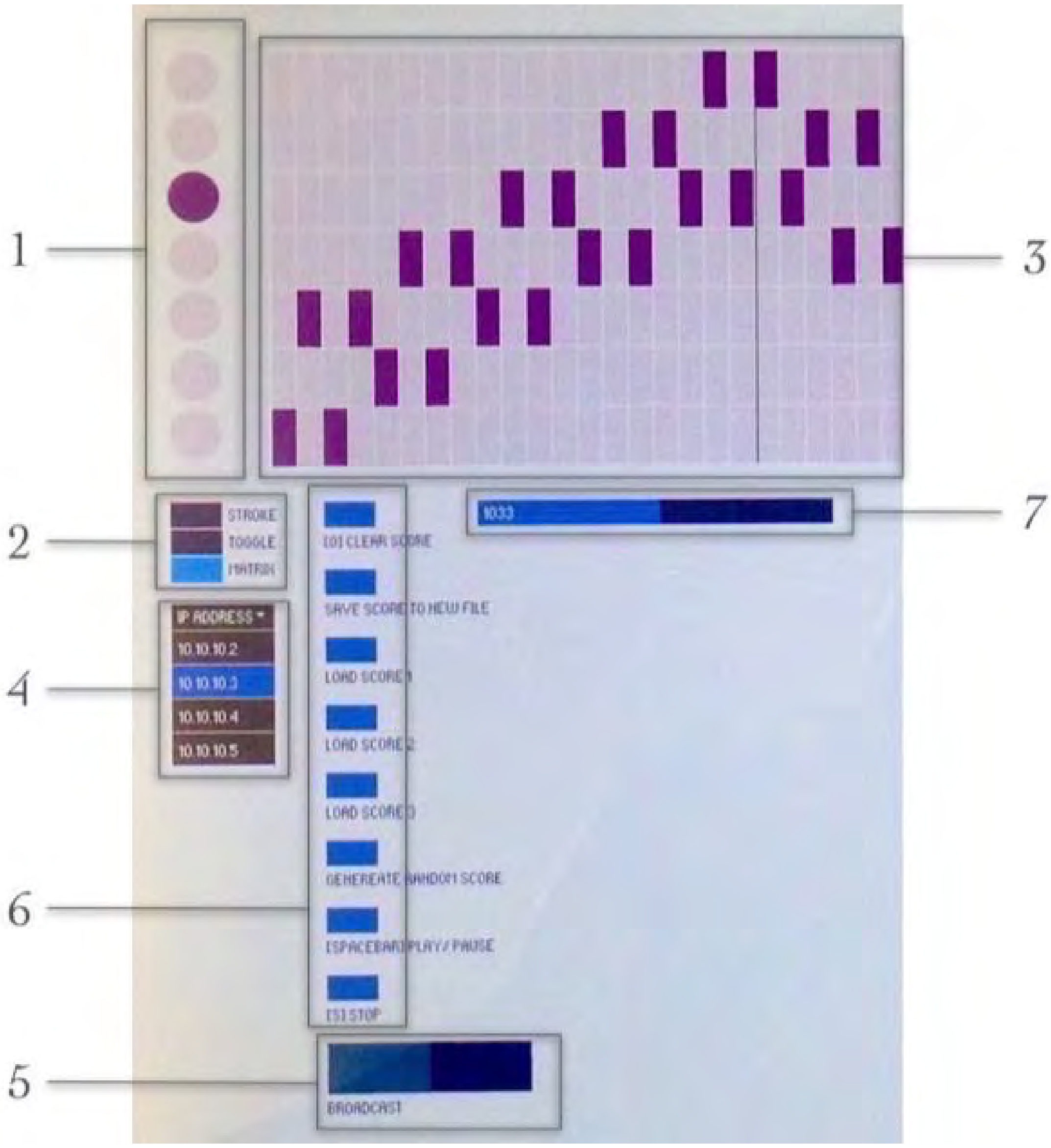

Figure 25: A close-up of the GUI. 1) Visualisation of motor activity. 2) Choice of three interaction modes. 3) Vibrotactile pattern sequencer. 4) Target device selection. 5) Option for mass transmission of patterns. 6) Playback, file loading/saving, and random score generation controls. 7) Playback speed control.

4.5.3. Hack the Brain 2016 hackathon

By the end of the secondment at Kin, the design of the motors, the circuit board, and the firmware were feature-rich enough to be used as part of Bisensorial, a wearable prototype that was developed over three days at the Hack the Brain 2016 hackathon[55] in collaboration with a group of artists and scientists. Because Bisensorial was an offshoot of the main branch of this research, a more detailed discussion of Bisensorial is deferred for section 5.7.2. Figure 26 shows the motors connected to the circuit board as incorporated in Bisensorial.

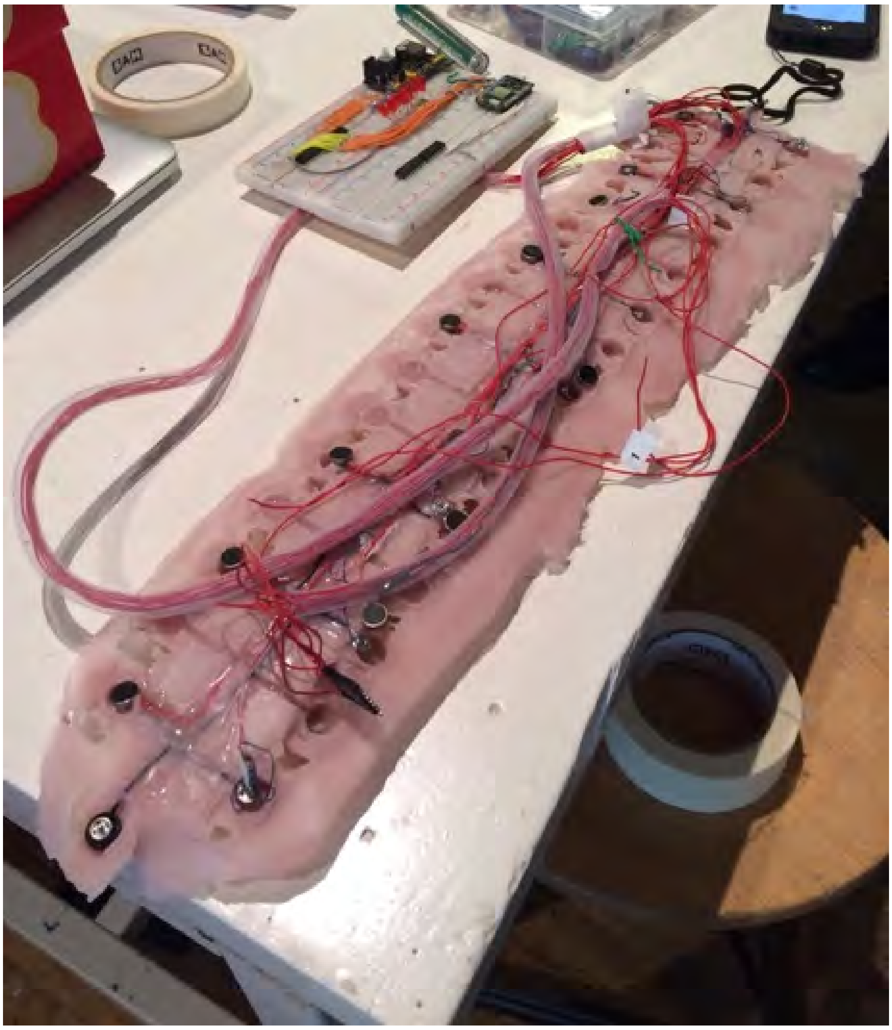

Figure 26: The Haplós motors connected to the circuit board as used in Bisensorial

[55] More information about the Hack the Brain event is available on http://www.hackthebrain.nl.

4.6. Chapter summary

The Haplós physical prototype was initially inspired by Dean's Balloon Spine-Leg costume, subsequently reimagined for everyday use, and developed through a consideration of the FM conceptual framework and neurophysiological research on vibrotactile stimuli. In this chapter, I described the design process that has led to the most current version of the prototype. Advancing existing wearable vibrotactile technologies, the prototype features easily repositionable motors, a graphical user interface that allows users to author their own vibrotactile composition, the capability to send vibrotactile compositions over the Internet or a local network, mass-broadcasting of patterns, and easy integration into a wide variety of existing garments and artefacts. It is also, to the best of my knowledge, the first vibrotactile wearable technology specifically designed to be used as part of a somatic learning experience by enhancing the human sensory capacity for tactile and proprioceptive discrimination.

To use Haplós as a somatic learning tool, it needs to be configured in specific ways and used with instructional guidance; precisely how to do this is the subject of Chapter 5.

Chapter 5: Configuring and using Haplós for vibrotactile somatic learning and aesthetic experience

5.1. Introduction

In Chapter 4, I described the evolution of the physical components of Haplós by elaborating on the first two of the three phases of the research process. These components were configured and used in a series of evaluative studies that comprise the third and final phase of this research. This phase commenced after the *Hack the Brain* hackathon, after which I returned to Plymouth University and set up a small prototyping lab (Figure 27) at the CogNovo workspace.

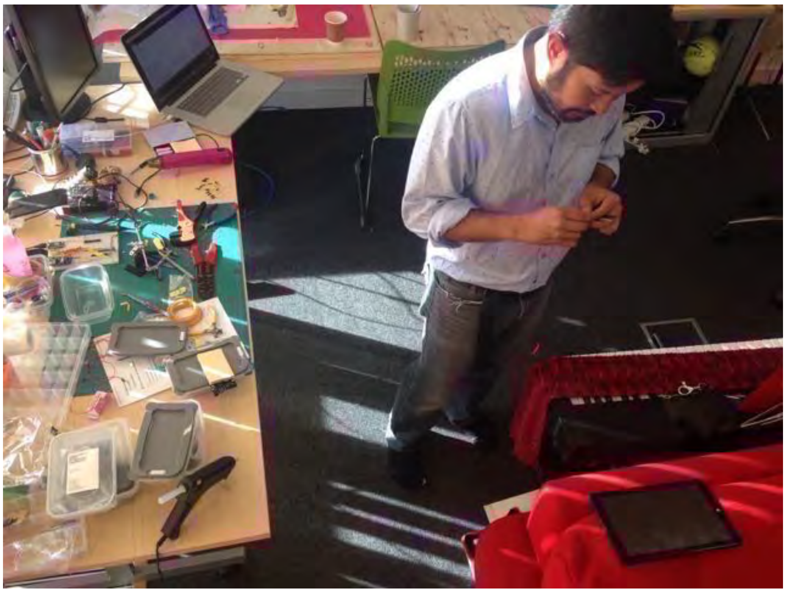

Figure 27: The author working at the prototyping lab in the CogNovo workspace.

At the prototyping lab, I prepared the Haplós prototype for the final two major studies of this research. The first study was the Manufactory workshop, while the second study involved participants experiencing Haplós at a demonstration I had set up for a public engagement event called Bizarre Bazaar. Both studies were part of Off the Lip 2016, a research festival organised by CogNovo and held on the 20th till the 22nd of October at Plymouth University.[56] I supplemented and prepared for these studies by continually conducting informal prototype trials. The protocols for these studies were designed based on what I call *vibrotactile somatic learning principles*. These principles in turn determine the Haplós *configuration, usage, and instructional schemes* and point to *somaesthetic "heuristics"* (Polya, 1988) to vibrotactile pattern design. Together, these principles, schemes, and heuristics form a *vibrotactile pragmatic somaesthetics*, which I define here as a prescriptive strategy for facilitating somatic knowledge as well as creating aesthetic experiences through vibrotactile stimuli.

In this chapter, I elaborate on vibrotactile somatic learning principles; the configuration, usage, and instructional schemes for Haplós; and somaesthetic heuristics for vibrotactile pattern design. I then recount the preparations, protocols, and outcomes of the informal prototype trials, the Manufactory workshop, and the Bizarre Bazaar demonstration. In addition, Haplós generated interest from other artists and scientists that were part of the CogNovo network and who were interested in applying Haplós to new research areas. I thus took advantage of opportunities to collaborate with these partners to explore and speculate on applications of Haplós that branch off from, and were conducted in parallel to, this research's main line of

[56] Information about Off the Lip 2016 website is http://otlip16.cognovo.eu.

inquiry on the use of vibrotactile stimuli to facilitate body awareness. I report on two such applications of Haplós after summarising the chapter.

5.2. Vibrotactile somatic learning principles and their application

The protocols for the Manufactory workshop and the Bizarre Bazaar demonstration were crafted around six related vibrotactile somatic learning principles that I have developed, which in turn were based on the FM conceptual framework and supported by neurophysiological research on vibrotactile stimuli. I list these six vibrotactile somatic learning principles below, along with references to the sections where the associated FM concepts and neurophysiological research are discussed:

- Bringing more parts of the user into their self-representation through vibrotactile stimuli (sections 3.3.1.2, 3.3.1.3, 3.3.2.1.1, and 4.5.2.1);
- Increasing the resolution of the self-representation through developing finely spaced distinction of vibrotactile cues (section 3.3.3.3);
- Making vibrotactile stimuli as perceptible, distinguishable, and comfortable as possible (sections 3.3.1.6 and 3.3.3.1);
- Providing opportunities for making distinctions in their somatic experience by leveraging bilateral symmetry (section 3.3.3.6);
- Facilitating the user's curiosity about how vibrotactile stimuli influence their bodily experience (section 3.3.3.2); and
- Engaging user's attention to their self-organisation before and after experiencing the vibrotactile stimuli (section 3.3.3.7).

The six vibrotactile somatic learning principles can be applied to a scheme for configuring and using Haplós and for providing instructional guidance for its use.

They can also be applied towards approaches for designing vibrotactile patterns. I unpack the substance of these six principles by discussing in detail both these applications in the following sections.

5.3. Haplós configuration, usage, and instructional schemes

The vibrotactile somatic learning principles can motivate configuration, usage, and instructional schemes for Haplós, which include the following:

- Placing motors particularly in areas that are poorly represented in self-representation
- Spacing motors closely
- Minimising postural tone before activating motors
- Deciding whether to position motors symmetrically
- Facilitating engagement through participatory pattern design
- Facilitating curiosity through verbal instructional guidance
- Comparing experiences before and after the vibrotactile experience

I discuss these schemes in this section.

5.3.1. Placing motors particularly in areas that are poorly represented in self-representation

Through the prototype trials I conducted, I realised that in order to bring more parts of the body into the user's self-representation, body areas that are poorly represented should have at least one motor assigned to them. For the purposes of the workshop and through my experience of testing Haplós, I assumed that the entire length of the thoracic area of the back was represented equally well in the cortical representation, and that the motors can thus be equally distributed. This appears to be a reasonable premise to make since tactile acuity is uniform across the torso except horizontally across the midline of the back (that is, across the spine) (Erp, 2005). I also chose to space the motors equidistantly because I postulated that if the users know that the motors are equidistant, they gain more information about the size of their back; the equidistant motors would function like a tactile measuring tape, in a manner of speaking.

5.3.2. Spacing motors closely

To increase the self-representation resolution of a given body area, I postulated that the motors should be spaced more closely together. For the studies that I ran, motors were spaced 2-3.5 cm from each other, based on testing the motors on my own back. This spacing is consistent with spatial discrimination studies, which shows that humans can distinguish vibrotactile stimuli when they are positioned no less than 2-3 cm from each other on the torso (Erp, 2005; Gallace & Spence, 2014, p. 22 footnote 6). I contend that the smaller the inter-motor spacing is, the finer the differences between which a user can discriminate (as discussed in section 3.3.3.3) and the greater the resolution that can be achieved in the somatosensory representation.

5.3.3. Minimizing postural tone before activating motors

To make the vibrotactile stimuli both comfortable and perceptible, the postural tone should be minimised and the motors kept as close to the body as possible, as discussed in sections 4.5.2.2 and 4.5.2.3, respectively. During the Manufactory workshop, participants explored different positions—sitting, standing, lying prone—in order to meet this goal.

5.3.4. Distributing motors symmetrically or asymmetrically

To provide opportunities for making distinctions in their somatic experience by leveraging bilateral symmetry, participants only experienced vibrotactile patterns on one side of their back during the Manufactory and Bizarre Bazaar studies. Ideally, if testing Haplós one-on-one with participants, I would work with them to determine which side to give the one-sided experience based on a number of factors, such as their handedness, which side of the torso was longer, which arm had more mobility, and their stated personal preference, much the way an FM practitioner would decide which side to focus on first when teaching a one-sided ATM or FI lesson. However, given the number of participants in the Manufactory workshop, a preliminary investigation of this kind would have taken up too much time and interfered with the flow of the study. Similarly, in the Bizarre Bazaar demonstration, the constant stream of participants was too rapid to permit such individual customisation. Thus, for both studies, I chose to place motors consistently on the left side.

5.3.5. Facilitating engagement through participatory pattern design

To facilitate the participants' curiosity about how they responded to the vibrotactile stimuli, I asked them to compose vibrotactile scores using the Haplós GUI, either for themselves or for someone else wearing the suit. Whenever possible, the participant wearing the Haplós suit was asked to keep still so that they could clearly experience the vibrations without disturbing their organisation of their hands, arms, and shoulders. I postulated that as participants used the GUI to experiment with composing patterns, they would also become increasingly familiar with the location of each motor and thus increase the perceptibility and distinguishability of the stimuli.

5.3.6. Facilitating curiosity through verbal instructional guidance

To facilitate the participants' curiosity about how they responded to the vibrotactile stimuli, I also gave verbal instructions, prompts, and questions to the participants to direct their attention to their experience, using the same careful use of language employed in FM instruction (section 3.3.3.2). For instance, I avoided asking participants to attend to their body and instead asked them to attend to themselves. While I did not point out my deliberate use of language to participants, it was notable that some participants would similarly avoid distinguishing between themselves and their bodies in the studies I conducted. For instance, whereas participant P22 could have said that she could feel her body after experiencing Haplós during one study, she talked about her*self* instead: "[I could] feel more of myself … I couldn't feel myself as much before." (#P22.161022.PublicDemo.a5)

5.3.7. Comparing experiences before and after the vibrotactile experience

To engage the participants' attention to their self-organisation before and after experiencing the vibrotactile stimuli, I asked participants to feel themselves in standing, walking, sitting, and lying down before and after playing the patterns. I also asked them to visually sketch their impression of how their back contacted the ground before and after experiencing the patterns, a method borrowed from similar activities in the FM training programme (section 3.3.3.6).

5.4. Somaesthetic heuristics for vibrotactile pattern design

In this section, I apply vibrotactile somatic learning principles described in section 5.2 to outline a novel set of heuristics for vibrotactile pattern design. Specifically I apply the FM strategies of introducing repetition, variation, and temporary use of complexity (section 3.3.3.4) in the patterns that I constructed for the studies described later in this chapter.

5.4.1. Arranging motors based on strength

To make the vibrotactile stimuli comfortable, and because of small differences in the vibration intensities across motors, I strove whenever possible to place the strongest motors towards the pelvis and the weaker motors towards the neck, so that the intensity of the motor is proportional to the amount of body mass the motor contacts. My intent was to keep the vibrotactile stimulation within the bounds of comfort (just like in FM, as previously discussed in section 3.3.3.3), otherwise the desired somatosensory cortical reorganisation would be lost (Tamburin et al., 2001).

5.4.2. Finding bounds for the duration of experience

To make the vibrotactile stimuli comfortable, I planned the duration of the total experience for each participant to last at most 45 minutes during the Manufactory workshop, and at most 15 minutes during the public engagement events. Based on personal experimentation with Haplós and the fact that FM lessons typically last around 45 minutes,[57] I estimated that these durations were sufficient for differences in the self-representation to be perceptible by the user, and not so long that user

[57] It is worth noting that Rosenkranz and Rothwell's proprioceptive training protocol, described in Chapter 4, lasts 30 minutes.

attention starts to fatigue or the experience of wearing the suit becomes uncomfortable. Hoggan points out that "stimulating an area of skin for an extended period of time can result in adaptation or even pain." (Hoggan, 2010, p. 35)[58]

5.4.3. Progressing from simple to complex

To make the vibrotactile stimuli perceptible and distinguishable from each other, I used the FM lesson structure of creating experiences that progressed from simple to more complex, as discussed in section 3.3.3.4. For the Manufactory workshop and Bizarre Bazaar demonstration, I devised three simple patterns of increasing complexity (as I explain in section 5.5.2.2) for participants to experience before moving on to substantially more complex patterns. For the Cravings experiment, I designed a 3-minute vibrotactile experience that progressed from simple patterns to substantially more complex ones, and then gradually returned to the initial simple patterns.

5.4.4. Multimodal mapping for tactile perceptibility

In addition, I postulated that the vibrotactile stimuli could be mapped to visual or auditory cues to make it easier for participants to perceive the relative positions of the motors. This strategy was inspired by previous findings in neurophysiological research that vibrotactile stimuli can be associated cross-modally with visual stimuli (Gallace & Spence, 2014, p. 64). Moreover, research on the

[58] Interestingly, during one informal prototype trial, a participant who experienced around three repetitions of the 3-minute Cravings study pattern reported feeling surprised that the vibratory sensations became "stronger" (#P47.160126.ProtoTrial.a5) over time even though nothing had really changed in the patterns. She experienced Haplós lying down, and it may have been the case that her postural tone diminished over the course of the trial and led to the perception of increased motor intensity.

rubber hand illusion (Barnsley et al., 2011; Botvinick & Cohen, 1998; van der Hoort, Guterstam, & Ehrsson, 2011) has shown that participants can form an astonishingly strong proprioceptive and interoceptive correspondence between tactile and visual cues if the cues are isomorphic (every tactile cue is mapped to a visual cue, and vice versa), varied and unpredictable, and simultaneously presented. These conditions can be met by Haplós and were used during the Manufactory workshop. In particular, the Haplós GUI provides a visual representation of which motors were being activated (Figure 28). While vibrotactile stimuli have previously been used to reorganise cortical representations of sensation and action (as discussed in section 5.4.4), the use of visual cues as a strategy for potentially strengthening the cortical reorganisation is a novel contribution and has not been reported in previous technologies for body awareness.

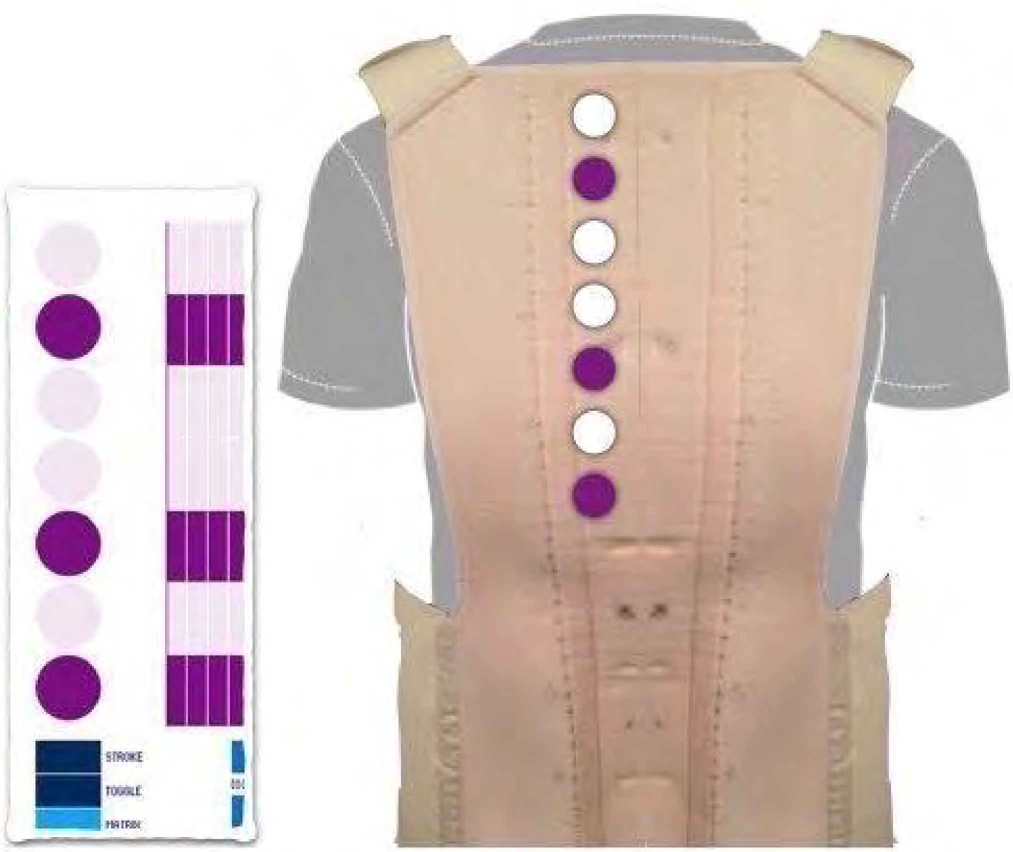

Figure 28: Visualisations of the motor activation shown on the GUI used in the Manufactory workshop and at the Bizarre Bazaar demonstration.

I also experimented with mapping each motor to a MIDI (Bryan-Kinns, 2004, p. p.7) piano note corresponding to a tone in a pentatonic scale. Low notes corresponded to motors lower down the back. A tactile-audio mapping is supported by existing research showing that tactile stimuli can be associated with auditory qualities such as pitches (Eitan & Rothschild, 2011). Moreover, "congruent [tactile and auditory] cues enhance meter recognition" and can be "integrated to produce coherent meter percepts." (Huang, Gamble, Sarnlertsophon, Wang, & Hsiao, 2013) However, the congruency is with respect to temporal and not spatial organisation of the cues, which is what I explored with my mappings. But from a design exploration perspective, I reasoned that these prior research findings provided sufficient warrant for me to pursue a sound-tactile mapping.

I note that while multimodal presentation of vibrotactile stimuli has been studied in the past, I deployed visual and audio information in direct service of facilitating vibrotactile pattern perceptibility, a departure from previous work done in vibrotactile composition, as reviewed in section 5.4.4, wherein tactile and auditory stimuli were considered independent elements of the experience that could be designed independently (Gunther & O'Modhrain, 2003, p. 11).

During the Manufactory workshop and at the Bizarre Bazaar demonstration, I asked the participants to watch the visuals as the vibrotactile patterns played across their back and to listen to the tones.[59] However, results from these studies suggested that the loudness of these piano notes should be minimal as they detract from the experience of the vibrations. In addition, because the motors have an audible pitch that is not entirely predictable and contingent on the way they contact the body (as

[59] The visualisations were hidden from the user during the Cravings study, for reasons that will be made clear shortly.

discussed in the previous section, 5.3), their pitch was not always consistent with their vertical order; e.g., the motors at the bottom of the line of motors did not always generate the lowest pitch.

5.4.5. Starting with the user's preferences

To make the stimulus perceptible, distinguishable, and comfortable, I worked with study participants whenever possible to establish a tempo that they found pleasant. This was done in the spirit of the FM principle of "meet[ing] the person where they are" (Field, 2010) and starting with what the participant would find easy, as discussed section 3.3.3.2. To do this, I would play a simple pattern at several different tempi and ask them which they preferred, thus tuning the prototype to their preferences. I found throughout the study that there was a range of preferences for tempi. In addition, during the Bizarre Bazaar demonstration, one participant suggested that their preference would also depend on whether they wanted their mood to be elevated or calmed, corresponding to a preference for faster or slower tempi, respectively. Once the tempo was established, the participant and I would explore new and more complex patterns together, co-creating them if there was opportunity.

5.4.6. Limiting the number of simultaneously activated motors and frequency of simultaneous motor activations

Finally, to make the stimulus distinguishable while designing vibrotactile patterns, I kept in mind that the number of simultaneous vibrotactile stimuli that a user can distinguish is limited by the degree to which the surface of that body area is cortically represented (Gallace & Spence, 2014, p. 75). I thus limited the number of simultaneous motor activations if the intent at a particular moment in the pattern was to highlight the distinguishability of each motor. This heuristic was applied even to the random generation of vibrotactile patterns available through the GUI (section 4.5.2.4.2). While this random pattern generator was meant as an exploratory tool for discovering new vibrotactile patterns, I constructed the randomisation algorithm so that highly clustered, simultaneously activated motors were unlikely to occur. Thus, even if participants from the Manufactory and Bizarre Bazaar studies decided to use this feature, the patterns generated would still likely allow the individual motors' activity to be distinguishable from each other.

5.5. Phase 3: Evaluating the Haplós system

The Haplós configuration, usage, and instructional schemes and somaesthetic heuristics for vibrotactile pattern design were applied in a series of studies that were introduced at the beginning of this chapter. These studies aimed to evaluate how well Haplós worked as a somatic learning aid. What do participants experience when using Haplós? And to what extent are their experiences somatic learning ones? These are the questions I take up in the studies discussed in this section.

5.5.1. Informal prototype trials

I conducted informal prototype trials with colleagues, friends, and on myself throughout the entire prototyping and evaluation process, including the period preceding and following the three studies described in this section. In summary, enjoyability, body awareness, and the sonic qualities of Haplós were three themes that emerged in the responses.

5.5.1.1. Enjoyability

Responses related to enjoyability were marked by positive descriptors in participant responses:

> *Yeah… yeah. That's very good, that one.* (#P34-55.160624.ProtoTrial.a5)
>
> *The feeling/sensation is nice, it's enjoyable, it feels quite relaxing. I'm enjoying it.* (#P43.170121.ProtoTrial-B.a5)

One participant, P51, was reluctant to take it off (#P51.170222.ProtoTrial.a5). Similarly, when participant P43 was invited to stop the motors and take off the suit when he was tired of the experience, he replied, "I don't think I can get tired of it [laughs]." (#P43.170121.ProtoTrial-B.a5) The novelty of the experience is likely to have played a role in their reluctance to take off the suit.

I have similarly found Haplós enjoyable. Moreover, through somatic introspection and examination, I have found the feeling of enjoyability to be located not just in the area to which the stimuli were applied, but also in adjacent areas. For instance, I have observed that after simulating my left shoulder, my left hand subsequently "felt good" (#P0.161006.ProtoTrial.a5).

5.5.1.2. Body awareness

Responses related to body awareness included one from a participant (P34) who noted that the experience of Haplós "doesn't feel like a massage, like a muscular thing that's working into you… It's more an awareness thing." (#P34-55.160624.ProtoTrial.a5) Another noted Haplós' ability to draw attention to areas of the body where attention is often absent:

> *It reminds me of when you're in a meditation class, and they ask you to pay attention to your toes [and other parts of your body]… it makes me aware of parts of my back that I normally wouldn't think about.* (#P49.170205.ProtoTrial.a5)

It is illuminating to expand on the experience of participant P43 (#P43.170121.ProtoTrial-B.a5) who—though he enjoyed the experience of the vibrations— seemed more circumspect about how he felt after I asked him to take the suit off, get up from a prone position, and then finally feel himself in standing and walking. He pointed to the area between his cervical spine and his thoracic spine and said that it felt "different," though he had difficulty describing how it felt different. He then remarked that his "spine feels crushed for years now," and the Haplós experience made him aware of how "out of shape his spine had become." I did not probe his experience further and at the time merely explained that it was not my intention to make him feel like his spine was out of shape. P43 was wearing a symmetrical, fourteen-motor version of the suit. Reflecting on this trial, I speculated that a one-sided pattern may have yielded better results for him as it might have created a difference in sensation across the midsagittal plane that could have yielded better learning outcomes. Improving a pupil's self-representation is more easily achieved if they are given an opportunity to clearly experience an alternative organisation, and a one-sided lesson is a particularly good way to provide such an experience.

5.5.1.3. Sonic qualities

One of the first things that many participants found surprising when trying out the Haplós prototype is that the motors have sonic qualities. Indeed, each motor has a particular sound, and its intensity and audible pitch are determined by a combination of the motor's mechanical properties and the pressure of the motor against the body (Gunther et al., 2002, pp. 5–6, 9). Indeed, Haplós' sound is a co-creation between the body and the technology. In *Acoustic Territories,* LaBelle (2010, p. xvi) asks, "Where do sounds come from and where do they go?" In Haplós, the mechanical energy of the motors is mediated by and travel through the body's cutaneous, subcutaneous, and interior structures (which both interface with the motors to co-create sound) as well as serve as the medium by which acoustic energy is propagated. However, because "sound is pervasive and is unconstrained" (Grant et al., 2014:6), the acoustic energy does not travel through the soft tissues of the body alone, but is also propagated through the air and is transmitted through the ear. As a result, the motors are inevitably felt *and* heard, as one participant in a prototype trial had reflected on:

> *It feels like when you smell and taste something. The taste is kind of unavoidably connected with smell. It's like touch and sound, in a way they can be … touch and sound are a vibration. It feels more like a balance between the sound and the feeling… That was the biggest kind of sensation, that it was part sound but very much feeling more vibration.*
> P43.170121.ProtoTrial-Bisensorial.a5

Moreover, anatomical location matters—a motor will sound and feel different when it is placed on, say, an easily palpable bony landmark such as the acromium process on the shoulder, as opposed to a fleshier region such as the middle of the thigh. As such, the sonic and tactile experience created by each motor evokes a diagnostic technique from medical clinical practice called *percussion*, where the clinician uses their fingers to tap the regions of the torso and which is "taught not only as a technique of listening or of touch only but both" (Harris, 2016).

In addition, Haplós patterns can have rhythmic qualities that result from my choice to use a sequencer as the primary "authoring metaphor" (Barfield, 2004) for the patterns.[60] Using the sequencer, a user can create multiple phrases of different tempi that can be combined to create longer, more complex pieces of vibrotactile

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[60] Because the choice of a sequencer as the authoring metaphor resulted in a particular kind of regular, rhythmic, vibrotactile patterns, exploring other authoring metaphors for vibrotactile compositions such as Western music score (Lee et al., 2009) or abstract token-based representations (Nam and Fels, 2016) could lead to altogether new sonic and felt vibrotactile experiences.

patterns. These patterns create a unique experience that prompted one participant in a prototype trial to call it a "techno-massage" (#P45.17017.ProtoTrial.a5) and another to observe that it "seems like an electronic tune but it feels like the notes are vibrating through my spinal column." (#P43.170121.ProtoTrial-B.a5) Notably, one participant remarked that it was "like using your whole body as an instrument" (#P49.170205.ProtoTrial.a5).[61] This last observation is reminiscent of soprano Marilla Homes' statement that the FM "is where you learn how to play the body". (Homes, 2016) Indeed, "the body's role as our primordial instrument or ur-medium has long been recognized," Shusterman observes, noting that "the basic somatic terms of 'organ' and 'organism' derive from the Greek word for tool, *organon*." (Shusterman, 2008, p. 4)

In one particular prototype trial, I paired Haplós with a low-frequency drone created by composer Sean Clarke. The drone was played at a low volume while the participant lay prone on a couch. While this low-frequency drone was not used in any of the studies that I describe in sections 5.5 and 5.7.1, I discuss the prospect of incorporating auditory stimulus with Haplós in the section on future directions for Haplós, 6.4. In section 5.7.2, I describe a version of Haplós that was paired with auditory stimulus.

5.5.2. Manufactory workshop

The Manufactory workshop was held as two independent 2-hour sessions on the evenings of the 20th and 21st of October 2016, respectively. Seven members of the public participated the first night, while only one participated on the second. To

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[61] The idea of the distinction (or blurring a distinction) between a musical and a somatic experience was first raised during the design critique at Kin (#P34-55.160624.ProtoTrial.a5).

prepare for the Manufactory workshop, I proceeded to refine the GUI and replicate the physical prototype to create four complete wearable systems (Figures 29 and 30).

Figure 29: Four complete Haplós physical prototypes being prepared, to be used with the five differently-sized back support braces pictured here.

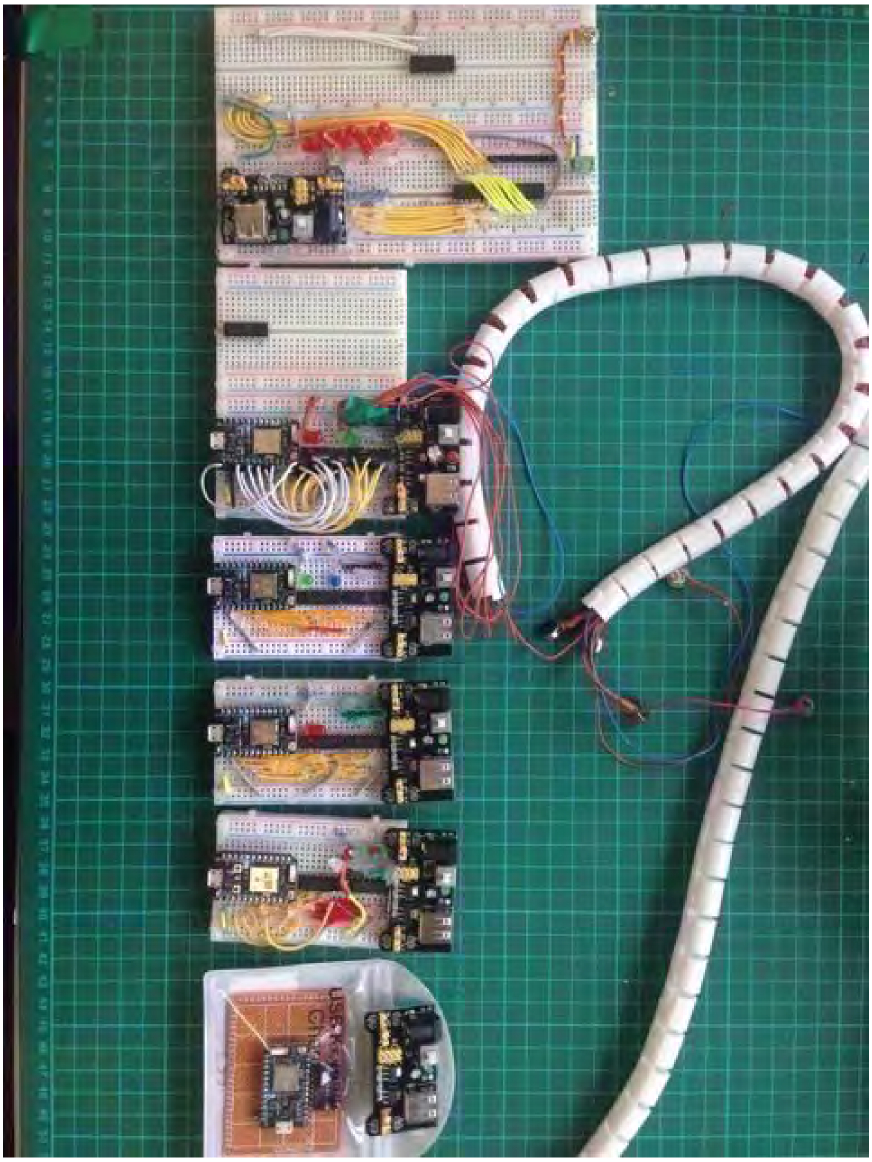

Figure 30: Haplós circuit boards. From top to bottom: the first version (missing a Photon microcontroller); four compact versions used in the Manufactory workshop; a smaller and lighter version still in development.

The workshop was held in a dance rehearsal studio at Plymouth University. Mats to lie on were prepared for participants. Four complete Haplós systems were provided, along with four Windows tablets on which the Haplós GUI was installed. A laptop running the GUI was used to mass-broadcast the three introductory patterns, which were projected onto a large screen. Figures 31 and 32 are photos taken from the 20th October session of the workshop.

Figure 31: The Manufactory workshop: participants putting on Haplós suits.

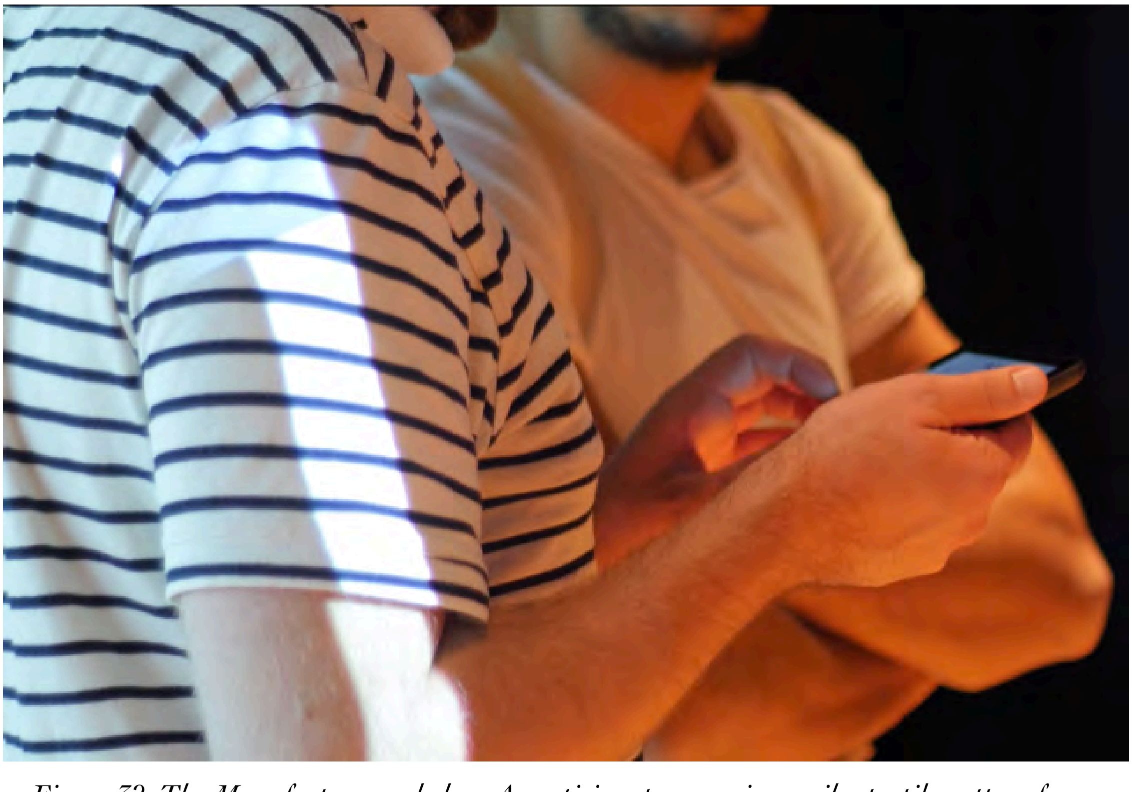

Figure 32: The Manufactory workshop: A participant composing a vibrotactile pattern for another wearing the Haplós suit.

In this section, I discuss three vibrotactile patterns I prepared in advance for the workshop, the workshop goals, the workshop activities, participants' reports of their somatic experiences, and the vibrotactile patterns that participants created for each other.

5.5.2.1. Workshop goals

The Manufactory workshop had two goals. The primary goal of the workshop was evaluative; it aimed to verify whether a one-sided vibrotactile pattern could create a perceptible difference in how participants experienced their body across the midsagittal plane, much in the way that a one-sided FM lesson might. The secondary goal was exploratory, and sought to uncover what kinds of vibrotactile patterns the participants would find enjoyable, which could then lead in the future to new design principles for vibrotactile patterns. Both workshop goals contribute to the larger research aim of evaluating user experiences of Haplós (section 1.2). In particular, they seek to address the two evaluative research questions: What are user experiences of the wearable technology that I have developed? Can Haplós facilitate somatic insight? If so, what kind of somatic insight? Answering these questions is the central objective of this section in particular and this chapter as a whole.

The workshop goals were not independent, however, and related to each other in a very specific way related to the use of deception in social science research. In particular, to meet the workshop's evaluative goal and avoid biasing the results, I used two strategies borrowed from experimental psychology. The first strategy involved withholding details of experimental aims. To this end, I did not fully disclose my intent to generate asymmetrical proprioceptive and tactile experiences nor give reasons for why there were only motors on one side. The second strategy was to provide an explanation for the activities being performed during the workshop. I thus told participants that the aim of the workshop was to explore the design of vibrotactile patterns, which, not entirely by coincidence, was precisely the secondary goal of the workshop.

5.5.2.2. The three introductory vibrotactile compositions

As described in section 5.4.3, I propose that experiencing vibrotactile patterns that progress from simple to the more complex is important in the vibrotactile somatic learning process. To this end, I composed three single-sided, seven-motor patterns of increasing complexity that I would play for workshop participants to introduce them to Haplós. Figure 33 chronologically shows the visual score for all three patterns, each of which was played individually two or three times before proceeding to the next one.[62]

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[62] The similarity of these phrases to piano exercises is not coincidental. As a classically trained pianist, I also drew inspiration from the Hanon's progressive exercises for the piano (Hanon, 1986), which are similarly predicated on developing piano-playing skill through increasingly complex exercises.

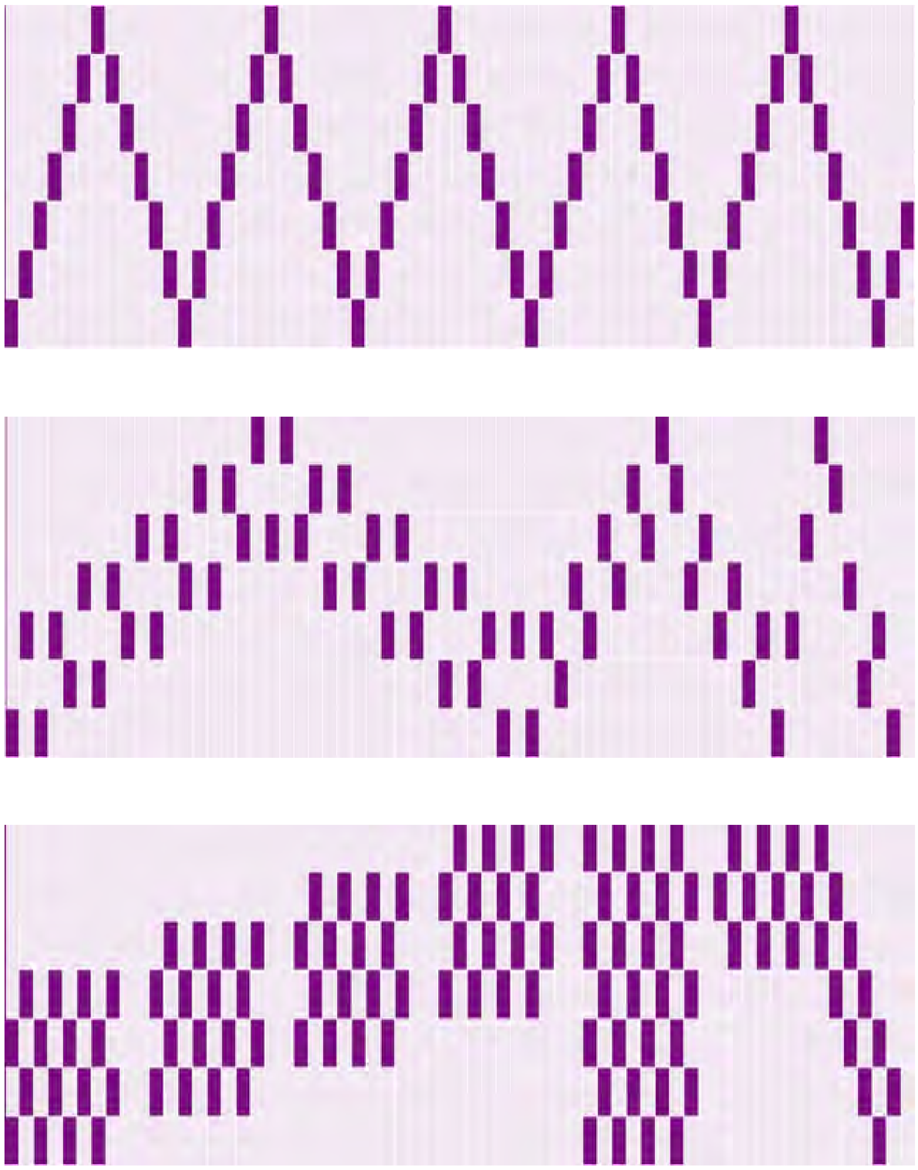

Figure 33: The three introductory vibrotactile patterns used in the Manufactory workshop. These were also used in the Bizarre Bazaar demonstration. From top to bottom: patterns 1, 2, and 3.

To frame the discussion of the vibrotactile design process, I borrow terminology from Western music theory (Schmidt-Jones, 2013). Pattern 1 is a simple stepwise scale going up and down the spine. Patterns 2 and 3 resemble what in Western music might be seen as studies in "thirds," wherein two notes separated by a note in between are played in succession (pattern 2) or simultaneously (pattern 3).

All three patterns exhibit varying degrees of predictability. By this, I mean the degree to which I expected participants to anticipate which motors would next be activated, even if the visual scores were hidden from them. (The scores were visible to the workshop participants for reasons described in section 5.4.4.) Pattern 1 is particularly predictable, and I contend that it would be reasonable to assume that halfway through the playback of its score, a participant would be able to anticipate the rest of the "melody." I estimate that patterns 2 and 3 have about the same predictability, which would be less than that of pattern 1. They also share a common structure, consisting of short repeated phrases that start from the bottom of the thoracic spine and then are translated upwards towards the head in a stepwise manner before descending again.

However, pattern 3 plays simultaneous vibrotactile notes, making it more difficult to distinguish and attend to each individual motor than in the other two patterns. It is because of the potential reduction in motor distinguishability that I chose to repeat each phrase within the melody four times in pattern 3, as opposed to only twice in pattern 2. I also added two beats of silence in between the phrases in pattern 3 for three reasons: to prevent habituation to the stimuli; to prevent discomfort from the amount of stimulation; and to allow users more time to integrate the more complex tactile information. I also took the opportunity in pattern 3 to activate up to four motors at a time to probe participant opinions on how they responded to multiple simultaneously activated motors.

5.5.2.3. Workshop activities

The following activities were conducted during the workshop, in sequence:63

1) **Welcome and introduction.** Participants were welcomed and given an overview of the workshop. Participants were told that they were going to explore making vibrotactile music.
2) **Self-scanning.** Building on the knowledge I gained through the FM training programme, I asked participants to lie on their backs and then guided them through an FM-style scan. Participants were instructed to attend to the contact that their entire body made on the floor. I systematically went through the different areas of their anatomy and asked them to attend to any differences in sensations between their left and right sides.
3) **Drawing the self-scan.** Participants were asked to sketch out on a blank piece of paper how they sensed their contact on the ground. I asked the participants to imagine that they had ink smeared across their dorsal areas and that they were thus making an imprint on the ground—an imagery exercise I borrowed from an ATM lesson by Frank Wildman (2006b).
4) **Pairing up and putting on the suits.** Participants paired up so that one participant put on the suit while the other provided assistance. Participants not wearing a suit were asked to simply observe until step 8 in this sequence.
5) **Broadcasting the three introductory vibrotactile patterns.** I broadcasted the three introductory patterns to all the Haplós systems being used. Patterns were initially played to participants at about 0.7 seconds per note, or about 86 beats per minute (BPM).

[63] The 21st October session was conducted along similar lines, despite the fact that it was attended by only one participant.

6) **Finding a comfortable position**. While the patterns were playing, I asked participants to explore the room and use whatever furniture was available to find a position that was comfortable and made the patterns feel the clearest. Some chose to sit in a chair while wearing the suit, as they judged that position to be most comfortable and rendered the vibrations most clearly. Others elected to remain standing.

7) **Experimenting with tempi**. After the suit-wearing participants had found a comfortable position, I experimented freely with trying slower or faster tempi to demonstrate tempo possibilities to users, as well as probe for participant tempo preferences.

8) **Composing patterns for each other.** The participants returned to their pairings, and I asked the unsuited participant of each pair to compose a pattern for their workshop partner. The suited participant guided their workshop partner throughout the process and made their pattern preferences known to their workshop partner. Pairs were given around ten minutes to complete this activity. In addition to giving the unsuited participant something to do while their workshop partner was wearing the Haplós, their role as composer ensured that suited participants did not use their arms and hands as much and consequently disturb the organisation of their torsos, as explained in section 5.3.3.

9) **Sharing**. We convened as a group and shared each other's patterns, noting interesting differences and similarities between them.

10) **Self-scan and redrawing.** Suited participants removed their suits. All participants were asked to return to their mats, lie on their backs again, and attend to their contact on the floor, as in step 2. Afterwards, I asked the

previously suited participants to draw another sketch of how they sensed their contact on the mats, much like in step 3.

1) **Reversing roles**. Activities 4-10 were repeated with the roles reversed.
2) **Verbal feedback and debrief**. We convened as a group and I invited participant feedback on their experience of the workshop, after which I revealed the evaluative goal.

The results of the workshop indicate that in general, Haplós can change not only participants' perception of their tactile contact with the floor but also their awareness of areas of their body that were exposed to the vibrotactile stimuli. In addition, different pattern design strategies emerged which reflected participants' preferences for how patterns of vibrotactile stimuli could be designed. I take up these results in this section.

5.5.2.4. Somatic experiences

Figures 34 to 41 presents all participants' sketches of how they felt their contact with the floor as well as any written and verbal feedback they provided.[64] Half of the participants drew their impressions of their contact with the floor as if they were looking down from above at their bodies' ink blot, while the rest drew a representation of their body as if they were looking at themselves from behind and then marked the places where they felt contact. Because of this difference, sketches by participants whose codes are marked with an asterisk are presented here in mirror image, so that handedness of each sketch is consistent. Participant responses and sketches are referenced in Appendix 5.

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[64] For table layout purposes, I will only cite the participant code in the table; the full citation has been referenced in Appendix 5.

Three themes that emerged from the sketches and the written and verbal feedback were (1) asymmetry in sensations of contact with the floor and in bodily awareness; (2) lingering sensations; and (3) feeling relaxed. I discuss these themes in the remainder of this section.

Asymmetry in sensations of contact with the floor and in bodily awareness. Figures 34 to 38 demonstrate that participants P09, P10, P12, P14, and P21 experienced increased awareness of—or felt more contact with the ground on—their left side.

P09

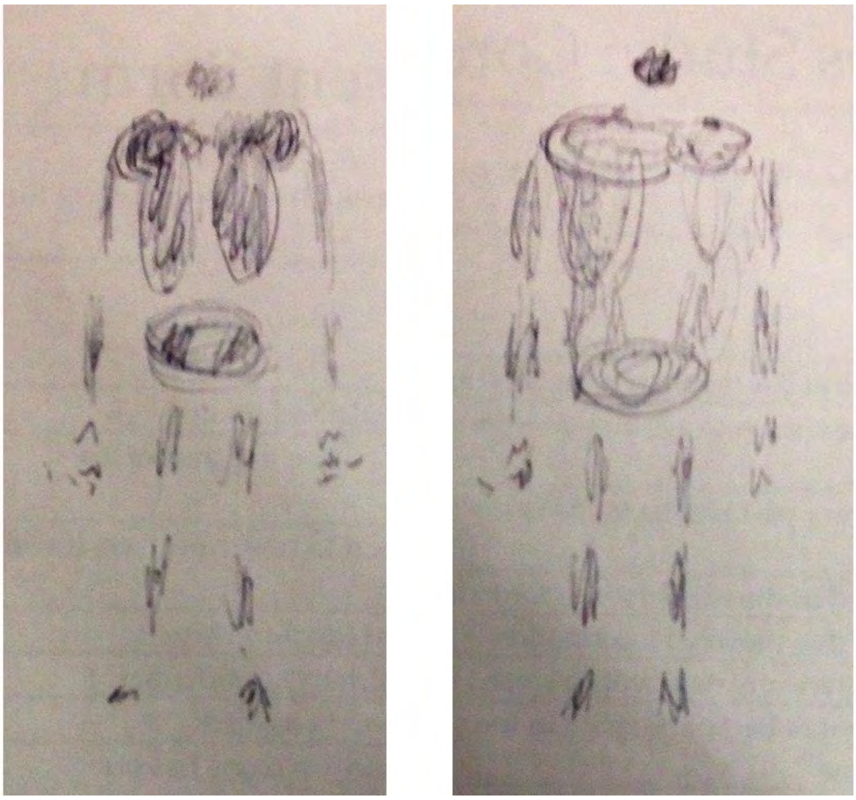


Figure 34: Participant P09's impression of their contact with the ground.

P10*

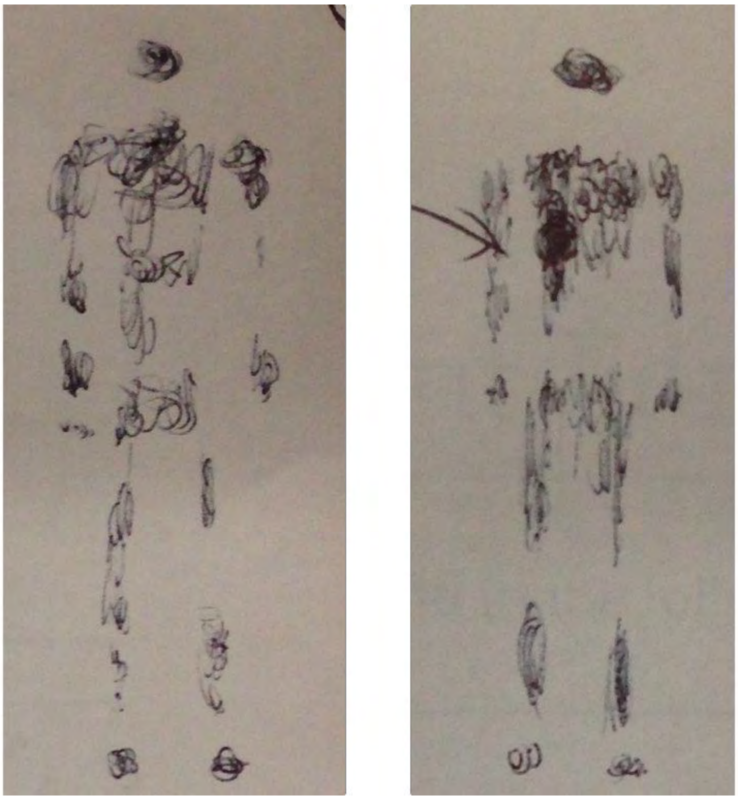


Figure 35: Participant P10's impression of their contact with the ground.

P12*

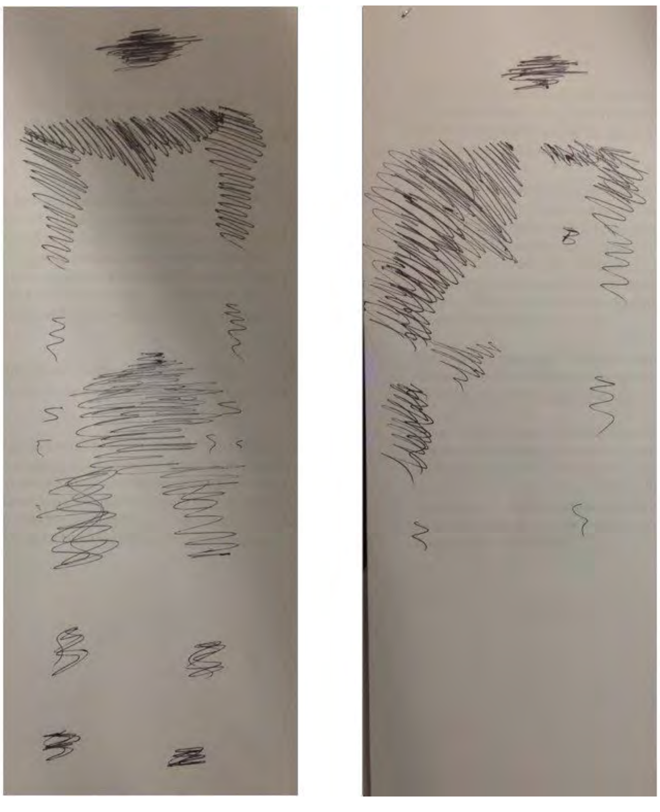


Figure 36: Participant P12's impression of their contact with the ground.

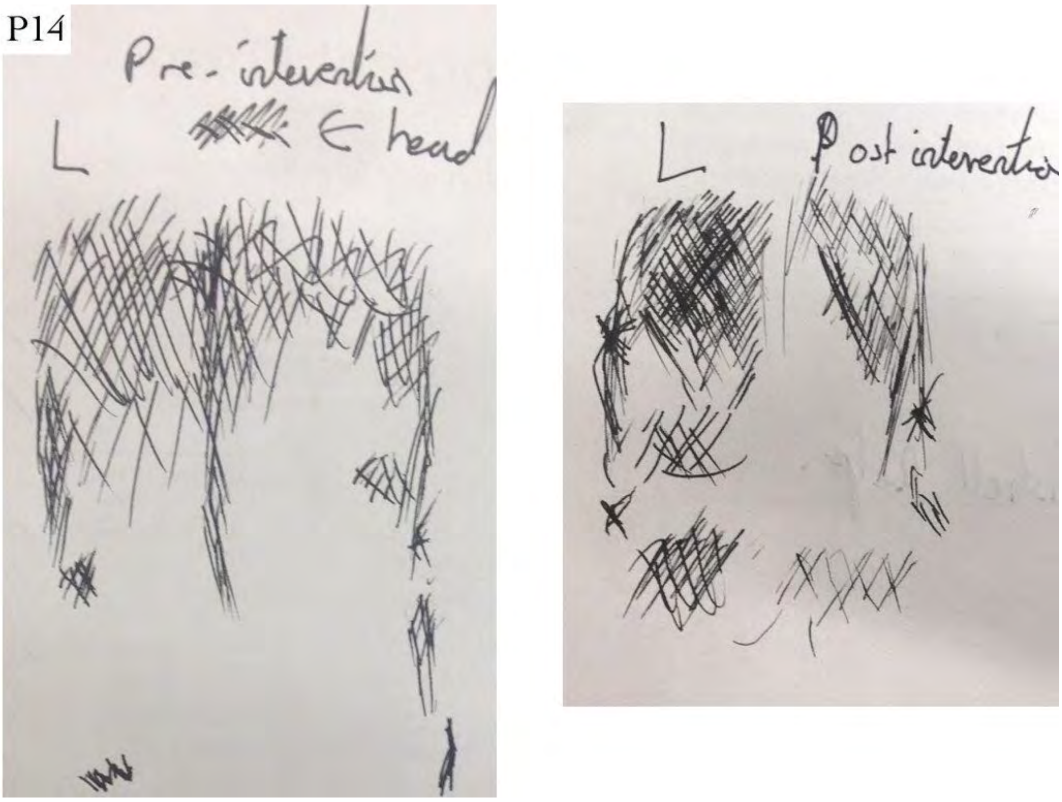


Figure 37: Participant P14's impression of their contact with the ground.

P21

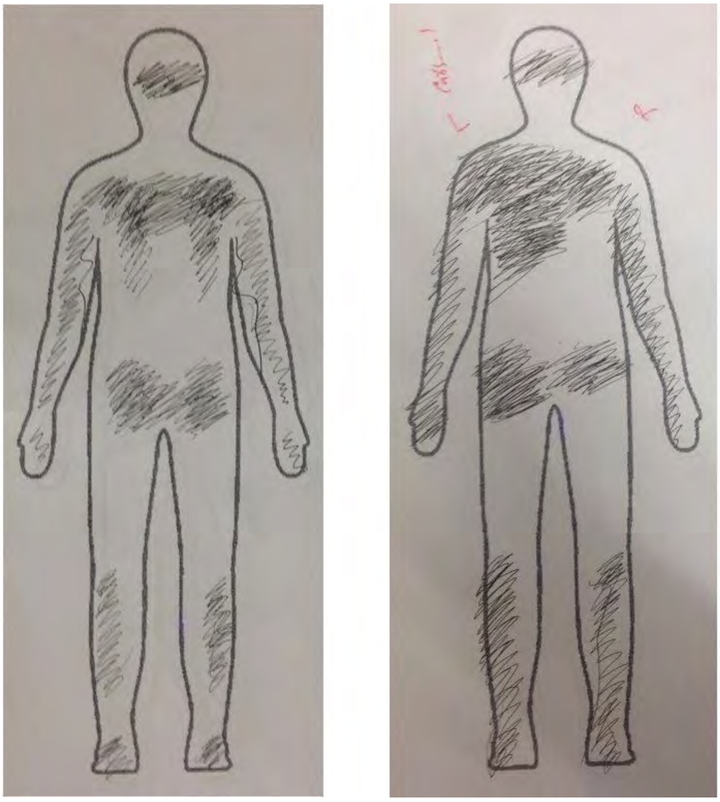


Figure 38: Participant P21's impression of their contact with the ground.

My analysis of these sketches are further supported by participants' written and verbal feedback:

> *Definitely felt more sensation/awareness of this particular spot… I just notice my back a lot more from doing that* (#P10.161020.Manufactory1.a5)
>
> *Was slightly more aware of my left side than i was beforehand... i was more sensitive to its location and which parts were making contact with the floor. so if anything, the resolution with which i can feel my back increased. i feel like i have a sharper image.* (#P14.161020.Manufactory1.a5)

Participant P14's choice of words is particularly notable because it addresses, to an exceptional degree, my goal of using Haplós to increase the resolution of the self-representation.

When I interviewed the lone participant (P21) of the second evening's workshop after experiencing the suit, she noted that her arms felt "interesting," and gestured in a way to indicate that her left arm and hand was more outwardly rotated. Her sketch—the seventh in the table—correspondingly shows that she felt more contact towards the outer edges of her upper arm and forearm. She also motioned with her arms and shoulders in a way that indicated that she felt her chest and collarbone area to be wider and her shoulder blades more retracted. Indeed, her physical demonstration of what she had experienced is reminiscent of the proprioceptive Eureka moment with which I introduced this thesis. This is consistent with her sketch which correspondingly shows more contact with the floor in the region around her left deltoid.

The sketch by participant P11 (Figure 39) shows her impression of her contact with the ground at different scales; the first drawing (representing her contact with the ground before experiencing Haplós) shows the entire body, whereas the second focuses on her shoulder alone. Her written feedback makes her experience explicit and clarifies the intent behind her drawing:

My back feels more engaged with the ground. feels like it has more sensation on the left side. (#P11.161020.Manufactory1.a5)

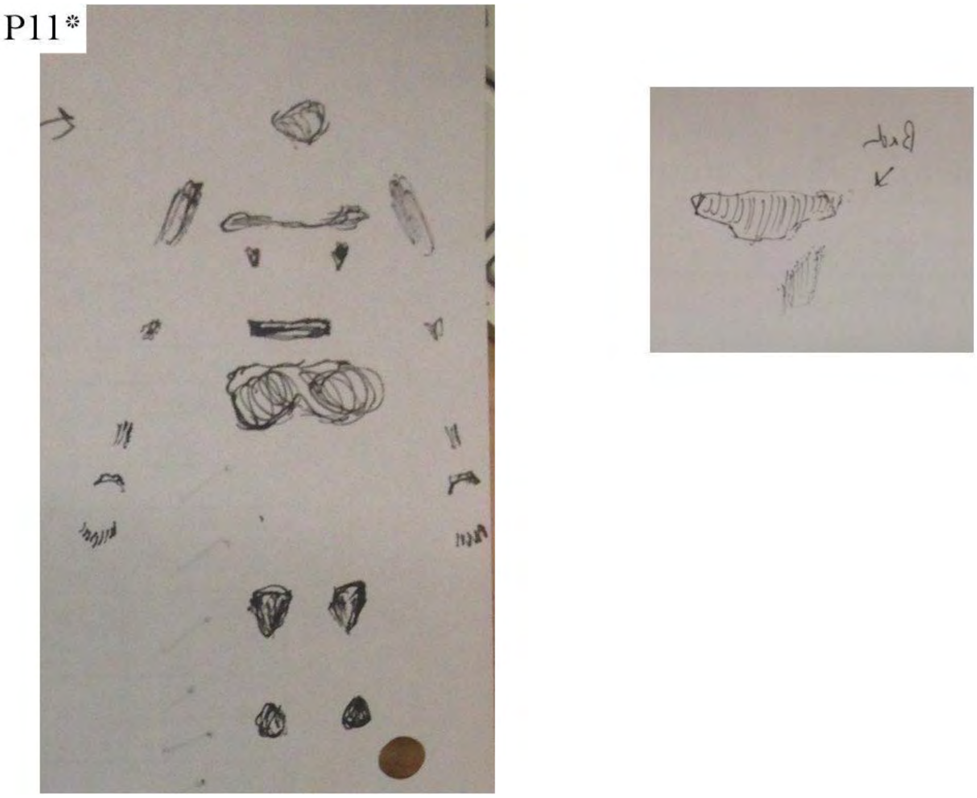


Figure 39: Participant P11's impression of their contact with the ground.

The sketch by participant P15 (Figure 40) is somewhat ambiguous; what can be said is that whereas in the first sketch she drew her arms as being composed of two separate parts (perhaps an upper arm and forearm, or as arm and hand), her second sketch shows her left arm as a whole entity, although drawn somewhat shorter than the right arm. In addition, whereas the right side of the torso tapers strongly towards the waist, the left side tapers more gradually and to a lesser degree. I suggest, as a reasonable explanation for this drawing, that she felt more contact along her back and arm on the left side.

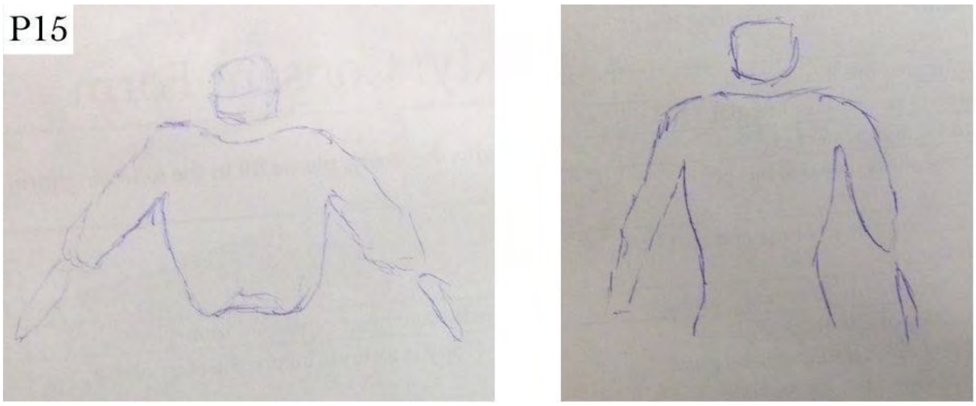


Figure 40: Participant P15's impression of their contact with the ground.

Lingering sensations. The sketch made by participant P13 in Figure 41 shows little to no difference in her perception of her contact with the ground after wearing the Haplós suit. However, she did report an echo of the vibration after she had taken off the suit and even after she spent some time on the floor lying on her back, as did participant P14 when I asked the group if they felt anything in their left hand after taking off the suit.

> *I didn't feel any 'differences' … i can still feel the sensation of the motors on the LH side of my spine though (a tingling sensation)* (P13.161020.Manufactory1.a5)

> *[Left hand feels] tingly* (#P14.161020.Manufactory1.a5)

Participant's P14 report is interesting in that it echoes my own experiences of sensing something interesting and enjoyable in my left hand during prototype trials of Haplós (#P0.161006.ProtoTrial.a5).

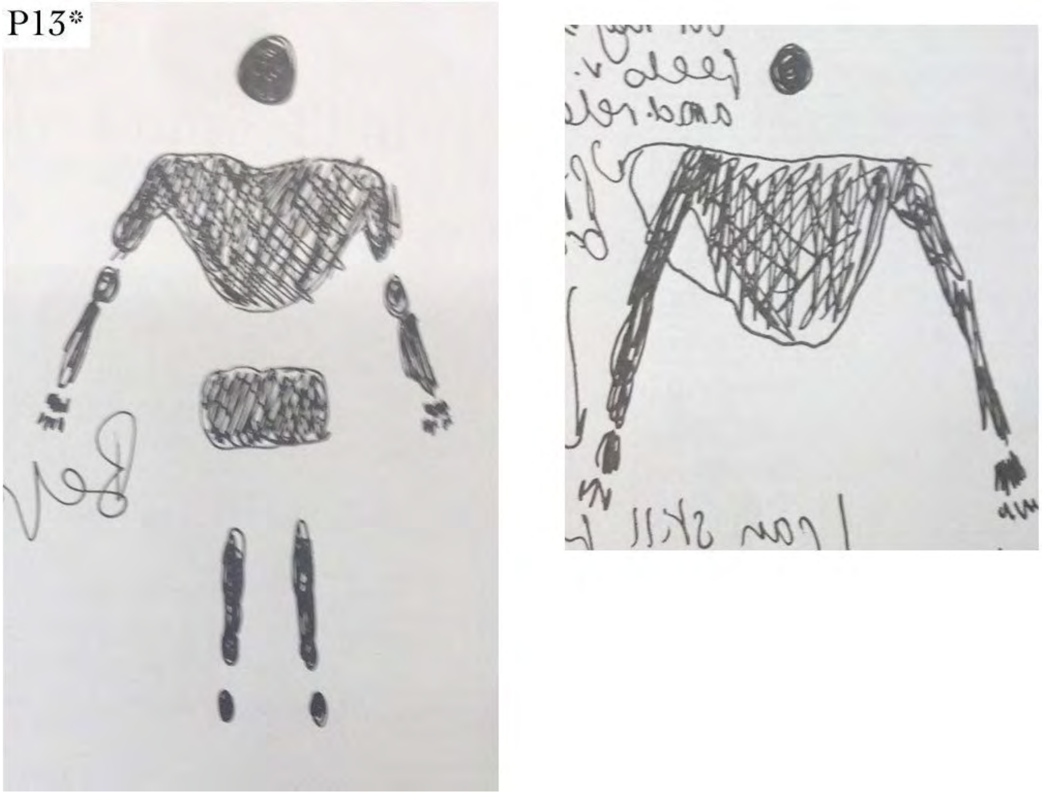


Figure 41: Participant P13's impression of their contact with the ground.

Feeling relaxed. Participant P12 stated at the end of the workshop that she felt "relaxed" (#P12.161020.Manufactory1.a5) while participant P13 noted that her "back feels v. 'alive' and relaxed." (#P13.161020.Manufactory1.a5) The use of the word "alive" is notable, and while I did not get a chance to probe what she meant by this, I submit that feeling a part of yourself as more alive is related to having an increased awareness of that part of yourself and its connection to the rest of yourself, based not only on my experience of feeling a part of myself come alive through FM practice, or the experiences of fellow students who reported on their somatic experiences during the FM training programme, but also on what other FM practitioners have articulated about the experiences that FM can generate. For instance, Wildman (2006b) links an expanded body awareness with "aliveness." (p. 7) Krausneker and Blaschke note that in FM-based workshops that they have led, participants have reported “a quality of being connected, a sensation of feeling alive and authentic in each action” (Krausneker & Blaschke, 2012).

5.5.2.5. Pattern preferences

Table 4 shows the scores for some of the patterns that were designed by unsuited partners to meet the preferences of the suited participants.[66]

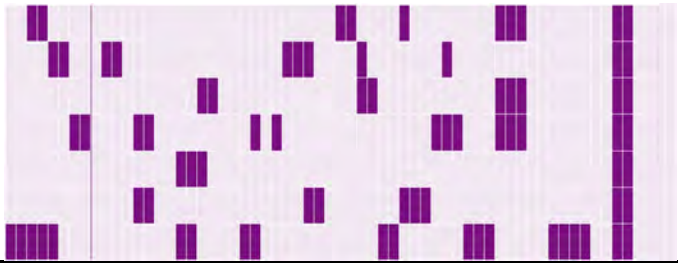
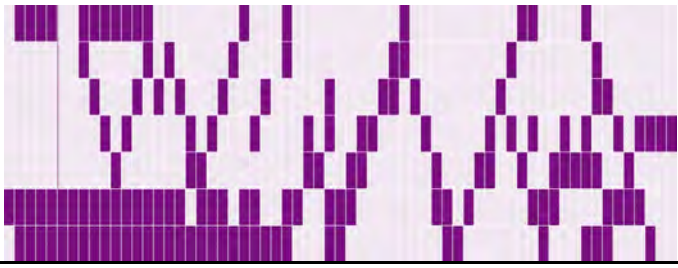
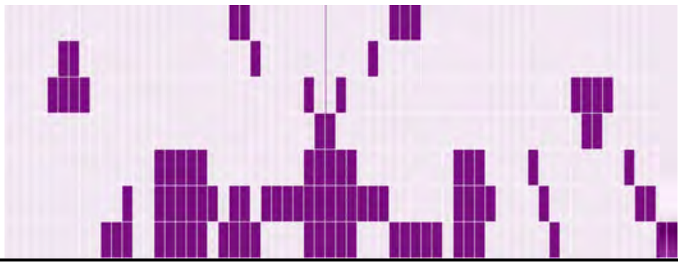
Participant code	Vibrotactile score created for them
P10	
P12	
P14	
P21[67]	

Table 4: Example scores of vibrotactile pattern created for workshop participants

[66] Because there was an odd number of participants, I partnered with participant P12 and designed her preferred vibrotactile pattern. I note as well that unfortunately, I was not able to record the speed at which the patterns were played for later analysis. This will remedied in future implementations and studies of Haplós.

[67] Because participant P21 was the sole participant in her workshop, she composed her own vibrotactile pattern.

Although participants only had a maximum of ten minutes to compose a score for each other, and had not (to the best of my knowledge) created or experienced vibrotactile patterns in the past, their patterns nevertheless suggest that a wide range of vibrotactile pattern "styles" are possible and can be crafted based on individual tactile preferences and sensibilities. For instance, participant P10 enjoyed experiencing single, point-like, focused vibrotactile notes, whereas participant P12 enjoyed densely clustered vibrotactile textures; these can be seen in the scores that were composed for them by their workshops partners. Indeed, during the workshop, when P10 first experienced all seven motors on, a delighted smile lit her face. The score for participant P21 is notable in its use of silences, as was the score for P10. The predominance of "bass notes" (so to speak) in the score for both participant P14 and P21 indicate that these participants enjoyed vibrations in areas closer towards the lumbar spine. This is unsurprising particularly in light of reports by participants from another study (which I discuss in section 5.7.1.3.3) who indicated their enjoyment of the motors located in precisely those areas.

A visual examination of the score for P14's pattern clearly illustrates that his partner used the introductory vibrotactile pattern I presented as a starting point for creating the pattern. P14's workshop partner found it difficult to create the score that he wanted because he found the tablet screen was small; he also had difficulty activating and deactivating the precise slots that he wanted. I return to GUI usability considerations in section 6.4.1.

5.5.3. Bizarre Bazaar demonstration

The Manufactory workshop results provided support for my claim that the Haplós system could be used to facilitate somatic insight. However, the workshop was conducted in the quiet, controlled environment of a dance studio, where each participant had 45 minutes to attend to their experience, explore different vibrotactile patterns and different postural organisations, and lie down. The Bizarre Bazaar event on the 22nd of October, 2016, was held in a large atrium of a building in Plymouth University and populated by other booths. At its peak, it was a noisy, bustling event with music performances occasionally being conducted in the midst of the booths. I set up a demonstration table for Haplós (Figure 42) to see how well vibrotactile-facilitated somatic experiences could be developed in stimulus-rich, social environment—that is, in a situation that might resemble everyday urban life. In addition, because of the number of people who wished to try the Haplós system, I explored how much of the Manufactory experience could be replicated with no more than 15 minutes per participant—one-third of the time that participants had at Manufactory.

Figure 42: The Haplós demonstration table at Bizarre Bazaar.

I evolved throughout the day an abbreviated version of the protocol from Manufactory, involving the following activities conducted in the order listed:

1) **Self-scanning (seated or lying down).** I set up a small secluded space behind the demonstration booth where participants could lie down on a mat. I led participants through a short self scan, focusing on their torso, arms, and head. However, I also experimented with asking a few of the participants *not* to lie down on the mat and to instead remain seated. I then led a self-scan in sitting. I did so because during the course of everyday activity, users may not always get a chance to lie down and feel themselves in lying down.

2) **Drawing the self-scan**. Participants drew a representation of how they felt themselves on the mat, just like at the Manufactory workshop. However, I adjusted the method for this activity; based on a suggestion from one of the participants, I preprinted outlines of the human form which the user could shade in. This provided a standard frame of reference from which I could more reliably compare users' visualisations of their somatic experiences. In addition, because participants who performed their self-scan in sitting did not have their back in contact with a horizontal surface, I asked them to instead draw a visual representation (still using the pre-printed form as a template) of the sensations they could feel on their torso, arms, neck, and head without reference to contact with a surface.

3) **Playing the introductory patterns.** Participants then put on the suit and sat in a chair while I played each of the three introductory vibrotactile patterns. Figure 43 shows a participant experiencing one of the patterns.

4) **Co-creating a customised vibrotactile pattern.** I briefly explored co-creating a pattern with a user based on their preferences. A notable exception was when two strangers each put on a suit and collaborated on making patterns together, shown in Figure 44.

5) **Removing the suit and self-scanning**. If participants did the self-scan lying down, then they performed the second scan the same way; the same was true for participants who scanned themselves while sitting down.

6) **Redrawing the self-scan**. As in activity 2, participants were asked to draw a representation of their contact with mat.

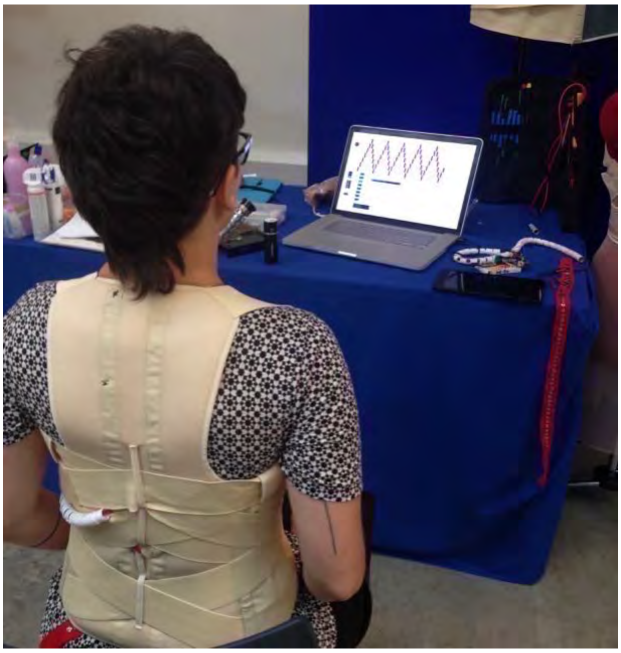


Figure 43: A participant trying on Haplós at Bizarre Bazaar.

Figure 44: Two participants co-creating patterns and experiencing them simultaneously.

I did not always carry out all the activities because visitor interest was fairly high throughout the day, and so I often was only able to give brief demonstrations in the interest of being able to provide an experience of Haplós to as many people as possible. When I was able to conduct all six activities with a user, I collected sketches of their impressions.

5.5.3.1. Somatic experiences

I present six participants' sketches in this section. In general, they reflect participant experiences from the Manufactory workshop and themes of asymmetry in sensations, bodily awareness, and lingering sensations.

Participants P22, P23, P24, and P27 performed their self-scans lying on a mat. Figures 45 to 48 are their impressions of their contact with the mat before and after wearing Haplós.

P22

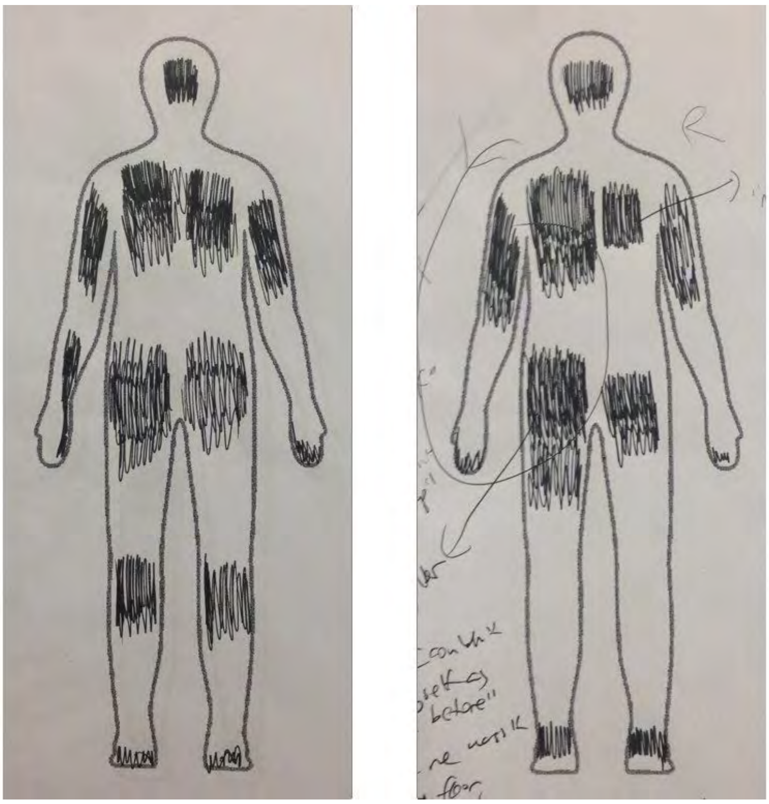


Figure 45: Participant P22's impression of their contact with the ground.

P23

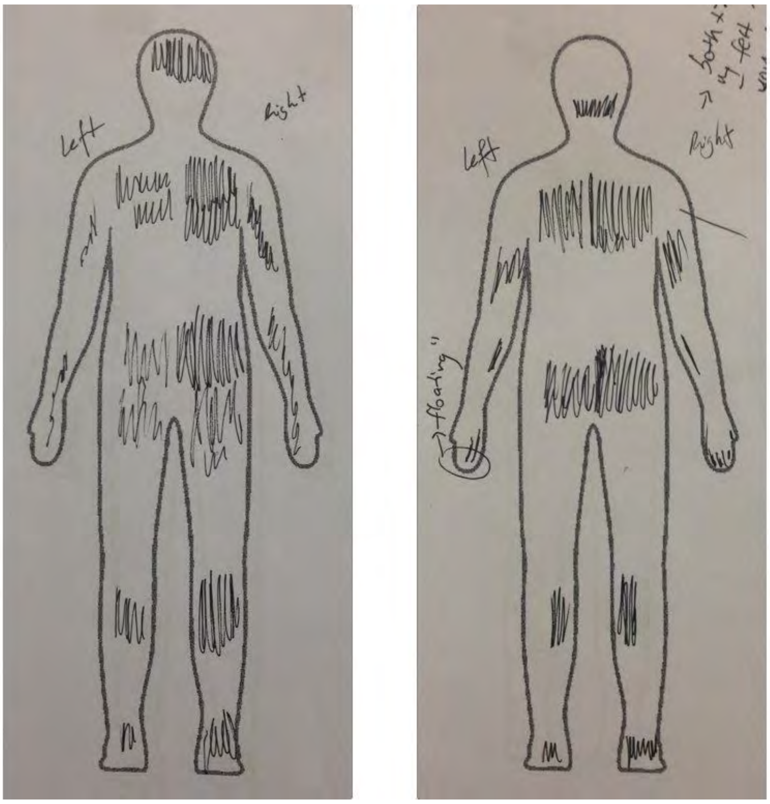


Figure 46: Participant P23's impression of their contact with the ground.

P24*

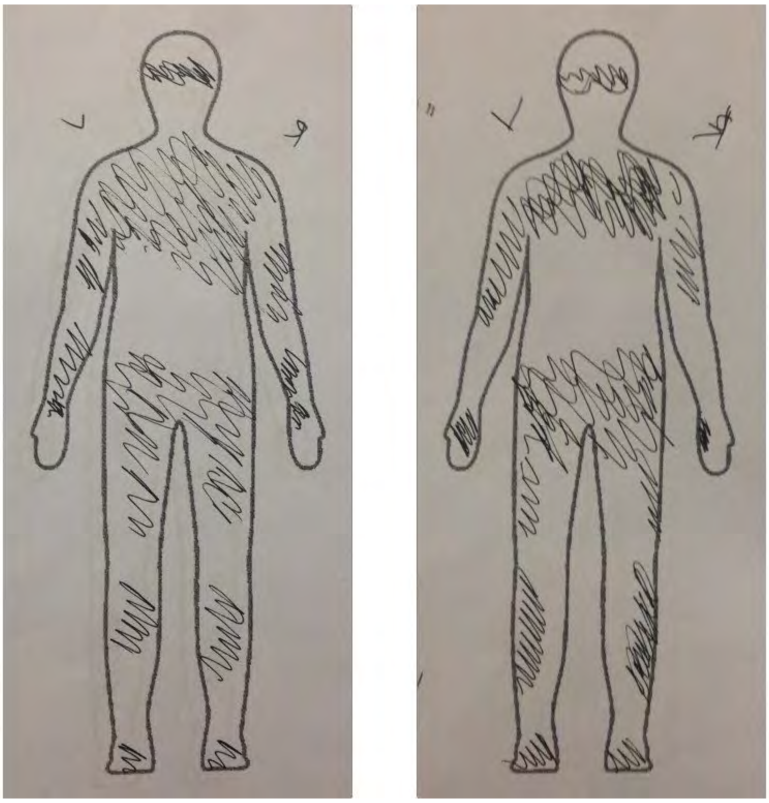


Figure 47: Participant P24's impression of their contact with the ground.

P27*

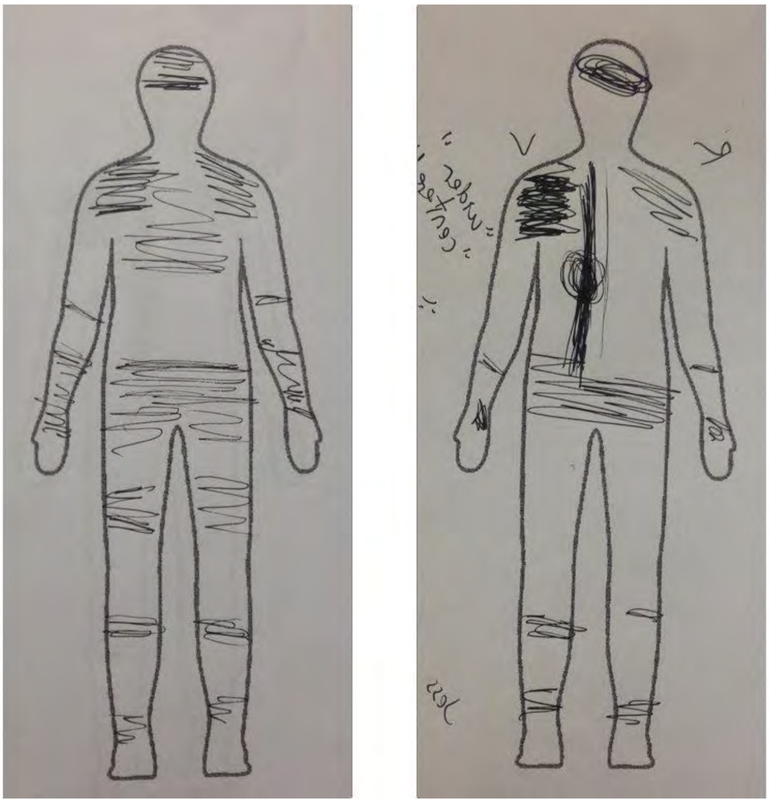


Figure 48: Participant P27's impression of their contact with the ground.

Participant P22's sketch clearly shows a difference in the symmetry of sensations before and after the Haplós experience. Interestingly, her sketch also shows an increase in sensation in the fingertips of her left hand; there is also the disappearance of sensation around the calves but an increase in sensation around the Achilles tendons. In addition, after the second self-scan, she made an interesting distinction between awareness of a part of herself through contact with the ground and awareness despite the absence of contact:

> *Even though part of me wasn't touching the floor I could still feel that there was something there.* (#P22.161022.PublicDemo.a5)

She also described feeling more of herself, a phenomenon that recalls the FM aims:

> *Feel more of myself … I couldn't feel myself as much before.* (#P22.161022.PublicDemo.a5)

Participant P27's sketch (Figure 48) shows a similar increase in awareness of areas of her left side. She noted that she also felt "wider" and "centred" (P27.161022.PublicDemo.a5) after experiencing the vibrations.

Participant P23 is notable in that unlike other participants, she already felt an asymmetry in her contact with the ground before wearing the Haplós suit, as reflected in her drawing (Figure 46) and she observed that she felt that her right side "was touching the ground more." (P23.161022.PublicDemo.a5) However, after experiencing the vibrotactile patterns, her sketch indicates an increase in sensations on her left side and, consequently, more symmetry in her sensations of her back. In contrast, participant P24 did not report any changes related to the symmetry of her ability to sense herself on the ground, as shown in her sketch (Figure 47), much like participant P13 from the Manufactory workshop.

However, P24 did report feeling "lighter" (#P24.161022.PublicDemo.a5) after the vibrations. Participant P22 also reported feeling lighter (#P22.161022.PublicDemo.a5), while participant P23 noted that her left fingers felt like they were "floating" (#P23.161022.PublicDemo.a5). Interestingly, during the Manufactory workshop, the theme of lightness did not appear in participant responses; neither did any mention of changes in the sensations of the left fingers (except for P14's report of feeling a tingly sensation in his hand). I speculate that this might be explained by the fact that during Bizarre Bazaar, I was able to control participants' movement and gestures more; I asked them to sit still and not use their hands while experiencing Haplós. On the other hand, in the Manufactory workshop, I chose to allow the workshop partners to interact with each other and the equipment more freely.

Participant P25 reported an experience contradictory to the trend thus far of Haplós facilitating more sensation on the left side. P25's sketch (Figure 49) shows that she felt *less* sensation on her left side after experiencing the vibrations. Indeed, her left shoulder was "almost not touching the ground" (#P25.161022.PublicDemo.a5) after experiencing Haplós. It is possible that the motors triggered a tonic vibration reflex (previously discussed in section 2.4) in that area, which might have resulted in contraction of surrounding muscles that did return to their pre-stimulation length by the time the participant returned to their mat. This, however, is speculation. The effects on the self-representation of vibrotactile stimuli are complex and somewhat difficult to control; I thus submit that it is unsurprising to find a case such as hers. Nevertheless, that the prototype created an asymmetry in her experience is still notable. In addition, her sketch shows an interesting increase of sensations in both hands.

P25

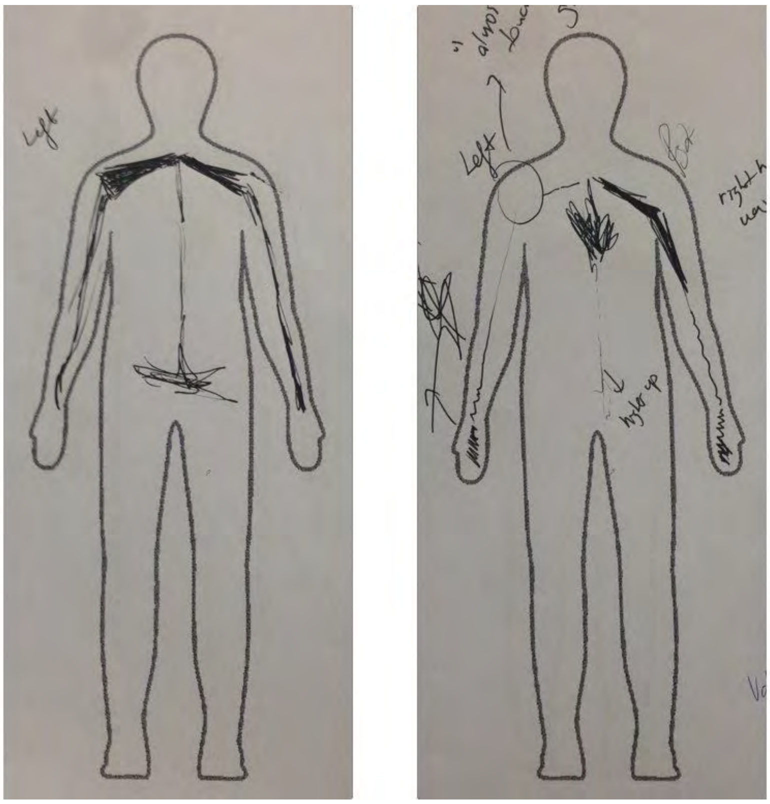


Figure 49: Participant P25's impression of sensations in their body while sitting.

Finally, Figure 50 is the sketch of a participant who, upon my instruction, conducted his self-scan while sitting, as part of an initial exploration on how much somatic insight could be gleaned by not lying down and attending to one's contact with the mat. In both the pre- and post-Haplós self-scans, I asked him to close his eyes and to pay attention to what he was feeling in his torso, neck, and arms. In hindsight, I realise that these instructions were vague and imprecise at best. It highlighted the difficulty I faced in that moment of deciding towards which aspect of their somatic experience I should draw the participant's attention. It also highlighted the fact that awareness of the body is often awareness of the body *in relationship to* something else, as I discussed in section 3.3.2.1. However, despite the quality of the instruction I provided, the post-Haplós sketch suggests an increase in the user's sensation of their back, particularly on their left side.

P26

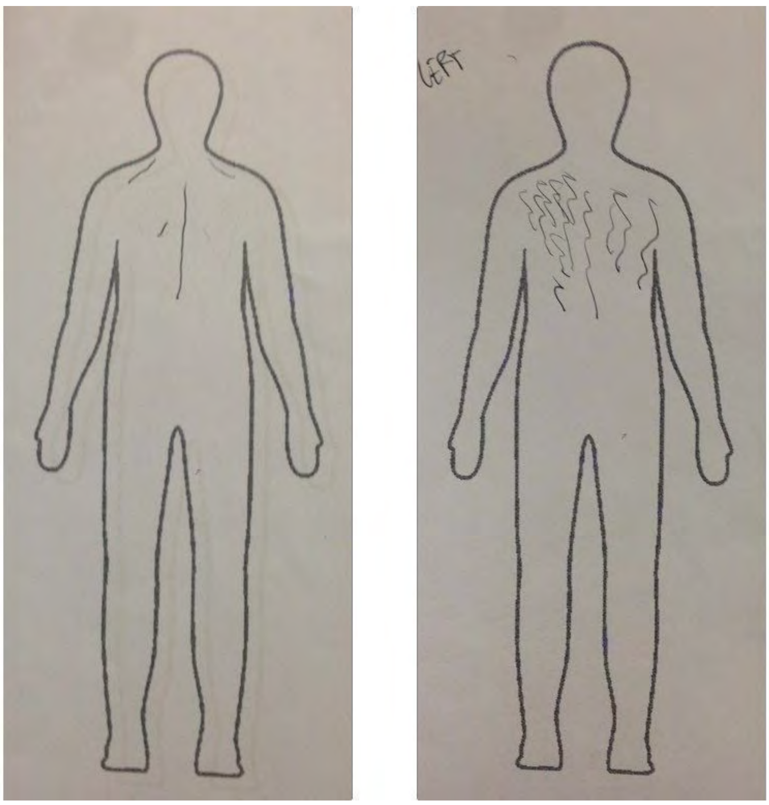


Figure 50: Participant P26's impression of sensations in their body while sitting.

5.5.3.2. Pattern preferences

Figure 51 shows various scores for vibrotactile patterns designed for and by the participants of the Bizarre Bazaar demonstration.

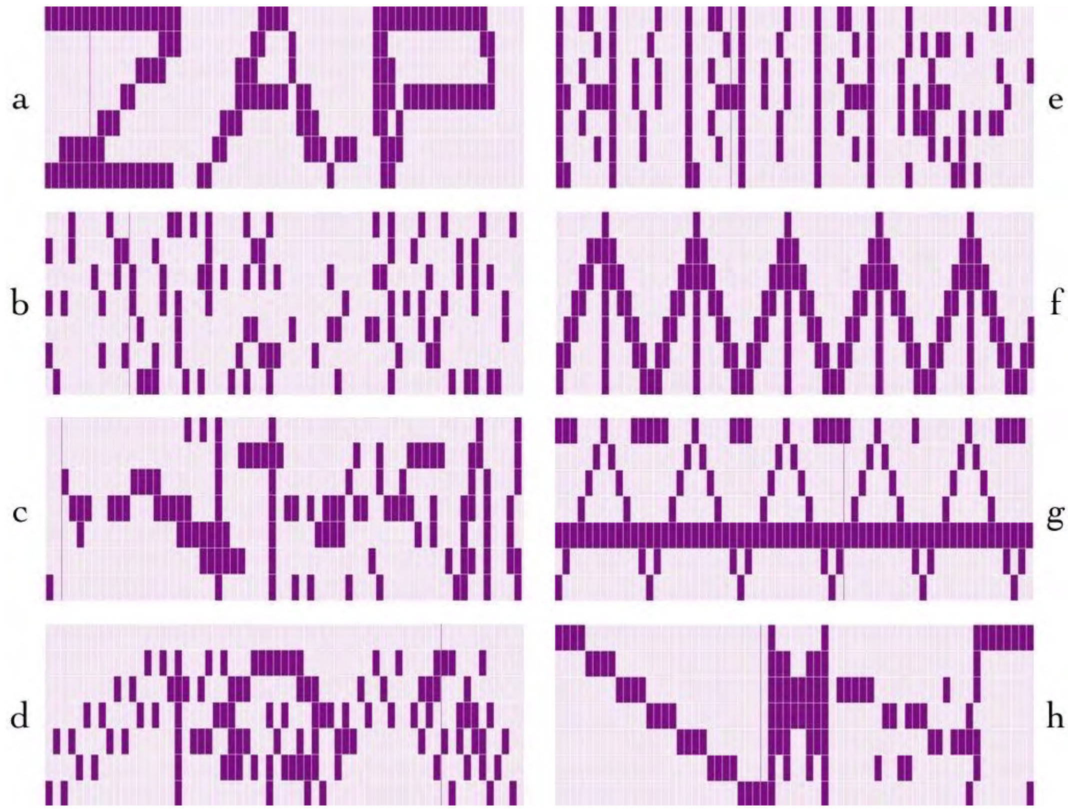


Figure 51: Scores for vibrotactile patterns designed for and by the participants of the Bizarre Bazaar demonstration.

The scores demonstrate a diversity in pattern design techniques, including the whimsical and purely visual approach exemplified in the "ZAP" score (Figure 51a). Many of the scores feature a balance of point-like and densely clustered textures. Figure 51 indicates that one motor near the bottom/middle of the thoracic region of the back should be sustained throughout the entire pattern, punctuated by a repeating note from the topmost motor, near the neck. On the other hand, Figure 51d is marked by complete silence in the top-most motor. This suggests that the participant did not find this motor enjoyable, which is reminiscent of the critical feedback from the Awaken the Spine workshop regarding the topmost balloon in the balloon spine (section 5.5.3.2).

5.6. Chapter discussion

As discussed in section 5.6, one of the major aims of this research was to translate the principles of somatic practice into usage scenarios for this technology. This was precisely the subject of section 5.3 in this chapter, in which I discussed configuration, usage, and instructional schemes for Haplós in order to facilitate increased body awareness. Additionally, though I had developed configuration schemes (section 5.3) and pattern design heuristics (section 5.4), the Manufactory and Bizarre Bazaar studies uncovered pattern design strategies motivated by user preferences around vibrotactile textures, placement, and pattern tempi (sections 5.5.2.5 and 5.5.3.2). These strategies contribute to somaesthetic heuristics for vibrotactile patterns. For instance, because individuals have different speed preferences (which might depend on a variety of factors that shift through time), the tempo of a particular vibrotactile pattern might need to be tuned to their speed preference at the moment of playback.

In addition, the prototype I aimed to design was intended to be easily integrated into everyday experience. I had already discussed in section 4.5.2 how this aim guided my choice of materials and form factors. In this chapter, I explained how I explored usage scenarios for Haplós that would not require potential users to break their workflow significantly. For instance, during the Bizarre Bazaar demonstration, I experimented with doing a self-scan in sitting instead of lying down as I reasoned that users may not always have to lie down during the course of their day. I also evaluated Haplós in a noisy environment that might more closely simulate a typical public urban space. Finally, I created shorter vibrotactile somatic experiences to explore whether somatic insights could still be developed within a more limited time frame. Each participant in the Manufactory workshop experienced Haplós for 45 minutes (including time for self-scanning pre- and post-stimulation), while in the Bizarre Bazaar demonstration, they experienced Haplós for only around 15 minutes.

The final aim of this research was to evaluate user experiences of the resulting prototype. This aim was met through the series of studies discussed in section 5.5 of this chapter. The results of the informal prototype trials, the Manufactory workshop, and the Bizarre Bazaar demonstration collectively show that Haplós can significantly influence participants' bodily self-perceptions and bodily awareness. In particular, the results of the Manufactory workshop and Bizarre Bazaar demonstration indicate that in most participants, a one-sided vibrotactile pattern could create a perceptible difference in how participants experienced their body across the midsagittal plane. Participants reported feeling more aware of the area that was stimulated; these reports were captured both in verbal reports and through visual representations they created of their perception of their awareness of their body. A tool for recording these experiences—an outline of the human form that participants could annotate—was used to record and share these perceptible differences in their embodied experience. In addition to confirming Haplós' ability to create a somatic learning experience, across all studies—including the Cravings experiment, which I discuss shortly in section 5.7.1—users of the Haplós system reported finding the experience enjoyable and interesting. While I certainly did not design Haplós to create discomfort, the degree to which participants enjoyed the experience of wearing Haplós nevertheless was a pleasant surprise.

In this chapter, I developed the notion of vibrotactile somatic learning principles, which led to configuration, usage, and instructional schemes for Haplós, as well as a set of somaesthetic heuristics for vibrotactile composition. I deployed these principles, themes, and heuristics in designing, conducting, and analysing four different studies that explored how Haplós can be used as a vibrotactile, somatic interface with which an individual can play themselves. I submit that while Haplós has a material component (composed of its software, hardware, and textile aspects), its conceptual component can be best described as one of a *vibrotactile somaesthetics*. Because Haplós creates increased proprioceptive and tactile awareness while generating reports of pleasure and wellbeing, I believe that it is a technology-based testament of Shusterman's notion of somaesthetics, and that Haplós can be understood as a system for creating vibrotactile somaesthetic experiences.

Much as Shusterman's somaesthetics has analytical, pragmatic, and practical branches, I propose that vibrotactile somaesthetics inherits from somaesthetics, and similarly has three branches. *Analytical* vibrotactile somaesthetics comprises the set of theoretical positions formed by the following theories from embodied cognitive studies, including the embodied cognition hypothesis and theories on body awareness; somatic theories particularly FM aims and theories and epistemology; and neurophysiological theories on vibrotactile stimuli and its influence on somatosensory organisation. *Pragmatic* vibrotactile somaesthetics is the main subject of this chapter. It is the set of prescriptive strategies for facilitating somatic knowledge as well as creating tactile and aeshetic experiences through vibrotactile stimuli, which include vibrotactile somatic learning principles; configuration, usage, and instructional schemes; and somaesthetic heuristics for vibrotactile composition, which in turn derive in part from FM teaching and learning strategies. Finally, *practical* vibrotactile somaesthetics is that aspect of vibrotactile somaesthetics that cannot be captured in words. It must be experienced, as the various participants (of which there are at least seventy-three) of the studies discussed in this chapter have by using the Haplós system. Their sketches, and written and spoken feedback, which I have documented to the best of my abilities in this thesis, serve as traces of their experiences. Practical vibrotactile somaesthetics can only be felt to be understood.

5.7. Postlude: Exploratory and speculative extensions of Haplós

Because the studies described so far engaged the CogNovo network of researchers as well as the general public, Haplós attracted the attention of CogNovo-affiliated scientists and artists who expressed interest in exploring applications of Haplós in other contexts. I took advantage of their interest and collaborated with them to use Haplós in two explorations that branched off from, and were conducted in parallel to, my main goal of using vibrotactile stimuli to facilitate body awareness. These explorations were the Cravings study and the Bisensorial prototype created at Hack the Brain 2016 (which was introduced in section 4.5.3).

These two explorations were warranted by Haplos' ability to direct users' attention to areas of their body in a compelling and unusual way that had been described as enjoyable and relaxing by participants (see sections 5.5.1.1 and 5.5.2.4). The Cravings study leverages Haplós ability to direct users' attention to a compelling and unusual sensory sensory experience, and evaluates the use of Haplós as a tool for placing demands on the user's cognitive capacities in a beneficial way. On the other hand, the Bisensorial prototype builds on Haplós' ability to create enjoyable and relaxing experiences, and incorporates the Haplós hardware, firmware, and software in an award-winning, speculative, "neuroadaptive" (Kosunen et al., 2016) prototype for inducing mental states.

In this section, I discuss these two explorations. I note that while Hack the Brain occurred before the Cravings study was conducted, it is the more speculative of the two activities. In addition, the Cravings study more directly extends the main research questions and goals of this research. I thus discuss the Cravings study before concluding this chapter with a discussion of Bisensorial.

5.7.1. The Cravings study

During the Bizarre Bazaar event, Haplós caught the attention of research psychologist Professor Jackie Andrade, who was curious about whether the prototype could be used to reduce food cravings. The basis of this conjecture is the Elaborated Intrusion theory of desire (Andrade, May, & Kavanagh, 2008; D. J. Kavanagh, Andrade, & May, 2005). In this theory, craving starts with the triggering of an intrusive thought related to the object of desire—for instance, a bar of chocolate. The trigger may come from the environment or from physiological cues. The intrusive thought may then get subsequently elaborated, and a discrepancy develops between the individual's current physiological and emotional state, and a mental image of their state that would arise if the desire were fulfilled. A craving is the felt experience of that discrepancy.[68] In short, the Elaborated Intrusion posits "the conscious experience of craving as a cycle of mental elaboration of an initial intrusive thought." (D. K. Kavanagh et al., 2012). Haplós, we hypothesised, could interfere with the cycle of mental elaboration by directing a participant's attention to the

[68] From this perspective, a craving could be seen as a somatic "counterfactual" (Briazu, Walsh, Deeprose, & Ganis, 2017), in that a craving represents the gap between the user's current somatic state and a potential, "what if" somatic state.

pleasant and unusual sensations created by the patterned motors of stimulation, much like other experiences—such as clay modelling (Andrade, Pears, May, & Kavanagh, 2012) or a video game (Skorka-Brown, Andrade, & May, 2014)—could.

To test this hypothesis, we set up a controlled experiment in collaboration with other members of the Plymouth University Cravings Lab, notably Kirsten Woodman, Despina Djama, and Professor Jon May. The main objective of this study was to test whether Haplós could reduce the frequency and strength of chocolate cravings. We chose chocolate as the subject of the cravings because it is a common food craving that can be induced in the lab (Andrade et al., 2012). A detailed description of the study protocol is available in Appendix 2. In summary, the protocol included the following steps:

1) Assessing the initial chocolate cravings of the participant;
2) Inducing a chocolate craving by offering the participant a range of different types of chocolates and asking them to pick one;
3) Administering one of two interventions that map to two different experimental conditions (as described below);
4) Reassessing the chocolate cravings of the participant;
5) Administering a qualitative questionnaire probing for participants' reactions to the intervention; and
6) Debriefing the participant.

The experiment had two conditions: the experimental condition involved wearing the Haplós suit and experiencing a three-minute vibrotactile pattern that I made for the study; the control condition involved wearing the Haplós suit but *without* the motors attached, also for three minutes. To test the strength and frequency of cravings, we used the Cravings Experience Questionnaire (see Appendix 2)

(Andrade, Pears, May, & Kavanagh, 2012). Sixty-six participants took part, with thirty-eight of them belonging in the experimental condition.

After running the experiment and analysing the data, we found that Haplós significantly decreased the frequency (but not the strength) of chocolate cravings. A summary of the statistical analysis is available in Appendix 6. However, further discussion on this aspect of the study is deferred for another publication. In this section, I instead discuss the design of a three-minute vibrotactile pattern used in the study, and present an analysis of participant responses to experiencing the pattern.

5.7.1.1. The Cravings study vibrotactile pattern

In section 5.7.1.1 I had advanced six somaesthetic heuristics of vibrotactile pattern design that I applied to the design of three short patterns used in the Manufactory study (section 5.5.2.2). A subsequent research question arose: how else might these heuristics be applied to the design of other patterns? To this end, I present a case study in this section that applies the heuristics to the design of a more complex vibrotactile pattern that lasts for three minutes. This pattern was used in the Cravings study and aimed to create a compelling vibrotactile experience that would capture the participant's attention. It was crafted for a fourteen-motor, bilateral version of Haplós. I decided to make a bilateral pattern because during the Manufactory workshop and Bizarre Bazaar events, two participants found it "bothersome" (#P14.161020.Manufactory1.a5) or "felt irritated" (#P30.161022.PublicDemo.a5) that the pattern was one-sided. I also simply wished to experiment with composing a bilateral pattern.

Figure 52 shows the configuration of these motors and how they appeared on the GUI. In the Manufactory and Bizarre Bazaar studies, I explored the visual cues provided by the GUI to participants because I was exploring the ability of these cues to aid the perceptibility and distinguishability of the vibrotactile stimuli (as previously explained in section 5.4.4). However, the GUI was never seen by the participants, as I wished the experiment to focus solely on the vibrotactile sensations. Any additional sensory stimuli would confound the analysis of the data. However, I propose that well-designed vibrotactile patterns—structured with at least as much care as I had exercised in designing the Cravings study pattern—might minimise the need for multimodal cues.

Figure 52: Visualisation of the motor activation shown on the GUI used in the Cravings study, but which was not exposed to participants during the study.

Figure 53 shows a summary of the score for the pattern. The pattern has an A-B-A form, where the beginning recurs at the end. It takes three minutes to play before it loops to the beginning. For brevity, some phrases (18 and 23 in the figure) are omitted from the score. In addition, some of the phrases are repeated. For instance, phrase 3 is played only once, phrase 1 is played twice, phrase 12 is played four times. The number of repetitions are also omitted here for brevity. Phrases that I considered complex, which demands additional exposure for the user for maximum perceptibility, were repeated several times. The full score is archived in Appendix 4.

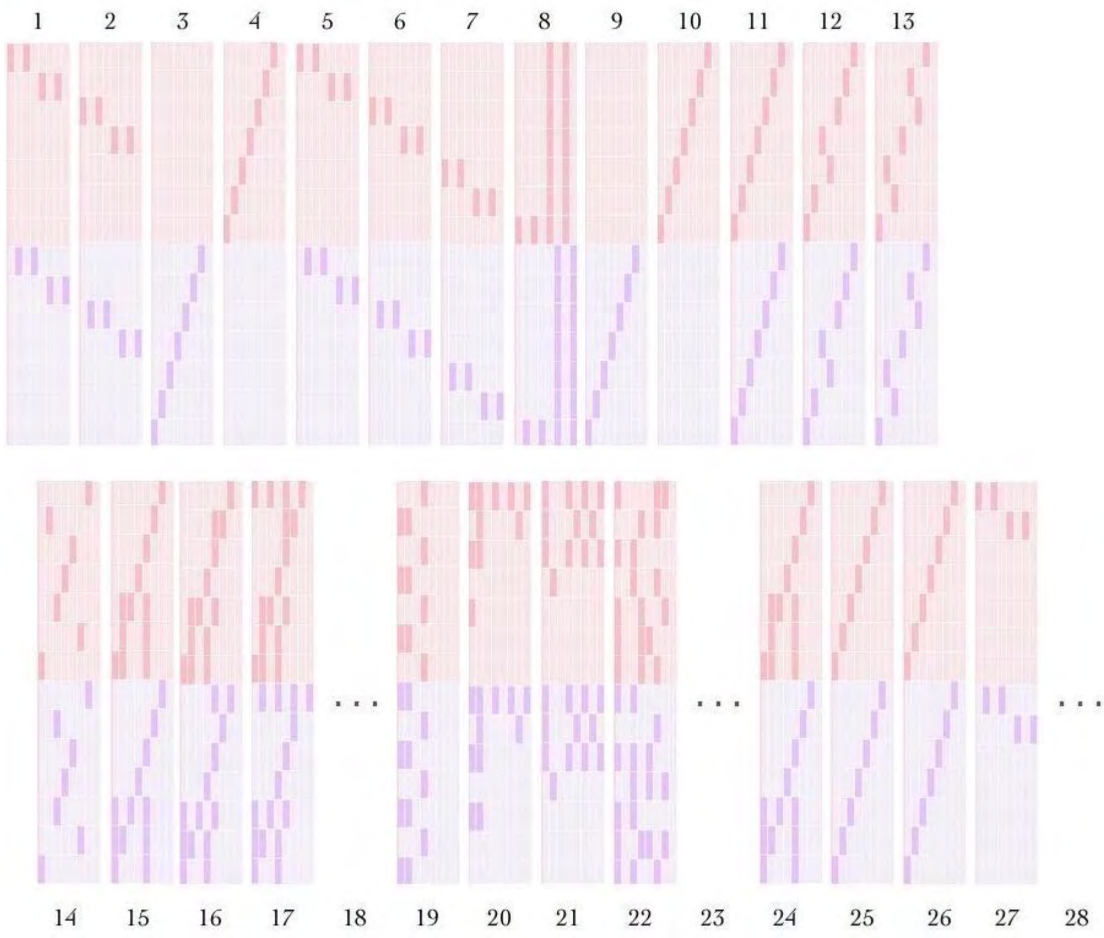


Figure 53: Summary of the vibrotactile score used in the Cravings study.

Phrases 1-10 aimed to highlight the experiencing of the participant's midline by activating motors on the left and right sides in an alternating way, starting from the top of the thoracic spine (phrases 1 and 5) all the way to the bottom of the thoracic spine (beginning of phrase 8). Phrases 3, 4, 9, and 10 aimed to help the participant feel the full length of their thoracic spine by playing a continuous upward scale.

Phrases 1-4 were played at around 57 BPM, where a beat corresponds to an individual slot. The rather ponderous tempo was intentional; I reasoned that users would be unfamiliar with the sensations and I thus took the time to introduce the participant to the individual motors and their sonic and vibratory qualities to ensure stimulus perceptibility and distinguishability at the start of the pattern. At section 5, however, the tempo doubles to around 115 BPM, then doubles yet again from section 9 to 230 BPM.

From phrase 12 until right before phrase 19, each phrase was a slight variation of the phrase before it. For instance, phrase 12 is the same as phrase 11 but with two of the notes switched. Phrase 16 elaborates on phrase 15 by adding a syncopated note on the fifth beat using one motor at the top and one at the middle of both sides of the back. Because the phrases were becoming increasingly complex, I played each phrase four times from around phrase 12 until phrase 25 to ensure maximum perceptibility without being too repetitive.

Phrases 15, 16, and 17 show a steady beat in the lower motors, which continues until just before phrase 19. This was inspired by what I observed to be a general preference among participants for those lower motors (see sections 5.5.2.5 and 5.5.3.2).

Phrase 19 is the climax of the pattern, with a dramatic, syncopated, two-note figuration followed by silence. The silences also gave the participant a break from the rather relentless series of variations that preceded it. Phrase 20 adds three syncopated beats to phrase 19 in order to begin a return towards the beginning of the pattern.

This journey concludes with phrase 25, which is a repeat of phrase 11, which in turn is a combination of phrases 3 and 4. Phrase 26 repeats phrase 25 exactly but at half the speed. The pattern then finally loops back towards the beginning, with phrase 27 being exactly the same as phrase 1 and at the same initial tempo of 57 BPM.

To experience the pattern, participants were helped into the suit by the experimenters conducting the study. Participants were then instructed to sit in a cushioned armchair, lean back against the chair, place their hands on their lap or on the chair's armrests, and close their eyes. They were then informed that the experimenters would return in a few minutes, during which time the pattern was played. In their instructions, the experimenters did not use words related to awareness or attention. No information about the device or its purpose was given. The studies were run entirely by two placement students from the Cravings Lab, and I did not interact with the participants while sessions were being run in order to minimise biasing participant responses.

5.7.1.2. Questionnaire

After experiencing the pattern and completing tasks related to the experiment's main objective of studying cravings, participants were asked to describe and rate their experience of Haplós using an online questionnaire. Several questions were asked, including the following:

1) How did you feel while wearing the suit?
2) How did you feel after taking off the suit?
3) Were there any physical sensations that were interesting to you either while or after wearing the suit?

4) Where did you feel the vibrations? Did you feel them in parts of yourself other than your upper back? (e.g., your neck, head, arms, hands, shoulders, lower back, hips, legs, feet)

5) The *suit* is composed of two components: the *vest* and the *vibrating motors*. On a scale of 1-10 with 10 being the most pleasant, how pleasant or unpleasant was the experience of wearing the VEST?

6) On a scale of 1-10 with 10 being the most pleasant, how pleasant or unpleasant was the experience of the MOTORS playing?

These questions were asked with three goals in mind: The first was to validate that the overall experience of Haplós was attractive and acceptable to a larger number of participants, similar to a "user acceptance" (F. D. Davis, 1993) test. The second was to confirm that I had created a compelling and interesting vibrotactile experience that did not create any discomfort. Uncomfortable experiences can easily be created by prolonging a vibrotactile stimulus or applying a stimulus too often in one location; I wished to review whether I had avoided this in my pattern. The third and final goal was to examine to what extent this usage of Haplós can still generate somatic knowledge, as compared to when it was used as part of a somatic learning usage scenario exemplified by the Manufactory and Bizarre Bazaar studies.

5.7.1.3. Analysis of participant responses to the Haplós experience

To aid my analysis of participant responses, I organised the responses in a matrix, then rated and colour-coded them as positive (green), mixed (orange), negative (red), or neutral (grey). I regarded responses as neutral when they provided information about their experience with words that had no specifically negative or positive connotations, such as "warm" or feeling the vibrations "deep into the muscles." I regarded "ticklish" as neutral since ticklish sensations can be experienced negatively or positively (Harris & Alvarado, 2005). My coding took context into account; for instance, though relief is a positive experience, if someone reported feeling relieved after taking off the suit, I considered the response as mixed rather than positive since their response indicates that they were uncomfortable while wearing the suit. The pleasantness rating of the vest and the motors were similarly colour-coded along a gradient. Figure 54 shows this matrix, which is presented and discussed in more detail in Appendix 5. Questions 5 and 6 were inserted in the questionnaire only partway through the experiment; thus only 22 participants (E17-E38) provided responses to these questions.

#	How did you feel while wearing the suit?	How did you feel after taking off the suit?	Were there any physical sensations that were interesting to you either while or after wearing the suit?	Where did you feel the vibrations?	Is there anything else you want to say about what the experience of wearing the suit with the vibrating motors was like for you?	Vest pleasantness	Motor pleasantness
E1	The suit was comfortabl	slightly more relaxed	Just the sounds and feelir	Only felt the sensations	[Not answered]		
E2	Tight and uncomfortable	relaxed and relieved	the vibrations relaxed my	i felt them just on my sp	[Not answered]		
E3	fine, slightly uncomforta	better, still felt a bit odd	afte I felt as though where	no, just the back	no		
E4	Slightly constrained. It f	More freedom, relaxed. I	My fingers were tapping t	Neck and shoulders	It was surreal, but became		
E5	comfortable, safe, giggly	cold, wanted the support	my back felt very warm d	my shoulders, upper, ar	[Not answered]		
E6	A bit weird, i didn't kno	Not too much different r	The vibrations were inter	I felt the vibrations pre	I wasn't too sure what to		
E7	comfortable, relaxed but	I felt normal. I felt the sa	The upper part of my bac	I felt the vibrations on a	The vibrations appeared t		
E8	felt really relaxed	to be honest I didn't feel	While I was wearing the s	Lower back	It was very interesting an		
E9	Restricted by the tightne	Released, free.	I felt like I was wearing a	Only felt them in my up	In a strange way it was en		
E10	Relaxed and felt like i w	More relaxed then before	The sensations on my low	Neck, lower back	In enjoyed it it was a plea		
E11	it was slightly uncomfor	i felt a slight sense of reli	i noticed that when i was	shoulders	[Not answered]		
E12	It was weird, but it felt c	I didnt want to take it off	The tingles radiating over	No, just in my back pre	It felt like music coming f		
E13	Comfortable, it was fine,	Not much different to wh	None	No, just my upper back	I found the sound of all th		
E14	slightly uncomfortable a	felt more free	during when the motors w	felt them in my lower b	it felt like having a massag		
E15	Like I couldn't relax pro	Relaxed	I found out that I am tickl	Neck, shoulders, lower	At first I was very ticklish		
E16	Confined and weird	relieved	after taking off the suit pa	lower back, neck and sh	[Not answered]	4	5
E17	Relaxed, calm.	the same.	The motors on my back. T	My neck	Nope	4	8
E18	It was ok, i felt a little tir	normal, it was easier to sl	The sounds the vibrations	i felt the vibrations whe	it was ok	6	6
E19	i felt secure and embrace	slightly exposed and less	my muscles relaxed whilst	i felt the vibrations in m	I enjoyed the sequential p	10	10
E20	A little bit tense because	I feel a bit lighter and a b	I found myself really feeli	I felt them on my neck,	[Not answered]	4	7
E21	it was a little strange to s	I felt like I wanted to arc	I felt that when the patter	I felt them in my neck,	[Not answered]	4	7
E22	Restricted but relaxed a	More relaxed to how i fel	my back felt more relaxed	in my shoulders as well	[Not answered]	3	8
E23	it was a really nice feelin	it was nice to be unrestric	The vibrations made a noi	upper back and shoulde	I'm not sure if the motor v	4	8
E24	Relaxed, thought free	Still relaxed	my back felt tender, but it	i felt numerous vibratio	I felt as though the vibrati	9	8
E25	It felt strange feeling the	I felt a lot more relaxed o	The feeling of the vibratio	I felt them in my neck a	[Not answered]	3	3
E26	A bit strange, it was sort	The same as before I put	The buzzing was a pleasa	I felt the vibrations all c	I felt a little bit tense after	7	8
E27	At first it was quite inter	The relaxation felt whilst	The vibrations were inter	I felt them in the lower	/	9	10
E28	Comfortable, intrigued a	Bit disappointed, would l	The vibrations on the bac	neck, shoulders, lower l	it was a very interesting e	8	10
E29	Relaxed, though the vib	Still relaxed	While wearing the suit I f	I felt them in my lower	No	8	8
E30	Relaxed and comfortabl	Warm	It was warm and ticklish	Yes down my leg	It was enjoyable	8	8
E31	Very relaxed, I was able	was strange taking it bac	The vibrations at the lowe	Felt them a little bit in r	It was quite therapeutic!	7	10
E32	Intrigued	I wanted to know how th	No	Lower back, and should	No	5	3
E33	Comfortable and relaxec	Relaxed	Vibrations on my back	Lower back	[Not answered]	10	10
E34	very relaxed, it was quit	My muscles and body fel	My back still could feel th	My neck and lower bac	It seemed like it was a tun	7	10
E35	I was a bit apprehensive	Lighter, it isn't heavy but	I can still feel the places w	I just felt it where the m	I wouldn't mind wearing i	3	9
E36	Relaxed, Peaceful, Desti	Relaxed, Awake, Calm	The vibrations from the s	Very slightly in my han	Very relaxing.	8	9
E37	Very aware of my back a	Calm, almost like the effe	My muscles relaxed and f	I felt some on my shoul	N/A	6	8
E38	it was a strange sensatio	more comfortable	the sounds it made moire	lower back and shoulde	it felt as it the vibrating m	4	5
	23	21	18	0	12		
	9	12	3	0	2		
	6	1	2	0	1		
	0	4	15	38	23		

Figure 54: Responses of participants in experimental group from Cravings study

Based on my analysis as aided by this matrix, the response to the Haplós experience was largely positive, particularly with respect to the vibratory motors, as opposed to the back support garment which provoked mixed reactions. Furthermore, the vibrotactile stimuli were regarded as generally enjoyable and interesting without causing discomfort, except perhaps in the case of two participants. Finally, while the response to the experience was generally positive, few reported the kind of somatic insights that were reported in the previous studies. I expand on these points in this section.

5.7.1.3.1. User acceptability

The first goal was to test whether the overall experience of Haplós was acceptable to participants. To this end, I compared the positive, negative, ambivalent, and neutral responses across all questions. While nineteen participants reported feeling "relaxed" and two reported feeling "calm," there were mixed feelings about the comfortableness of the suit. For instance, participant E22 noted that they felt "restricted but relaxed and calm," while E26 felt that wearing the suit "was sort of relaxing but at the same time not." Six felt either "uncomfortable" or "confined" while wearing the suit, and felt "better" or "relieved" after taking off the suit.[69] The juxtaposition of comfort/discomfort sensations is reminiscent of similarly mixed reports from the Awaken the Spine workshop, pointing to the fine line between

[69] During the study, I worked with experimenters conducting the study and monitored participant responses to the online survey as they came in. Partway through the experiment, I began to suspect that the suit might have be consistently fastened too tightly and might be exerting excessive pressure around the participants' belly. An uncomfortable learning environment would not be conducive to vibrotactile somatic learning. I thus instructed the experimenters to choose a vest one size larger than what might have been previously assigned. As Figure 54 suggests, negative reports while wearing the suit (column 2) appear to begin to diminish, likely as a result of this adjustment to the protocol.

feeling secure and feeling restrained. Eleven found the experience strange, though not necessarily in a negative way.

Overall, however, twenty-three out of the thirty-eight participants (82%) positively described their experience of the suit. Indeed, four participants (10%) spontaneously provided feedback that they wanted it on for longer or would like to wear it again:

> E35: *I wouldn't mind wearing it again.*
>
> E5: *wanted the support back on again*
>
> E28: *Bit disappointed, would have enjoyed it for longer.*
>
> E35: *I wouldn't have minded leaving it going for longer, it was quite nice.*

In contrast, while there were similarly mixed reports on the vest's comfort in the control group, only one participant (4%) spontaneously remarked that they wanted to keep the vest on.

The motors were rated to be more pleasant on average (7.74 out of 10) than the vest (6.13 out of 10), with only two participants (E32 and E25) rating the experience of the vibrator motors to be less pleasant than that of the vest. However, as discussed in sections 5.7.1.3.1 and 5.7.1.3.1, the motors can be incorporated into form factors other than a back support garment, which has served as a convenient way to lessen postural tone and bring the motors closer to the body for testing purposes. I thus conclude that Haplós, even in its current prototype state, would be likely to pass future user acceptability tests or could be easily modified to do so.

5.7.1.3.2. Interestingness and enjoyability of the vibrotactile pattern

The second goal was to confirm the pattern was compelling and interesting but did not create any discomfort. While the motors were generally rated favourably, four out of the twenty-two participants (E38, E32, E25, and E16) rated the pleasantness of the motors as either 3 or 5. Participant E25 found the sensations and the sounds of the motors "distracting" and gave the motors a rating of 3. Though participant E32's comments were neutral or ambivalent, the participant nevertheless gave an equally low rating of 3. Participant E38 found the experience "strange" and the sounds "weird," and rated the motors as 5. E16 reported that, "after taking off the suit parts of my back went a little numb for a few seconds," accounting for their rating of 5.

It is possible that E16 may have been overstimulated by the motors, but without more evidence it is difficult to come to a more conclusive analysis. Another participant (E24) might have also received too much vibrotactile stimulation, because although they scored the pleasantness of the motors quite high at 8, they noted that their "back felt tender." Looking in hindsight at the pattern, I believe it could have benefited from more periods of silence to allow for an integration of the experience and prevent discomfort.

However, eighteen (82%) ratings of the pleasantness of the motors were scored at 7 or above, with sixteen (72%) rating it between 8 and 10. In addition, four participants found the patterns interesting or intriguing:

> E8: *It was very interesting and it was very different*
>
> E28: *it was a very interesting experience. I am intrigued of the outcome*
>
> E32: *Intrigued*
>
> E27: *quite interesting to feel the movement it made*

Thirteen of the participants (34%) remarked on some aspect of musicality in the vibrotactile sensations:

> E4: *My fingers were tapping to the rhythm of the suit vibrations. My breathing became deeper.*
>
> E7: *The vibrations appeared to be making up a song / sequence. Some vibrations felt as if they were chords*

E12: *It felt like music coming from the vibrations and they were playing a song on my skin.*

E13: *I found the sound of all the vibrations together quite 'creepy', like a song (sounds strange).*

E18: *I enjoyed the sequential patterns of the vibrating motors, i could predict the next rhythm and it was more relaxing to make the vibrators in a sort of symphony*

E20: *I found myself really feeling almost the beat of the vibrations and I started tapping my foot to the rhythm they were performed in.*

E21: *I felt that when the pattern of the sensations changed I was more aware of the different movements.*

E23: *The vibrations made a noise like an old electronic song, something like Kraftwerk… I'm not sure if the motor was meant to be randomised but It sounded too much like analogue electro to me to not be designed into a pattern.*

E24: *I felt as though the vibrations were in the pattern of a song*

E27: *as the time d[r]ew on, i became more used to the pattern of the vibrations. This made me relax more, and felt quite soothing…The vibrations were interesting to me as i could feel them move up and down my back, each with varying type of pressure which was very relaxing. I felt my body un-tense.*

E31: *Very relaxed, I was able to focus on the rhythm of the vibrations and take my mind off of other distractions which is something I usually struggle with.*

E34: *It seemed like it was a tuneful rhythm and was very enjoyable*

E37: *I felt quite entertained by the musical element. It was easy to focus on just the vibrations but hard to focus on anything else.*

5.7.1.3.3. Ability to facilitate somatic insight

The final goal was to examine whether the way Haplós was used in this study can generate somatic insights, particularly since the protocol in this study differed substantially from that of the Manufactory and Bizarre Bazaar studies in five ways. Firstly, the duration of the vibrotactile experience was considerably shorter than in the previous studies. Secondly, no instructional guidance was given to the participants on what aspects of their experience to attend to. Thirdly, the pattern was composed entirely without user participation or feedback. Fourthly, participants did not get a chance to feel themselves in lying down and observing their contact with a horizontal surface. Finally, the pattern in this study was bilaterally symmetrically, not one-sided as in the previous studies.

While many of the participants reported cognitive and affective states such as calm, wakefulness, relaxation, and feeling free, I reviewed participant responses and looked for those that related specifically to bodily awareness, neuromuscular organisation, or changes in proprioceptive sensation. I identified six responses that met this criterion:[70]

> E4: *Slightly constrained. It felt quite odd. I became more aware of my breathing and what my body was doing.*
>
> E5: *cold, wanted the support back on again, more open back feeling … my back felt very warm during, and after taking it off I had an 'open back' sensation, feeling more loose around my upper back*
>
> E11: *i noticed that when i was wearing the suit i became much more aware of my breathing and my body temperature felt like it had increased slightly.*
>
> E22: *[I noticed the] upper back and shoulders and lumbar area of spine. Felt it in my breathing too, made me more aware of the exhale of breath*
>
> E31: *was strange taking it back off because I got quickly accustomed to it, my posture felt funny… The vibrations at the lower end of the suit particularly caught my attention and allowed my mind to empty. After taking it off it felt strange- I noticed my natural posture more.*
>
> E37: *Very aware of my back and arms.*

However, these six participants represent only 16% of the thirty-eight who experienced the vibrotactile patterns. Moreover, there is a marked absence of some of the more sophisticated somaesthetic observations that were reported during the previous studies, such as experiencing a "sharper image" (#P14.161020.Manufactory1.a5) of the self-representation or "feeling more of"

[70] It is interesting to note that awareness of breathing was more prominent here than in the Manufactory or Bizarre Bazaar studies, most likely because I directed participants' attention in the previous studies to other bodily sensations.

oneself (#P22.161022.PublicDemo.a5). I submit that without additional instructional guidance or strategies for comparing somatic experiences (provided by one-sided vibrotactile experiences or observation of contact with a horizontal surface, for example), using Haplós as it was in this study limits its efficacy as a body awareness tool. Nevertheless, given that *some* somatic insight was generated in such a short amount of time, with no instructional guidance, I also speculate that it is possible to develop a set of concise, quick vibrotactile somatic learning lessons which can benefit potential users. I discuss this possibility further in section 6.4.2.1.

5.7.1.4. Summary and discussion

In this section, I reported on a controlled experiment using vibrotactile patterns to reduce chocolate cravings. I described features of the three-minute vibrotactile pattern used in the study to illustrate how somaesthetic heuristics for vibrotactile pattern design can be applied. In addition, I summarised the participants' qualitative responses of their experience of Haplós. While primary objectives, methodology, and outcomes of the Cravings experiment are outside the scope and main narrative of this thesis, the experiment nevertheless contributed to the methodology and to the outcomes of the project in three ways. Firstly, the vibrotactile pattern I designed specifically for this study using pattern design principles exemplified in depth the application of vibrotactile pattern design heuristics. Secondly, I collected qualitative responses from the study participants about their experience of Haplós which contribute to my evaluation of the prototype as a tool for vibrotactile pragmatic somaesthetics. Thirdly, the study showed that a novel and compelling vibrotactile experience can be achieved in 3 minutes, which opens up possibilities for creating vibrotactile somatic "mini-lessons" that a user could follow anytime during the course of the day—an important element that contributes to my goal of designing a somatic learning technology for everyday use. However, the study also highlighted the importance of instructional guidance and the value of attending to one's contact with a horizontal surface for developing somatic insights. Nevertheless, despite what I view as a reduction in the quality of somatic observations during the 3-minute experience, I speculate that Haplós can be used in the future for creating short, condensed vibrotactile somatic learning experiences, which I sketch out in section 6.4.2.1.

In addition, this study makes a contribution to the study of appetite in experimental psychology. The study yielded a statistically significant relationship between experiencing a vibrotactile pattern as provided by Haplós and a reduction in laboratory-induced cravings, thereby pointing to new approaches in dealing with intrusive thoughts using a novel application of vibrotactile stimulation. It is not unreasonable to imagine that a version of Haplós could in the future be incorporated into everyday clothing and, with a touch of a button, be activated whenever one experiences an intrusive thought or an unwanted craving. Randomising or generative procedures (such as the genetic algorithm that I discuss in section 5.7.2.2.2) could be used to ensure that patterns remain relevant but surprising to the user.

5.7.2. Bisensorial

Bisensorial is a speculative application of Haplós for cognitive enhancement that resulted from a rapid and intensive collaboration. It was developed over two and a half days at Hack the Brain 2016, a hackathon in Amsterdam which was introduced in section 4.5.3 and in which fifty-eight artists, scientists, and developers participated. Bisensorial was co-created with speculative designer Agi Haines, computational neuroscientist Jack Fletcher, film composer Sean Clark, fashion designer Kim

Jansen, and science communicator Ricardo Mutuberria. The members of the Bisensorial team were finalised on the first day of the hackathon.

Working from the hackathon's theme of "hacking one's self better (or worse)," our team conceptualised and built a fully functional proof-of-concept that generates tactile stimuli (provided by Haplós) and auditory stimuli (in the form of precomposed musical fragments), based on readings created by a Muse portable electroencephalogram (EEG) headband that detects electrical activity in the brain.[71] A genetic algorithm (to be explained shortly) was used to customised the stimuli based on the EEG readings. The motors were encased in a silicone structure that evokes the shape and function of the human spine, and a bespoke dress was designed to bring the silicone spine and the encased motors closer towards the body. Figure 55 shows Bisensorial being presented by artist Esther Levigne on the last day of the hackathon.

Figure 55: Bisensorial being modelled by artist Esther Levigne.

[71] http://www.choosemuse.com/developer-kit/

At this point, it is crucial for me to acknowledge that the use of a brain measurement device to infer the user's mental state runs somewhat counter to one of the original stated goal of this research of designing a technology that aims to help users refine, not supplant their ability to self-sense. However, I chose to explore this usage scenario of Haplós in the spirit of cross-disciplinary collaboration that underpins the institutional context of CogNovo (as described in section 1.3), of which my collaborators Haines and Fletcher are a part.[72] Moreover, Bisensorial does not use brain activity measurements to tell the user what to *do* nor tells them what they should feel. In section 5.4.5, I discussed the notion of tuning Haplós based on the user's stated preferences; Bisensorial uses brain activity to similarly tune its activity to the user's state.

5.7.2.1. Brain-computer interfaces, vibroacoustic therapy, and genetic algorithms

The use of brain activity measurements for generating audio has a long history, with Alvin Lucier's piece 1965 "Music for Solo Performer" being an important precedent (Straebel & Thoben, 2014). Moreover, "brain-computer interfaces" (BCIs) (Chatterjee, Aggarwal, Ramos, Acharya, & Thakor, 2007) have previously incorporated vibrotactile cues as a way to provide user feedback on the state of the BCI-based system (Cincotti et al., 2007; Yao, Meng, Zhang, Sheng, & Zhu, 2013), especially for vision-impaired users (Apichartstaporn, Pasupa, & Washizawa, 2016) or users with severe disabilities (Lugo et al., 2014). In addition, BCIs aimed at facilitating mindful states have been explored in prior work (Chierico,

[72] For details on their CogNovo-related research, see http://cognovo.eu/people/research-fellows/agatha-haines.php and http://cognovo.eu/people/research-fellows/jack-mckay-fletcher.php.

2014; Kosunen et al., 2016). However, to the best of my knowledge, Bisensorial represents the first BCI in which vibrotactile stimuli were used not as information cues but as sensory prompts that are aimed at bringing users closer towards a desired mental state, including relaxed mindfulness.

In addition, while the Bisensorial team was not aware of it at the time we designed our prototype, Bisensorial builds on existing applications of tactile and auditory vibrations for therapeutic purposes, notably *vibroacoustic therapy* (Punkanen & Ala-Ruona, 2012; Skille, 1989).[73] In vibroacoustic therapy, low-volume low-frequency sounds are posited to induce relaxation (Skille, 1989, p. 63). These are played to the user, who lies down on a table or sits in a chair equipped with a mechanism for providing mechanical vibratory stimulation (Kelley, 2013). While Morrison et al. (2017) have reported creating a wearable vibrotactile-equipped device that can be used with a vibroacoustic wall installed in a public area and which emanates a "calming low-level hum" (Morrison et al., 2017, p. 3), Bisensorial customises the audible stimuli to a particular user. Thus, in summary and to the best of my knowledge, Bisensorial represents the first reported proof-of-concept of a wearable, fully portable, individually-tailored, neuroadaptive vibroacoustic therapeutic device.

Bisensorial's neuroadaptive capability is due to the genetic algorithm that lies at the heart of its software. A genetic algorithm is a procedure for finding optimal solutions to a computational problem in a manner that is inspired by biological evolution (J. H. Holland, 1992). Genetic algorithms define a criterion for determining how successful a particular solution is; the manner of assessing how well a solution meets this criterion is known as the *fitness function* (Fletcher & Wennekers,

[73] Another term for vibroacoustic therapy is Physio Acoustic Sound (Os, Aziz, Schalkwijk, Schols, & Bie, 2012).

2016). Genetic algorithms generate a number of potential solutions. The fitness function then takes each potential solution, looks at how well it solves the problem, and then rates each potential solution with a fitness value. Those solutions with higher fitness values have a greater probability of surviving, while the rest are discarded. The genetic algorithm then takes the successful solutions and recombines them to create new potential solutions, in essence allowing the more successful solutions to "breed" and generate new possible solutions. Mutations are introduced during the breeding process to create variation in the generated solutions. The process of testing the solutions, identifying the more successful ones, culling the less successful ones, and creating new solution variants is iterated repeatedly until the fitness function has been met to a satisfactory degree, or the number of iterations has reached a predefined maximum.

5.7.2.2. Collaborator-contributed components

Bisensorial had five components, each of which was contributed by a member of the team. The first component was the set of vibratory motors and the hardware and firmware required to control them (as described in sections 5.7.2.2 and 5.7.2.2), which I had developed as part of Haplós. For Bisensorial, I devised a representation for the vibrotactile patterns which would allow the patterns to be easily used by the genetic algorithm. I also worked with Ricardo Mutuberria to double the number of motors I had brought with me to the hackathon.

The other four collaborator-contributed components of Bisensorial were an auditory stimulus in the form of precomposed musical fragments; a genetic algorithm for optimising the vibrotactile patterns and musical fragments; a silicone casing for the vibratory motors; and a bespoke dress that supported the silicone casing and brought it closer to the wearer's body. These four components were developed during the hackathon.

5.7.2.2.1. Precomposed musical fragments

Using his expertise in film composition, Sean Clark crafted short evocative musical fragments, lasting about twenty-five seconds each, which he composed with the goal of affect the listener's mood. The fragments were a mix of mono and stereo recordings. Figure 56 is a screenshot of the waveform of one of the fragments. Our team worked closely together; Figure 57 shows Clark and Fletcher experimenting with composing musical fragments.

Figure 56: Screenshot of the waveform of one of the Bisensorial musical fragments, archived in https://archive.org/details/BisensorialAdaptiveBinauralAudio

Figure 57: Sean Clarke and Jack Fletcher experimenting with composing musical fragments

5.7.2.2.2. Genetic algorithm for optimising musical fragments and vibrotactile patterns

A genetic algorithm that generated and recombined the vibrotactile patterns and the musical fragments was implemented by Fletcher. In Bisensorial, the fitness function was the extent to which the user's brainwave readings from the Muse headband corresponded to a desired and pre-determined mental state. For instance, during Hack the Brain, the fitness function of the GA sought to maximise the amplitude of alpha waves, which are associated with the state of relaxed mindfulness (Kerr et al., 2013). Due to the severe constraints on time during the hackathon, we did not have a chance to confirm whether the GA would converge to an optimal solution of vibrotactile patterns and musical fragments. However, our team was able to confirm that the GA was up and running, and was successfully recombining patterns and fragments. Figure 58 shows Fletcher working with the Muse headband to extract EEG values.

Figure 58: Jack Fletcher (right) working with the Muse headband to extract EEG values. Also pictured is CogNovo fellow Michael Straeubig (left).

5.7.2.2.3. Silicone casing for the vibratory motors inspired by human anatomy

A silicone casing for the vibratory motors inspired by the form of the human spine was designed and created by Agi Haines. The spine housed the motors and the wires (as previously illustrated in Figure 25. Silicone was chosen because of its material properties, and notably because of its tactile resemblance to human tissue. Figures 59 and 60 show the creation of the silicone casing.

Figure 59. Agi Haines working with Ricardo Mutuberria and Kim Jansen on the clay mould for a silicone casing inspired by the human spine.

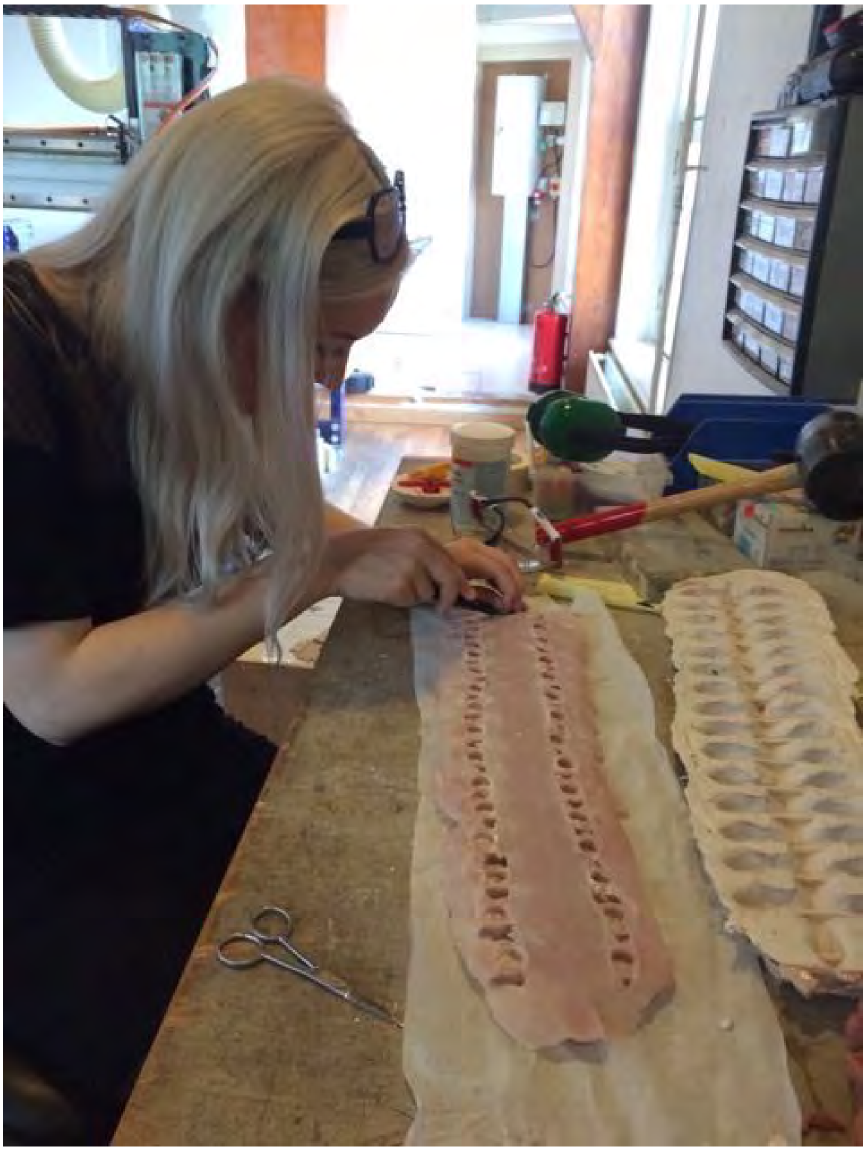


Figure 60. Agi Haines finalising the silicone casing.

5.7.2.2.4. Bespoke dress for optimise the sensory experience

A bespoke dress was designed by Kim Jansen, who took into account the material requirements that the silicone casing and the motors placed on the design of the dress. In particular, because the casing had to be pressed closely against the wearer's back, a corset-like lacing mechanism was incorporated on the back of the dress, shown in its early stages in Figure 61. Ridges were incorporated in the silicone casing to allow elastic cords to contact the casing securely, as can be seen in Figure 62.

Figure 61: Kim Jansen working on the Bisensorial dress.

Figure 62: The Bisensorial dress in full, as modelled by Kim Jansen.

5.7.2.3. Summary and discussion

Bisensorial is a working proof-of-concept of a wearable, fully portable, individually-tailored, neuroadaptive vibroacoustic therapeutic device, collaboratively designed and built during a neuroscience-inspired hackathon. It uses musical fragments and vibrotactile patterns—played on the wearer's back—to induce mental states. Measurements of its wearer's brain activity determine what sensory stimuli or information is presented to the user, which is refined iteratively by a genetic algorithm to optimise the stimuli to the user's current state.

While Bisensorial and Haplós appear to be at odds with each other, they nevertheless share a concern about the uniqueness of individual experiences, and how sensory stimuli can be crafted to address individual needs. Haplós addresses this concern by maximising the user's ability to customise their sensory experience by allowing flexible motor placement and pattern design; Bisensorial addresses it through neuroadaptive algorithms, which can perhaps be useful in instances where the user does not have the ability to customise the system themselves. During our team's presentation of the project, Agi crafted a speculative design position for Bisensorial, which I quote here in full by way of conclusion:

> *With the onset of AI and autonomous systems replacing jobs previously reserved for humans, how might cognitive wellness and therapeutic practices look in the future? Can mental discord be treated autonomously? And might this have a better or worse effect on the future of healthcare? Given that people are different and will therefore need different interventions, how can autonomous brain based therapy technologies be tailored to suit the needs of individual users at any given time?* (Agi Haines, from the Bisensorial team presentation at Hack the Brain 2016)

Bisensorial was awarded first place out of eleven projects developed during the hackathon. Prizes were awarded based on the projects' artistic value, scientific merit, and commercial potential. Figure 63 shows the team receiving the award.

Figure 63: The Bisensorial team receiving the first place award for Hack the Brain 2016.

Chapter 6: Conclusion

6.1. Review of research contexts, aims, questions, methodology, and process

This practice-driven research is nested in the interdisciplinary network of cognitive embodied studies, from where it affirms the importance of body awareness by pulling in perspectives across philosophy, somatic practice, and the cognitive neurosciences, and weaving their analytical principles and pragmatic approaches through a technology-based design practice. Specifically, I draw from Shusterman's somaesthetics, the Feldenkrais Method, neuroscientific studies on the effects of vibrotactile stimuli on somatotopic organisation, and soma-based design theories and creative work.

This research is motivated by my prior experience with the aesthetic experience and utility of body awareness, which in turn is reflected in Foucault and his stance on self-fashioning and self-care, Dewey's aesthetics of experience, and Alexander's notion of the use of the self. The principal aim of this research was to explore how a somatic practice for developing body awareness can be translated into a technology-mediated somatic learning experience. To narrow the context of my inquiry, I revisited the four levels of body consciousness within somaesthetics, which draws in part from Merleau-Ponty's distinctions, and I identified my interest in third-level body consciousness, which I called somaesthetic attentiveness.

How can somatic aims, theories, epistemologies, and strategies lead the design of a wearable technology for facilitating somatic learning? To address this primary research question, I pursued a three-stranded, iterative research-through-design process composed of immersion into the FM, prototyping, and prototype evaluation. Each of these strands was composed of multiple activities that overlapped each other across time. In summarising these strands below, I weave in secondary research questions which emerged throughout the research process that followed from the primary research question, *What are the principles of FM?* Informed by the research literature on FM, I engaged in an immersion into FM practice by participating in part of an FM training course and practice-teaching FM lessons. The outcome was a conceptual framework of FM which I used to integrate the Method into a set of aims, theories, epistemologies, and strategies. *How can somatic learning principles from the FM inform the physical design of a somatic learning technology?* In the process of constructing this framework, I developed a theory of somatic learning affordances that I presented as part of the discussion of the framework, and which influenced choices I made in the prototyping process. It was during the initial stages of the immersion that I began to develop the idea of using vibrotactile stimuli as sensory cues. This choice—in conjunction with the theory of somatic learning affordances—eventually contributed to a set of vibrotactile somatic learning principles that are an adaptation of the FM framework.

Prototyping was a continual activity that took place at Kin in London, at Plymouth University, and, to a limited but still crucial extent, at the Hack the Brain hackathon in Amsterdam. The Awaken the Spine workshop was an evaluative study that kick-started the prototyping process. Keeping in mind Ginot's critical questioning of somaesthetics' relevance to the postcolonial condition and de Beauvoir's recognition that somatic experience is shaped by power, I decided to hold the Awaken the Spine workshop—which explored participant experiences of an existing somatic technology, a variant of Dean's Balloon-Spine Leg costume—in the non-Western context of the Philippines. *What are participants' experiences of the somatic learning technology prototype? To what extent are their experiences somatic learning ones?* The Awaken the Spine workshop results showed an overall positive response to the costume, and a notable portion of participant responses indicated that the costume did afford somatic learning, spurring the prototype development process that led to the earliest versions of the Haplós prototype. The prototyping process was also informed by the ongoing construction of the FM framework and my development of the notion of somatic learning affordances. *How can somatic learning principles inform the use of a somatic learning technology?* Applying the vibrotactile somatic learning principles to the Haplós prototype, I developed over time a set of Haplós configuration, usage, and instructional schemes.

In addition to the Awaken the Spine workshop, prototype evaluation was composed of the Manufactory public workshop, the Bizarre Bazaar demonstration booth, and continual prototype trials, as well as the Cravings study. Each workshop led both to refinements in the prototype design as well as protocols for successive workshops. All the remaining evaluative activities were held in the UK. As with the Awaken the Spine workshop, these studies generated positive user responses and indicated that the Haplós prototype afforded somatic learning. Specifically the Manufactory and Bizarre Bazaar studies showed that a one-sided vibrotactile pattern experience created a difference in the way they sensed and perceived each side of their body, in a manner similar to a one-sided FM lesson. The Cravings study used Haplós in a different manner altogether, configuring it with a bilaterally symmetrical arrangement of motors that played a precomposed pattern for participants, who were not told of its purpose nor guided through the experience. However, across all the evaluative studies, participant experiences of Haplós were consistent with what I anticipated they would be and designed for. I concluded that Haplós can facilitate somatic insight (if configured and using the schemes and heuristics I have developed) that resonates with FM experiences associated with higher-resolution somatosensory cortical representations. *How can vibrotactile somatic learning principles guide the design of vibrotactile patterns?* The evaluation activities led me to refine over time a set of somaesthetic heuristics for vibrotactile pattern design. In addition, the Manufactory and Bizarre Bazaar studies uncovered additional, participant-generated principles for vibrotactile pattern design.

The artifactual output of this iterative design process was Haplós, a system for enhancing one's proprioceptive sense through thoughtfully constructed and carefully directed patterns of vibrotactile stimuli. Its physical component is a wearable, portable, easily customisable technology that seeks to cultivate somatic insight in a way that is supported by the unique neurophysiological properties afforded by vibrotactile stimuli, and by a structured method for developing somaesthetic attentiveness.

While the research questions have, broadly speaking, remained the same throughout the research process, my engagement with FM provided added precision to my methods in three ways: it refined my observational skills as a research instrument, shaped my evaluation studies, and led me to develop a novel theory on how materials afford somatic insight. Firstly, I used FM to refine my expertise in somaesthetic introspection and participant observation; this allowed me to generate deeper, more meaningful insights from the somatic explorations that I conducted, the FM practice-teaching lessons that I led, and the design workshops I conducted. Secondly, I borrowed from FM instructional strategies to help structure my evaluation studies. For instance, I asked participants to feel themselves in standing and walking and to do a self-scan before and after the experience of Haplós. Finally, my engagement with FM contributed to the development of a theory on somatic learning affordances, with an emphasis on the unique insights that can be afforded by horizontal surfaces possessing specific material qualities. This in turn led me to reorganize the importance of surfaces in designing the Haplós learning experience.

Finally, I note that throughout the course of the research, the initial research goals were elaborated and made more precise through collaborations with members and partners of the CogNovo network; my experiences in immersing in somatic learning experiences; and the ongoing review of literature I conducted across the diverse knowledge formations in the embodied cognitive studies network. For instance, my secondment at Kin heightened my interest in creating a technology that could conceivably be easily integrated into everyday experience, and my conversations with Kin designers reinforced an initial idea that I had previously had of using vibratory motors as body awareness cues. My participation in the Somatic Costumes workshop led me to an initial prototype that I could evaluate and use as a starting point for further design explorations. An engagement with the issue of the postcolonial soma led me to decide to conduct my first evaluation workshop in a non-Western context, which forms part of my ongoing research. My exposure to the research methods in experimental psychology influenced the methodology of the Manufactory workshop and the Bizarre Bazaar demonstration, and afforded me an opportunity to test the use of Haplós as a cognitive intervention for cravings. The radically interdisciplinary network of CogNovo encouraged a fruitful collaboration which has led to an award-winning proof-of-concept that extends my technology into new research directions.

6.2. Summary of the contributions

This research makes a number of contributions to the research contexts from which it draws.

6.2.1. Soma-based creative work

The primary contribution of this thesis is in the area of soma-based design. In particular, I have developed Haplós, a wearable, portable, and easily customizable technology that seeks to cultivate somatic insight in a way that is supported by the unique neurophysiological properties afforded by vibrotactile stimuli, and by a structured method for developing somaesthetic attentiveness. It is composed of a set of hardware, software, textile, and user interface components, as well as a set of instructional guidelines and usage protocols as exemplified in the Manufactory and Bizarre Bazaar Studies. Haplós features easily but precisely repositionable motors; a GUI that can easily be ported for a mobile or web browser interface; a vibrotactile pattern authoring tool that can load existing patterns and save new ones; a random pattern generator; the ability to be remotely controlled over a local network or over the World Wide Web; pattern broadcasting capability; and physical integration into a wide variety of garments, furniture, and other artefacts.

I conducted an exploratory semi-structured workshop involving a derivative version of a creative work—Sally Dean's Balloon Spine-Leg Costume—and collected and analysed qualitative data that supports its ability to create a transformative somatic experience. Of particular note is that the workshop was conducted in the Philippines, contributing to the study of soma-based design in the context of a non-Western public. In addition, I proposed explanatory mechanisms, sourced from neurophysiology and an FM conceptual framework, for the participants' self-reports of somatic experiences.

6.2.2. Soma-based design theories

I developed a set of guidelines—vibrotactile somatic learning principles— to apply sensory stimulation for the purpose of clarifying the cortical self-representation. While the principles were tailored for vibrotactile stimuli, I submit that these can be ported to other sensory modalities.

I described a case study on applying vibrotactile somatic learning principles to generate a set of configuration and usage schemes for a soma-based wearable technology.

I described *Integrating somatic reflection for design* (ISRD), a method for generating soma-based designs where the designer undertakes a somaesthetic reflective session and allows their attention to wander and switch between their somaesthetic experiences, design ideations, and theoretical implications.

6.2.3. Somatic practice

I applied the use of Gibson's notion of affordance to develop the notion of a *somatic learning affordance*, which is the capacity of a thing to facilitate a particular type somatic learning. For instance, a flat, horizontal, and uniformly textured surface uniquely creates an interface that facilitates the refinement of the proprioceptive self-representation by *affording proprioceptive distinction-making*. If the mat is not completely flat, or completely horizontal, or completely uniform in texture, then any differences in sensation that an FM student may sense cannot be adequately attributed to a change in their neuromuscular organisation.

6.2.4. Cognitive neuroscience

I reported a practical application of the research pioneered by Karin Rosenkranz and John Rothwell (2006) into the effects of vibrotactile stimuli on somatotopic reorganisation by applying it to the design of a wearable technology for facilitating body awareness.

In collaboration with a team of artists and scientists, I created Bisensorial, a working proof-of-concept of a wearable, fully portable, individually-tailored, neuroadaptive vibroacoustic therapeutic device that uses musical fragments and vibrotactile patterns to induce mental states. Measurements of its wearer's brain activity determine what sensory stimuli or information is presented to the user, which is refined iteratively by a genetic algorithm to optimise the stimuli to the user's current state.

I reported on a speculative application in Haplós of a crossmodal association between vibrotactile stimuli and visual cues as a strategy for potentially strengthening the cortical reorganisation.

6.2.5. Experimental psychology

I reported on a controlled study into the application of short, carefully designed patterns of vibrotactile stimuli that reduced intrusive food-related thoughts with statistical significance.

6.2.6. Somaesthetic philosophy

I developed a speculative category for somatic experience—structured somaesthetic phenomena—that pertains to an awareness of features and relationships within the proprioceptive sensations as phenomenologically structured through the process of attending to them. An example of a structured somaesthetic phenomenon is the experience of anatomical relatedness.

Finally, I integrated the discourse from the cognitive neurosciences to provide a neuroscientific understanding of a novel application of somaesthetic philosophy. I proposed the notion of a vibrotactile somaesthetics that inherits from somaesthetics and that forms the conceptual framework of the Haplós system. Analytical vibrotactile somaesthetics comprises the set of theoretical positions formed by theories from embodied cognitive studies, including the embodied cognition hypothesis and theories on body awareness; somatic theories, particularly FM aims, theories, and epistemology; and neurophysiological theories on vibrotactile stimuli and its influence on somatosensory organisation. Pragmatic vibrotactile somaesthetics is the set of prescriptive strategies for facilitating somatic knowledge as well as creating tactile and aesthetic experiences through vibrotactile stimuli, which include vibrotactile somatic learning principles; configuration, usage, and instructional schemes; and somaesthetic heuristics for vibrotactile composition, which in turn derive in part from FM teaching and learning strategies. Finally, practical vibrotactile somaesthetics are that aspect of vibrotactile somaesthetics that cannot be captured in words and must be experienced to be understood. I reported on a public engagement event during which I facilitated direct, practical somaesthetic experiences through demonstrations of Haplós with members of the public.

6.3. Future research and development plans for Haplós

Plans for future research and development for Haplós are in place. They involve enriching existing usage scenarios, refining and expanding its current technical capabilities, and exploring new applications for patterned vibrotactile stimuli.

6.3.1. Enriching existing usage scenarios

As noted in this thesis, spatial discriminations studies suggest that individuals can discriminate between tactile stimuli with an interstimulus spacing of a minimum of 2 to 3 cm. During my informal experiments I conducted using Haplós, I noted that with sufficient exposure I could discriminate motors that were spaced more closely than this. This warrants an investigation on whether individuals can be trained to make finer discriminations, increasing the somatotopic representations (and perhaps refining motor action) in stimulated areas in ways that have not been previously explored.

Another potentially fruitful direction for future research involves investigating the application of Haplós to other parts of one's self. Specific lessons and guided experiences could be developed based on where the vibrations are being applied. For instance, I sketched the following guided lesson for experiencing the relationship between the TFL and the movements of the hip, based on my TFL stimulation experience:

1. LYOB, bend your legs, and plant your feet on the floor.
2. Gently push off the ground with one foot, letting the pelvis roll. Do this several times, well within the range of ease and comfort.
3. Do the same action on the other side. Compare which side feels easier.

4. Arrange a line of motors along the TFL of one leg, starting from the outer knee (close to the lateral epicondyle of the femur) to the anterior superior iliac spine of that side, following what Myers (2014, Table 5.1) calls the Lateral Line of the myofascial system.
5. LYOB with both legs out long.
6. Activate the motors by playing a predesigned vibrotactile pattern, or use the GUI to explore vibrotactile sensations. Do this for 1-2 minutes.
7. Bend the leg that is being vibrated, and this time push off the ground with this leg to repeat the movement from step 2, while the motors are playing. Do this a few times.
8. Let your legs lie out long and take a rest for a few minutes.
9. Do the movements again from step 2, on one leg then the other. Does the movement feel different? Is the difference in sensation and ease movement more or perhaps less pronounced than before?

In addition to body area-specific stimulation, I propose that Haplós motors could be attached to along the length of one's entire body and be used to aid full-body scans, a practice that is done in somatic traditions such as FM and yoga**.** In a sketch I made in my design diary, I imagined a version of Haplós wherein motors are distributed from the base of the skull, down the length of the back, the buttocks, the back of the legs, and right down to the heels. A vibrotactile pattern can then be played that could sweep throughout the surface of the entire body, perhaps in wave-like phrases punctuated by periods of silences. This sweep could be of varying frequency, since my experience of conducting somatic self-scans over the years has taught me that one can become quicker at conducting a self-scan and refamiliarising with oneself. Haplós can be tailored to the user's experience with somatic practices, and its usage can evolve along with its user's somaesthetic expertise.

Paying attention to the vibrotactile stimuli—an important part of the somatic learning experience—can be achieved in different ways. For instance, there is potential in developing what could be thought of as 'vibrotactile games' for sensory discrimination that are intended to playfully engage the user's attention. For instance, users could be asked to discriminate between different patterns. Motors could be arranged in a bilaterally symmetrical way (e.g., one cluster or line of motors on each arm. A programme loaded on the GUI can then sequentially play increasingly complex patterns. The user's task would be to correctly identify whether the pattern played on one side is different from the pattern played on another. Inspired by a suggestion during the design critique at Kin, the GUI can play a repeating pattern that changes gradually (though unpredictably) over time. The user's task would be to indicate whether they've noticed a change in the pattern, with points awarded or deducted for correct and incorrect answers respectively. In general, gamification and play could be another way to keep users engaged with the vibrotactile feedback provided by Haplós.

6.3.2. Exploring new applications

Haplós could be applied to existing therapeutic approaches that already incorporate touch for technology-mediated therapeutic approaches with a tactile modality. Related work includes that of Chen et al. (2016), who have reported using mini robots to seek and stimulate acupressure points along the back, while Morrison et al. (2017) have reported using vibrotactile stimuli to "meridian" points. A practice known as Havening (Thandi, 2015) involves tapping parts of the body with a therapeutic intent; Haplós could conceivably be deployed as form of technology-mediated Havening. During the course of the research and only to a limited extent, I explored the application of Haplós to other areas of my body, including areas around the TFL band, the costal margin of the ribcage, and the region around the anterior superior iliac spine of the pelvis. These have generated unusual and notable experiences, as I recorded in the associated primary data sources (#P0.170304.ProtoTrial.a5, #P0.170322.ProtoTrial.a5, #P0.170322.ProtoTrial.a5), including more mobility in the hip socket (in the case of TFL stimulation), but also an initial feeling of tension and discomfort along the entire side of my body in the two other cases. However, these senses of discomfort resolved to a feeling of relief and pleasure and even vulnerability a few minutes after the stimulation had ceased. Haplós—and particularly in its incarnation as Bisensorial—could also be used as part of interactive intervention for improving the gait of people with neurological diseases, such as Parkinson's patients (Hove, Suzuki, Uchitomi, Orimo, & Miyake, 2012), who have been shown to respond well to a music therapy technique called rhythmic auditory stimulation (Hove et al., 2012). Finally, some users of Haplós noted that they felt sleepy while experiencing the sensations. For instance, in the case of one participant, he noted that after one minutes of experiencing a rather fast pattern, he reported feeling like he was "drifting off" and felt sleepy. This (and other anecdotal evidence I gathered during the research) suggests that Haplós be used as a prospective sleep aid, perhaps in combination with biofeedback or neurofeedback that can modulate motor timing and intensity envelope.

A key feature of Haplós is its capacity to be operated remotely. Because Haplós' motors can be wirelessly controlled by a device physically separate from the garment, remote interactions are possible. Haplós could conceivably be used as a way to communicate touch across a distance and facilitate remote presence in real time. The explorations that workshop participants did in the Bizarre Bazaar and Manufactory workshops of composing vibrotactile compositions for each other would be the starting point of this research direction. Another significant new research opportunity lies in Haplós potential to aid with teaching somatics from a distance. Can somaesthetic knowledge be cultivated through training delivered at a distance? Perhaps technologies such as Hapós can be used as a teaching aid for online and distance teaching of body awareness by using its capability for mass-broadcasting of patterns across the Internet.

6.3.3. Refining and expanding current technical capabilities

There are a number of ways in which the current technical capabilities of Haplós can be refined or expanded. For instance, the communication between the microcontroller and the GUI could be made more efficient with a different low-level communication protocol such as WebSockets, or by restructuring the information structure of data packets so that the system is more robust to data dropping. In addition, new vibroacoustic and vibromechanical devices continue to be announced, such as a tension-based vibroacoustic device introduced to the public last year by Yamazaki et al. (2016). It is worth exploring how different types of vibrotactile actuators might influence a user's experience of the Haplós system. Similarly, it would be good to explore different features of the motors, including pitch and "roughness" (Giordano & Wanderley, 2013).

Much is to be gained in exploring the use of vibrotactile illusions such as saltation and funnelling, which have already been used in existing research discussed in section 2.5 but mostly in relation to enriching human-device interactions. Rahal et al. (2009) report being able to leverage vibrotactile illusions to generate "a high quality of continuous movement" that simulate the sensation of being stroked by a human finger based on careful choices in inter-stimulus distance and the total duration of the pattern. This work exemplifies the overlooked potential of vibrotactile illusions to create novel affective and social experiences.

As described in this thesis, Haplós can be incorporated into a variety of existing clothing and artefacts. Other form factors—such as bags, underwear, mattresses, tights, cradles, hammocks—already designed to hug, enfold, or support the body could be equipped with Haplós motors as programmed by the GUI. Indeed, the Bisensorial team has recently proposed that a site-specific installation that would function as both a performative event as well as a research tool. The installation involves a cushioned table or reclining chair equipped with Haplós, and coupled with a mobile interface for users to design their own vibrotactile and somaesthetic experience.[74]

6.3.4. Concluding remarks

Moshe Feldenkrais is often credited with asserting that if you know what you are doing, you can do what you want. To know oneself, in turn, is to sense oneself. In refining our apparatus for self-sensing, somaesthetic practice and technologies ultimately allows us to feel more of ourselves and to feel more *like* ourselves. Self-sensing is part not of only being human but of *becoming* more human. In this thesis, I have documented and critically reflected on the process that led to the creation of a somaesthetic technology for improving self-sensing. Through carefully constructed patterns of vibrotactile stimulation, Haplós aims to elicit self-reports of heightened body awareness by supplying the user with higher resolution information about their body.

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[74] Soon after this thesis was first examined and passed, the Bisensorial team proposal was awarded a grant by the EU Commission to build this installation in partnership with DART 17, a development lab in San Francisco where the Bisensorial team will be taking residence in 2018. http://www.cognovo.eu/news/re-me-dart17.php

While this thesis must come to an end, the research and creative work that it documents need not. But to continue the work, a shift must be made from "I" to "we", as the future development of Haplós necessitates continued interdisciplinary collaboration, intellectual generosity, and strategic partnerships across the world. The most interesting (and unpredictable) pathway for future research with Haplós involves giving the technology away to hackers, designers, somatic enthusiasts, citizen scientists, and students to explore and play with—wherever they are in the world, and most certainly in non-Western communities as well. (Indeed, I am writing this conclusion mere days before I deliver a talk about and demo of Haplós in the Philippines, where I conducted the first workshops studies for this research. The work has come full circle.) To this end, I and other members of the Bisensorial team—in collaboration with other partners—have committed to work towards developing a low-cost open source toolkit based on Haplós that will allow anyone to explore potential uses of Haplós.[75] Our aim is to empower tinkerers to be able to experiment with the potential of vibrotactile and vibroacoustic technologies, and physical computing technologies in general, for well-being and play. Haplós generates promising possibilities for innovative cognitive interventions and novel aesthetic experiences and forms. We look forward to reporting on their development.

[75] See http://tinyurl.com/reme-bozar-pitch.

Appendices

Appendix 1. List of Acronyms Mentioned in Text

Acronym	Meaning
ASIS	Anterior superior iliac spine
ATM	Awareness Through Movement®
BBAT	Basic Body Awareness Technique
BCIs	Brain-Computer Interfaces
DMP	Developmental movement patterns
DSSM	Diego Silang Santos Maranan (Author)
FI	Functional Integration®
FITC	Feldenkrais International Training Centre
FM	Feldenkrais Method®
FMRI	Functional Magnetic Resonance Imaging
FOF/FotF	Feet on the floor
GUI	Graphical User Interface
HCI	Human-Computer Interaction
ISRD	Integrative Somatic Reflection for Design
LB	Legs bent
LS	Left side
LYOB	Lie on your back (I might also use it to refer to lying on *my* back)
OSC	Open Sound Control
PWM	Pulse Width Modulation
RS	Right side
SC	Somatic Costumes™
TFL	Tensor fascia latae

WBV	Whole Body Vibration

Appendix 2. Cravings Experience Questionnaire

Introduction

The Cravings Experience Questionnaire (CEQ)(Andrade et al., 2012) is a craving scale that measures craving factors as predicted by the Elaborated Intrusion theory of desire (Kavanagh et al., 2005). It measures the strength, frequency, and intrusiveness of the intrusive imagery. The version of the CEQ used in the Cravings study measured only strength and frequency.

#____________ CEQ-11

Think about the time in the LAST 5 minutes when you MOST WANTED chocolate.

For each item, mark an X in a box to make your rating.

At that time…		0	1	2	3	4	5	6	7	8	9	10	
…how much did you want it?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extremely
…how much did you need it?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extremely
…how strong was the urge to have it?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extremely
At that time, how vividly did you…													
…picture it?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extremely
…imagine its taste?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extremely
…imagine its smell?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extremely
…imagine what it would feel like in your mouth or throat?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extremely
…imagine how your body would feel?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extremely
At that time…													
…how hard were you trying not to think about it?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extremely
…how intrusive were the thoughts?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extremely
…how hard was it to think about anything else?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extremely

PLEASE TURN OVER

Now we want you to answer some similar questions,
but this time please answer HOW OFTEN these things happened in the last 5 MINUTES.

Over the last 5 minutes, how often did you		0	1	2	3	4	5	6	7	8	9	10	
… want it?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Constantly
… need it?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Constantly
… have a strong urge to have it?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Constantly
… picture it?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Constantly
… imagine its taste?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Constantly
… imagine its smell?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Constantly
…imagine what it would feel like in your mouth or throat?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Constantly
…imagine how your body would feel?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Constantly
Over the last 5 minutes, how often													
… were you trying not to think about it?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Constantly
… were the thoughts intrusive?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Constantly
… was it hard to think about anything else?	Not at all	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Constantly

Appendix 3. Immerse Primary Data

Introduction

Appendix 3 contains Immerse primary data for the following research in this thesis: somatic exploration (SE), practice-teaching Feldenkrais Method (both Awareness Through Movement (tATM) and Functional Integration (tFI), and training data.

Participant data strings are coded as follows:

#ParticipantNumber.Year/Month/Day.ResearchCategory.AppendixNumber

For instance, #P42.170325.tFI.a3 would read as Participant 42 on March 25, 2017, participating in a Functional Integration practice-teaching FM class. Please note that, in the somatic exploration data, the author is both participant and observer. In the other Immerse primary data, the author is coded as #P0 (Participant 0), e.g., #P0.150213.SE.a3.

Somatic Exploration Primary Data

The Somatic Explorations were somaesthetic introspective sessions I conducted using ISRD framework.

#P0.150213.SE.a3

From sullen to voluble

I am in class. I am quiet and sullen. We stretch our hip flexors. The teacher puts her weight on my pelvis. My hip flexors stretch. After the stretching session, I am more voluble, lively.

Context	Dance Class
Theoretical Implications	What's went on here? Is this reproducible? Is it generalisable? Sometimes I find it hard to interact with people if I am in physical pain or discomfort; did stretching merely alleviate that discomfort and subsequently give me more latitude to talk to others? But I don't remember feeling in pain or discomfort, and my notes didn't indicate that I was… simply that there was a change in my behaviour after the stretching.
Design Implications	–

#P0.150529.SE.a3

The reason I'm learning Feldenkrais and taking anatomy courses is because I want to describe my feeling *anatomically*. I want to be as precise and evocative as I can. For example, when I talked about feeling what it's like to have a dog's body, I came up with my ideas precisely because I had a clear(er) understanding of the bones and muscles in my iliosacral region.

Now that I've finished my first Feldenkrais training, I have better idea of what the shoulder girdle is like not just from a third person, "academic" perspective, but I can actually sense the different bones in my body.

So right now what's happening is that I'm being influenced by Feldenkrais training to be sensitive to bony landmarks, to movement and how they change the skeleton, etc.

Thus my training in *experiential anatomy* will provide me tools to investigate what it's like to be in another body.

Muscular tension: part of trying to understand what it's like to be in another person's body is to be able not only to imagine but to *simulate* their bodily experiences. but I need to be able to move in and out of those simulations. So being able to identify and embody their muscular tensions is important, but I
also need to learn how to get out of it. This is very much in the approach of actorly training.

Context	Unknown
Theoretical Implications	This note was from quite a while back, when I was still considering physiological empathy as something within the bounds of my research. It no longer is. However, I can speculate about how creating unusual sensations might be used to create novel proprioceptive sensations that might be mapped to others' physiological experiences (e.g., my example of a dog shaking off water) in the concluding chapter [170310]
Design Implications	–

#P0.150706.SE.a3

Ran with M__. For the first time in literally YEARS, i decided to a full-on, 20 minute hamstring stretch. it's so different now that i'm aware of my pelvis more.
at one point, i was lying down and i decided to put my hands on my lower abdominal muscles, just where they;re about to insert on my pubic bone, the southernmost tip of the "diamond" as it were… and i realised (again? or more than ever? with shocking clarity?) how little i know about that area. AND THEN i realised what i meant by that phrase "how little i knew about that area". I could feel it moving up and down with my breath and i realised that i've never really recognised what that moving was like. and i realised that this was one of the disconnects in my body, one of the bridges between upper and lower halves that just seemed to be missing. and i'm wondering what would happen as i increasingly make the connections between my upper and lower halves again…

tech tool idea: what about a phone or device that just constantly or occasionally vibrates? to just remind you of a body part?

Context	Doing some stretching post-running
Theoretical Implications	• Disconnects in the body (breaks in the pattern) that interferes with Gestalt pattern formation? [170309] • Learning process (Burch competence model?). Could this be from http://www.doceo.co.uk/tools/knowing.htm [170309]: you don't know what you don't know you know what you don't know you know what you know you don't know what you know
Design Implications	– First mention of vibration for body awareness in my notes and memo; "tech tool idea: what about a phone or device that just constantly or occasionally vibrates? to just remind you of a body part?" [170309]

#P0.150725.SE.a3

I can feel my hips moving in response to turning my leg inward. there's a pull on the lower back that nudges my sacrum towards the direction of the pull from underneath

I realise that I really should be more humble in class: both physically and mentally. a deep humility in learning.

Fascia. Fascia in my lower back: what's going on?

I can feel my back aching after all the lifting and walking and bag carrying. It came with the excitement.

Big assumption? (or is it): that symmetry is preferable. but question is: preferable to what? and why? (and who told you to ask?)
- but maybe it's not. or maybe we like the feeling of symmetry. (*why?*)

Total relaxation isn't the goal (as kristin linklater has pointed out), but an awareness that our muscles fire up in response to threat (flee or fight response) allows us to release the muscles when we don't need them.

Social anxiety: presence of other people can trigger the flight or fight

response.

Our previous body schema and our associated pains, fears, and reluctances are remembered and are being undone: it's like "my body" "saying" to "itself": "Oh but it begins to hurt when I do it that way".

I just realised how opaque my pelvis is to me. But the fact that I realised it is an amazing thing: i am now aware of what i am unaware of.

As I'm rolling around my right femur in its ball socket, i am realising/remembering: I've always had problems with this hip. First the physiotherapist, then me while biking. And strongly suspect that my wallet is the culprit!

Is attending to the entire body a serial process or a parallel process? Am I scanning in regions and then integrating? Or am I learning about the entire body as a set of interrelationships? Or a bit of both?

Wait. I think the weakness in my lower abs has cause me to use my hip flexors to compensate. And maybe it's not so much weakness (although there is that too) as a lack of awareness and *inability to make choices about how i use that part of myself*? (note: i'm not using "my body")

Discovery while doing a developpe lying down and allowing my muscles/fascia to pull my pelvis and my other leg
My bones surely cannot be symmetrical. So what it is that i have a partiular body tuned to particular parameters, and I am doing a *constraint-satisfaction* problem through self exploration. Two things note: the ultimate goal is to minimise pain and discomfort and to maximise ease and pleasure; it is likely that no set of parameters can yield *the* optimum solution

Context	unknown; probably directed somatic explorations at home
Theoretical Implications	1. "Is attending to the entire body a serial process or a parallel process? Am I scanning in regions and then integrating? Or am I learning about the entire body as a set of interrelationships? Or a bit of both?" 2. These days, I wouldn't say my pelvis is opaque to me. In fact, more than ever, i have a clearer image of the internal architecture of my pelvic area. Over the course of this research, i've become more aware of myself. [170310] 3. The notion of any activity, behaviour or function as a constraint-satisfaction problem. (cf. Field, 2010)
Design Implications	Sometimes new sensations can be uncomfortable, especially if there there's an asymmetrical exploration (one-sided lesson) going on. (cf #A5.PE.161022.P30)

#P0.151005.SE.a3

I did yoga for the first time in a long time, and I was shocked at how my body/self/movement had changed. (It felt like it really helps that i didn't do it in a long time, that i could "forget"). I could feel the weight of my torso much more, especially lying upside down. I felt the action of the flexors in upside down as well. IN the one-legged series, I could balance better on my leg, and felt like i could better (not completely) feel the counterweighting of the torso and my led. i was more aware of the action of my head and neck in relation to my torso…. my warrior postures were more open and deeper… Everything felt so pleasurable… the more slowly i did something the more pleasurable it became… Where does this pleasure come from???

Context	After a yoga class
Theoretical Implications	1. More evidence that not just my ability to sense my self but better at action improved during the course of the research 2. An example of slow is pleasurable
Design Implications	My current experimental pattern for the cravings is too fast. The whole halving and doubling of temp is a mathematical relationship, not really an organic one. I must change it.

#P0.160331.SE.a3

At the gym. I'm exploring my ribs. I need to do some of my exploration at YMBBT studio. I've just spent palpating my left ribs and treing to feel how moving them (particularly the floating ribs) affects the rest of my spine.

I just touched my left floating rub along the costal border and suddenly the vision in my left eye improved. Why?

No, not while palpating the costal border. It was while I was tracing the path of the rib so I could feel how it connected the back and front.

Now my right hand feels more open. Fingers release

Rion just interrupted me. I stood up. My entire left side feels different: I can stand more easily on my left leg. I feel my torso connected to my legs through pelvis (although much of my pelvis still feels unknown). But I certainly feel like I have a better sense of my ribs. My head wants to tilt in one direction. Damn I have such an imbalance with my head.

I'm switching to my right. I'm trying to move the ribs. Something doesn't feel right. I mean I'm feeling some of that vision clearing thing again but the quality of touch isn't good. It wants to do too much. It needs to be more curious. How can my motors have the same kind of curious quality? How can they suggest that they are asking a question??

Context	[at the gym?]
Theoretical Implications	–
Design Implications	–

#P0.160405.SE.a3

While jiggling my pelvis on the floor and feeling my torso and legs and feet moving in response, I think: all my costume does (and all that FI and FM does) is remind ourselves that our bodies and minds are intimately connected.

Why is it important to revisit old movement patterns? This question cropped up while I'm lying on the mat and suddenly rediscovered the movement of extending the head while rocking my pelvis to one side using the standing foot on the other side. Like a baby. Well, I thought about how amazing it is to return to a basic ballet class and do the simple movements again. Suddenly I had a deeper understanding of what a plie was. Similarly FM affords me a deeper understanding of what lying means, or raising my arms, or turning

Why do I care so much about the shoulder blades? I'm thinking this as I'm doing a flexor fm exercise that requires me to release my shoulder blades and let it be supported by the strength of my arm as much as possible. I think it's because I'm realizing that the organization of that upper chest and back organizes the head and neck and vision. I can see more clearly now.

Context	
Theoretical Implications	–
Design Implications	–

#P0.160408.SE.a3

While doing the pelvic clock, I discovered no less than 30 very subtle snapping sensations in my right foot (I counted), near the outside and top part of my foot. This was while I was doing the pelvic clock from 3 to 9 (or vice versa). I had noticed a connect between my foot and my pelvis before, but I had never counted a discrete number of snaps. There were also snaps in my left foot but I didn't pay as much attention (why?) and there weren't as many (why?). When I got up and walked my right foot felt flatter, more grounded, bigger. Like duck feet.

I think my initial discovery from several weeks back played a role in me discovering this relationship.

I'm sitting down now and I can feel the snaps on both feet as I do really subtle movements.

How did I discover this? I set my mind blank. I waited for sensation to catch my attention. I was probably primed by my prior discoveries.

30 snaps!

On the treadmill now. My two side feel SO different. My right foot feels actually warmer. And softer. And more responsive to the ground. I feel the work in my right calf. My left feels incomplete. Too much weight out in the outside. I feel a weird thing in my left inside knee

Context	
Theoretical Implications	–
Design Implications	–

Figure A3.1: Looking down at my feet

#P0.160611.SE.a3

I was using my soft hands to move my pelvis (giving us elf an FI) when I realized a justification for putting motors on bone. In FI the idea is to put two skeletons in contact with each other. Skeleton moving skeleton. You want to move skeleton, not muscle

Now I'm feeling again the relationship between the bottom of my feet and my hip flexors and in reminded that I'm really a whole entity. I think it's one thing to know, and another thing to EXPERIENCE yourself as a whole entity. And not just a whole entity but one that is connected and interacting with the world. A bit g a paradox: I am both a whole entity as well as made up of many independent components

These realizations were brought about by discovering unexpected relationships between different parts of myself. How can haplos help them discover which relationships (e.g. Shoulder-fingers, feet-hip flexors) to pay attention to?)

Context	
Theoretical Implications	–
Design Implications	–

#P0.161014.SE.a3

AudioRecording 20161014 08:54:17.m4a	[UNTRANSCRIBED. SUMMARY: Might be the first time that I talked about the reason for exploring the back (specifically area between the shoulder blades) using Haplós. I can bring—through touch—these parts into my body image. But not the back. For me to be able to touch my L shoulder blade, for example, I need to have quite a lot of mobility in my R shoulder and arm in the first place. I think also the first time where I talk about putting Haplós ribbons near the spine of the shoulder blades. Also hypothesised that touching or moving the L side—basically putting attention to my L side—might be facilitating some of my eureka moments. (which happened a few more times in this session)
AudioRecording 20161014 08:59:04.m4a	[UNTRANSCRIBED. SUMMARY: Example from a memory of the past showing that when i wasn't as proprioceptively sensitive, i used to need a lot of movement stimulus to feel something]
AudioRecording 20161014 09:07:11.m4a	[UNTRANSCRIBED. SUMMARY: Using motors to stimulate yourself—and maybe using voice activated controls to control Haplos—instead of your hands can help you create a more controlled experimental environment in your self.]

AudioRecording 20161014 09:25:18.m4a	[UNTRANSCRIBED. SUMMARY: Decreasing of muscular tonus is pleasurable]
AudioRecording 20161014 09:31:25.m4a	[UNTRANSCRIBED. SUMMARY: Using terms that are less fraught with connotations (e.g., "relax", "relaxation") and using more objective—and accurate—terms ("muscular activation", "muscular activity") enables us to approach and explore ourselves more dispassionately, with less judgment, and potentially with more curiosity.]
AudioRecording 20161014 11:09:07.m4a	[UNTRANSCRIBED. SUMMARY:] Because of brain lateralisation—some cognitive processes are more dominant in one hemisphere than another—can unilateral stimulation influence cognitive processes? Influenced by the observations that I made during some ISRD sessions (e.g. #A3.ISRD.161014) that many of the times I would come across a Eureka moment when I was moving the left side.]

Context	Walking down the Crescent in Plymouth, then later on the gym?
Theoretical Implications	1. Haplós makes it easier to self-stimulate yourself without placing huge demands your organisation 2. Haplós makes it easier to self-stimulate yourself without disturbing you organisation so you can create a controlled experimental environment 3. The importance of value-free words and instructions in order to avoid judging yourself and to encourage curiosity about yourself 4. Speculative use: unilateral stimulation as cognitive intervention based on brain lateralisation?
Design Implications	Need to include voice activation in the future

#P0.170105.SE.a3

AudioRecording 20170105 10:14:13.m4a	First day of really working in 2017. I'm walking down Armada Way. This morning i had a twinge in my right hip, i was working through it, lying on the floor, knees bent, shifting/pushing the ground alternately, allowing the pelvis to one side then another, finding where they were stuck, realising that i was unnecessarily holding my lower back. PARTIALLY-TRANSCRIBED. KEY MEMOS AND NOTES:

	Feeling connected is a really pleasurable sensation. Just feeling my body, feeling myself, feeling my toes. Changing the representation of the Enfield homunculus feels good.

Context	Walking on the street
Theoretical Implications	Feeling connected is a really pleasurable sensation. Just feeling my body, feeling myself, feeling my toes. Changing the representation of the Enfield homunculus fields good.
Design Implications	–

#P0.170107.SE.a3

[No Audio]	As I was entering the gym I was noticing how I continued to attend to the soles of my feet. I was thinking about how my attention to them has really helped me feel less anxious, more relaxed, more grounded. I recall that class in impulstanz in Vienna ages ago when the ballet teacher remarked on how it was all about tension in the feet. I also recall now how difficult it was to sense tension in my body when I was training as an actor. Could haplos help people sense muscular tonus better? I don't know.
AudioRecording 20170107 10:27:14.m4a	Reflecting on how my obssession [on virtuosity] from long ago is comign back. [Or actually has been the underlying motivation for many things..] This idea that technique and skill is related to being able to do as many things as elegantly as possible. And by elegantly, i mean with as little damage the to instruments as possible, either the body of the performer or the tool being wielded. To play quickly or loudly without damaging or overtiring the body. That's virtuosity: doing as much as possible using as little as needed in order to help preserve the resilience of the system. So there's something about resilience as well. I disocvered this while doing the usual rolling my pelvis [probably lying down, with legs bent, feet on the floor, pushing the floor with one foot then another]. Not sure whether they're connected, ha.

AudioRecording 20170107 10:36:36.m4a	Lying down on my back, knees on my back, rolling my pelvis side to side. I'm doing it really, really, REALLY slowly now. AS I'm doing this I'm feeling those kind of plasticky ticks in my feet [as before in previous sessions], but i can also feel them in my forearms. So clearly i'm begining to sense how all the body is connected, that it's one whole. How the movement of one part can relate to another. I've [reported? read?] on this before, but i think this is probably the first time that I'm really feeling it both in my upper and my lower body. Usually, when i'm doing the rolling of the pelvis, i can feel it in my feet, sure. but now, because I knew [intellectually] that the body is entiorely connected, i began to [see if i can] sense if i can feel it in my forearms, in my upper body as well. I was looking at my shoulders but I didn't feel it so much in my shoulders. But I can sense it in my forearms and my fingers. And I don't know what those sensations are; is it the fascia? Is it…? It's *something.* I can feel it right now in my left palm as I'm leaning against it. I'm going to take a photo right now What made me got up and record this is this idea [that suddenly sprang to mind while rolling around]: there are many pathways into experiencing/discovering the connectedness and the wholeness of the body. Movement is one of them, which is what I'm doing now. But maybe vibrations like as an external stimulus [as opposed to internal stimuli, like the proprioceptive senses upon which I'm relying on right now] is another.
AudioRecording 20170107 10:43:35.m4a	Why do I work on my pelvis so much? I think I'm realising that it's because it's … the central node [of a network]. And if there's any one place in mu body that i should move to feel the connections, it's that. It's my pelvis. [NB: Consistent with feldenkrais focus on the pelvis]. Putting vibrations in the upper shoulder makes sense in that it can influence hand dexterity, but i dont think it's going to do anything for the legs and the feet. And the workshop protocol can be modified to verify this. The question with the pelvis is where exactly should i put the vibrations? The lower back? Yeah, there's something the lower back.

AudioRecording 20170107 11:13:06.m4a	I really should use the ribbon for all the clothing and come up with a nice [and soft] form factor for the electronics.
	There's something about trying to get back not (just) a trancelike state but a childlike state. To the state of childlike learning... While standing around waiting to get back on the assisted pull-up machine, I thought: Soles of the feet are invisible! Just like the back! As part of becoming more aware of myself I simply am becoming more aware of the parts of myself that I don't see! I'm lying down and I'm doing little pelvic clocks. Finding new clicks, stretchy feelings in the lumbar:
AudioRecording 20170107 12:45:45.m4a	PARTIALLY UNTRANSCRIBED. KEY NOTES AND MEMOS: Justification for putting motors not on the spinous processes, but on the “groove” on either side. [In this note, I talk about “insertion points” on the spine, but two errors: 1) anatomically speaking, they would be the origins, not the insertions; 2) I’ve been reviewing some online dissection videos, and the cutaneous layer is really thick. I don’t know how much the vibrations can penetrate that. But it might be possible, and maybe there’s some kind of information transfer that goes on via the nerves that innervate the cutaneous layers… 170310]
[No audio]	I must clarify that by functional I or Feldenkrais means intentional, or. Behavioural , or neurological In the change room now. Sitting on the bench, right leg crossed right angles over left, I bend over to pull a sock on. I don't just feel the lengthening of my muscles down my lower back... I feel it all the way down to my lower left foot. It is amazing. Sensing connectivity is PLEASURABLE.

Context	Gym; change room
Theoretical Implications	1. "Sensing connectivity is PLEASURABLE”. [170310]

	2. The importance of sensing the feet for calm action [170310] 3. 'Somatic evidence' suggesting the connectivity of the body (movement in torso results in clicks in the feet) [170310]
Design Implications	• Where Haplós might be put to use: in parts of ourselves that we can't or normally don't touch (between shoulder blades, between the toes, etc.), though must guard against the tickle sensation. [170310] • Rationale for putting the motors where I initially did: the 'spine FI'; wanting to get to the origin of the aponeurosis; wanting to be able to create bilateral comparisons. [170310] • Creating a state of child-like wonder, facilitating curiosity: how do I do this? I'm almost beginning to have a vision of setting up a special womb-like room where Haplós can be worn. [170310] • Hey, this reminds me of this original idea I had: a room where the motors are kind of built into strips and cocoons and sinewy pillars that snake out of the walls... [170310] • " use the ribbon for all the" form factors

#P0.170118.SE.a3

AudioRecording 20170118 10:48:28.m4a	I'm rolling the pelvis but then using my eyes to roll left and right as well; first followign the movement of the pelvis, and then doing the opposite direction. Then I was reminded this idea of making things complex in order to make the simpler things easy and elegant and less effortful. And then I thought how do I apply this to the context of Haplos? You could apply a simple pattern first, which initially may not be clear to someone, and you lead them through more and more complex versions of the pattern, and then you return to the simple pattern, and you think, "wow, that was really simple [after all]". And it kind of reminds me of Steve Reich's *Piano Phase*; it's almost like you hear the music, and then you [*garbled*] when you first hear the unison, and then it complexifies, [and then when you return to the pattern again] there's this sense of relief, in coming together. It also reminds me of what Jack says [when he tried out Haplos with Sean's binaural beats], when he took it off, he said the silence sounded like something, and that he could hear his voice echo in the room differently

Context	Fitness centre. FM-style exploration.

Theoretical Implications	Complexification as a method for making the simple pleasurable and elegant and meaningful [n.d.]
Design Implications	1. Experiment with Steve Reich *Piano Phase* as peg for a vibrotactile composition [n.d.] 2. Try the *kulintang* music repertoire as a peg, whose structure maps quite clearly as that [n.d.]

#P0.170127.SE.a3

AudioRecording 20170127 10:03:56.m4a	Instead of exercises that I do after wearing the vest, I should do one that leverages the proximal-distal connection, which is for example touching my right shoulder blade using my left hand (laying on my back), then putting my weight on my right foot. And then pushing from my right foot so that my pelvis begins to tip over to my left but my upper torso is fixed. That involves some passive movement in the upper shoulders [which are fixed because of the left arm], but it should allow for more mobility (because of whole-body connection)
AudioRecording 20170127 10:06:36.m4a	I should come up with long and short versions of the study. The long version would include some drawing. Of both the front AND the back of the body.
AudioRecording 20170127 10:23:26.m4a	First off, new term: embodied introspection. Second, new exercise: Cross one arm over the chest, one foot on the mat, and do all the different kinds of explorations that I've already been doing, but do it in a rhythmic rocking motion. Then change arms. Then change sides. What I found was that my breathing changed. I became more aware of my chest. I think just being reminded of the ribcage is a fantastic thing. And I think that maybe Haplos (when placed on the back) is not as good [for reminding one of brething] as when it is placed closer towards the front or sides, where there would be more contact with the ribs [and intercostals]. I shoudl also really pay more attention to the breathing of the participants to see how it changes.
AudioRecording 20170127 10:11:01.m4a	Lying on my side, feeling how the movement of the hips are connected to the pelvis [??]. Kind of

	palpating my ribs softly. It's really surprising to realise that i have a skeleton. Like *really* understand it. I don't know how it makes me feel. i don't know yet. Which makes me realise something: that people will sometimes report feeling something, but wouldn't know how they like it. [They may not even be able to articulate in words what that feeling is like]

Context	In the gym
Theoretical Implications	This is also a design-related issue: do multiple checks (see points 1 and 2 below) because I don't know which part of user's selves they will necessarily detect a difference. Everybody is configured a bit differently. [170308]
Design Implications	1. After stimulating the thoracic area, get users of Haplós Somatic to explore pushing the floor with a foot while LYOB, or rotating legs inwards, or doing a pelvic clock, to show the connectedness of the body and the proximal-distal relationships [170308] 2. Make a version of Haplos for the front of the body: maybe sternum + intercostals? Harder for people with pecs or breasts [170308] 3. Remember to ask them to check in with their breathing and the movement of the ribs [170308] 4. Make long and short versions of Haplós Somatic protocols [170308]

#P0.170207.SE.a3

AudioRecording 20170207 10:31:46.m4a	I've just been lying on the floor. I discovered a new self FI: lying on the side, crossing my legs over and pinning one leg using the other so that my pelvis is fixed. (Thankfully i have the mobility to do that comfortably.) Using the hand of the arm that's underneath, i hold on to the wrist of the top arm and then rotating the forearm as if I were doing an FI on myself. And then I came up with this term 'bilateral bracketing' [or homolateral bracketing]. And that was really good because i felt like i could move my arm in six degrees of freedom: back and forth, up and down, rotation. I'm now on the treadmill and usually there's a tightness in [the front of] my right hip joint, but this time it's on my left. And it feels so *nice,* so

	liberating, even though what i'm feeling on my left side isn't as pleasurable as what I'm feeling on my right. it's nice to know that i have the choice. [garbled] [It means] that this is not destiny, my right hip isn't *destined* to be perpetually contracted.
AudioRecording 20170207 10:35:30.m4a	I should mention something I've been doing everyday: walking [with attention]. Shifting the weight of my torso backwards activates the (front) flexors. Interesting. Hadn't really noticed it before [until its was brought up, I think in the FITC programme]

Context	Walking
Theoretical Implications	Significance of movement availability: Undoing movement habits. Provides choice. Free will. [n.d.]
Design Implications	–

#P0.170216.SE.a3

AudioRecording 20170216 09:15:14.m4a	In the gym, lying on my back. Touching my ribs and thinking that the motors are proxies for my fingers. Not someone else's fingers. It's my own. Hence, no sensors. The configurability of the motors (like the ability to reposition them as you see fit…)
AudioRecording 20170216 09:24:59.m4a	While trying out a new exploration, which is the triangle-arm lesson but where my hands are actually under my pelvis or lower back, using my hands to feel how my back muscles are working every time my legs tilt to one side… anyway, during the exercise I've been thinking about the Philippines and Manila in particular and how noisy it is. Is it possible to appreciate Feldenkrais in that context? I mean, I know [now] from that workshop [Awaken Your Spine] that it is possible, but those workshops were done in such special circumstamces: a secure space, secluded, quiet, air-conditioned; it lent itself to [proprioceptive] introspection. The motors would fine at their current strength [in the Cravings

	version] if it were really noisy outside, so that there was a lot of external stimuli, so design implication is that I really need to control the motor intensity, especially for the 7 motor version. Maybe there could even be a calibration version where for a particular circumstance and person, we figure out what the Just Noticeable Difference or threshold of perception is.
AudioRecording 20170216 09:46:23.m4a	This time I'm walking to the university. I'm realising that I'm seeing different things, that my eyes are being used in a different way. I'm seeing things that are further out, on the horizon. Maybe because my back is reorganised, and so my head is in a different position [unintellgible]. Also i'm feeling my breathing. Another reason for putting the motors on the thoracic spine is that it has the most chances for contacting the participants back. [And maybe also to get closer the muscles' origin?]
AudioRecording 20170216 20:04:47.m4a	it's much later in the day now, about 8pm. I was untying my shoes afer coming from the gym. I found this beautiful, elegant, relaxed way of untying my laces that was very reflective. I would flick the laces undone, and then i would just pause and relish the moment after which the action unfolded. All of this reminds me of a thought that i had of a protocol that i shoudl establish in the somatic use case. I really want to put movement back. You're lying on the mat/table, and you raise one arm and then the other. And then you turn your head one way and then the other. And then you do a one sided lesson/composition with the motors.

Context	In the gym + at home
Theoretical Implications	Becoming more aware of one's self and enjoying the pleasure of moving might mean that one slows down! Which means that the initial findings i was seeing in the grooved pegboard task (slower times for the experimental group) is actually supporting this. [n.d.]
Design Implications	1. In some ways, the back support brace—which I was testing with the initial idea of creating less muscular tonus so that the motors could be felt more—was a kind of technology

	for introspection: like Dean's original balloon spine costume, it was meant to be a safe, secure place in which to feel subtle things. How do you design for that? Do you necessarily need to? I don't know. [n.d.] 2. "Maybe there could even be a calibration version where for a particular circumstance and person, we figure out what the Just Noticeable Difference or threshold of perception is." [n.d.] 3. Special memory foam pillow. [n.d.]

#P0.170217.SE.a3

AudioRecording 20170217 14:19:10.m4a	Prompted by what I was listening to—Garet saying that FM practitioners should[/could] be able to know where people think their hips (hip sockets) are—i just realised that it's taken me a while to understand the full length of spine. And by doing that, i was able to [now] do headstands, because then i could really sense the end of my [torso][i said spine, but what i really mean is torso], which is really in my pelvis/my sit bones [ischial tuberosities].

Context	At the gym
Theoretical Implications	An example of how body awareness can enable better motor abilities [170309]
Design Implications	–

#P0.170228.1.SE.a3

AudioRecording 20170228 10:53:18.m4a	I'm doing these rehab exercises that my physio told me to do a while back [for my rotator cuff], using a theraband. Was told to 12-20, I think. Question is, how do you know how much? [Slavish adherence could be dangerous.] If i do 20, i might be injuring myself some more. This is part of the importance of proprioceptive sensitivity.

Context	Gym; as above
Theoretical	Significance of proprioceptive sensitivity: can prevent injuries. cf. Garet's story of the ski slope [170308]

Implications	
Design Implications	–

#P0.170228.2.SE.a3

AudioRecording 20170228 10:17:55.m4a	Lying on the floor. I was kind of in a rush so I quickly going through my FM-type pre-warm up, and I'm realising that I'm getting quicker and quicker at doing a body scan. I've been doing the (self-)lessons I've been doing the past several weeks. I'd be doing one or two movements then lying on the back, doing a *very* quick scan. And I began to wonder: do you begin to get better and better at checking in, and using your interoceptive and proprioceptive sensitivity to check in? [NB: i think i'm mostly been doing proprioceptive checking in, tbh, with respect to the definitions i've laid out in Chapter 1]. And then I thought, what are the design applications for this? Well, maybe at first, you can have this very deliberate series of lessons, and you take it slow, and you have a lot of time to feel yourself in movement. And then as you become more and more somatically aware, maybe the vibrations can become almost just triggers--"attention triggers". And when you become really good at reorganising yourself, I kind of have this image where you play this vibration pattern that just does a quick sweep through your body, and then, boom. You're organised. And it's not a magic bullet. It's just a way to quickly but systematically do a check.

Context	At the gym, lying on the floor.
Theoretical Implications	Can somatic expertise lead to the ability to do quick body scans? I believe you can. I see it from my experience over the past two years (not to mention the past ten years), but also anecdotally: I seem to recall a story told to the Sussex 9 class where at a FM conference, the practitioners were not guided through the scanning process as one might with novices, but were asked to just scan themselves. [170309]
Design	As somatic expertise develops, the way Haplós is used could evolve

Implications	with the user. Additional use cases/scenarios could be developed [170309]

#P0.170303.SE.a3

AudioRecording 20170303 09:49:51.m4a	At the gym. I did the exploration yesterday of LYOB, rotating my legs inwards, then rolling my TFL against a roller. I reproduced the effects from yesterday: if i 'roll[er]' my right TFL, when I turned my R leg inward, i felt a pull in my left hip [actually front of the pelvis near the ASIS] more than if I turned my L leg inwards, there was not as much of a pull on my right hip. And then I thought, well, maybe I'm feeling this sensation because the sensation of the roller on the TFL was so intense that it 'blocked' any other sensation in the R side of my leg and pelvis, so I waited for a while, to let the memory of that sensation fade away [and also to integrate]. And so I did that for a second time, and my right hip [leg and pelvis?] still felt freer. But interestingly, so did my left hip [leg and pelvis?]. But it could be because of the way my L leg was being moved and moving while I was rolling [the TFL of] my R leg, so I'm not sure.
AudioRecording 20170303 09:51:47.m4a	Oh as I was using my cap turn my head, I thought "why don't I make a version of Hpls" that attaches to a cap?
AudioRecording 20170303 10:03:59.m4a	I think what I've just realised is that I recapitulate the developmental patterns/cycle when I go to the gym. Just like in the Feldenkrais training programme!
AudioRecording 20170303 10:10:33.m4a	Bringing together three separate ideas. 1. Garet's memory about Feldenkrais asking the students in her class to be able to spot where a person thinks their hip is by seeing them walk 2. My Pilates teacher making me use that leg rotation device to help me find my hips, because I had real trouble distinguishing the movements of my back from the movements of my hips 3. All these explorations I've been doing in the gym

	I'm discovering a new exploration, building on previous explorations I've been doing *which has been LOB, take one leg (say L) behind the knee with clasped hands, support the L elbow on the floor, as I very gently rotate the leg in and out [more in than out]). And then today, I put my left L hand behind my knee, and then use my R hand to hold my L ankle. And I do this kind of rocking motion where as I bring the knee over my chest, I extend the L leg with the help of my R arm. And i as I bring the knee closer to the floor, my head follows the knee as my bent L leg sweeps around in a circle, and then I come into [side saddle sitting]. Being able to send where your leg is and *what your leg actually is*—that it can be a separate entity from but has a relationship to the hip—is a pretty phenomenal feeling.
AudioRecording 20170303 10:16:27.m4a	I think I'm beginning to figure out Shusterman's fourth level of body consciousness [meta-attentiveness]. I'm LOB, doing the Wildman exercise with one arm under both knees {Wildman, 2006, "Volume 1, Lesson 01: Activating The Abdominal Flexors"} . As my legs begin to bend at the knees on the return of the movement, i let my legs tilt to the side. I realise that as my the legs tilt to the side, there's a point when the movement becomes harder and not as easy, and when the movement becomes less easy. Something happens to the quality of my attention. It just becomes blurry or jagged; I don't exactly know what it is [or how to describe it] but it just isn't as clear. And then as I get past this point, when my legs are closer to the floor, it becomes clearer again. And [the range when my attention isn't as clear] is the [same] range [as] when I begin to make an effort. But being able to notice when I'm making an effort, that's a *self-monitoring* thing, which I was writing about earlier today.
AudioRecording 20170303 11:42:07.m4a	I'm at the end of my workout, and I think I hit on something really important. LOB, I think I can feel more of myself, although there's a lot of

	sensations in my body right now just because the [muscles of my legs are toned, many of my muscles are more toned than usual]. But i was thinking that we're pattern-makers: we need to see patterns, we tend to complete things—it's a Gestalt thing. And when you're able to sense more of yourself on the floor, you're able to complete the pattern [of yourself] better, there's a sense of inevitability in my being. You have your more information points. You have more possibility to assemble yourself. And this ties to what Sue was saying about crafting the self [constructing the self]. What Shusterman says about self-fashioning. And I guess i'm trying to make a [learning] technology for self-fashioning.

Context	Gym; as above
Theoretical Implications	1. New ways of working out at the gym and doing any kind of physical activity: not only using Feldenkrais Methods to clear out neuromuscular patterns, but also recapitulating developmental patterns as a way to warm up for more complex activity [170308] 2. Vibrotactile musical aesthetic could be informed by developmental movement pattern (see design implication below) [170308] 3. This idea that being more aware of the whole requires becoming more aware of the parts, because then you become more aware not just of the elements of the whole, but their relationships with each other [170308] 4. Sensing more of yourself allows Gestalt processes to complete more of yourself because you more information points. "I'm trying to make a [learning] technology for self-fashioning." [170308] 5. Shusterman's fourth level of body consciousness might be related to self-monitoring, in this case monitoring your attention. [170308]
Design Implications	• Another support for adding rests and silences in between stimulation patterns? [170308] • Cap version of Haplos; could use the smaller ribbons I was planning on using for the shoulder blades.[170308] • A complete vibrotactile piece could recapitulate the developmental movement patterns [start near the ribs for breath, move to the core, upper-body/lower body,

	homolateral, cross lateral, and then do iterative loops, little back and forth between the patterns, alternating between simple and complex patterns, all the time paying attention to rests and silences, returning to the ribs and sternum, etc. [170308] • Ooh. There should [be] a Haplós ribbon configuration for the sternum [170308]

#P0.170308.1.SE.a3

AudioRecording 20170308 11:07:12.m4a	Structural/functional divide isn't great. LOB right now, exploring cross lateral sensations across leg and arm… fascia cannot contract on its own as far as i know, it has no afferent neurons, it's really the muscles that are responsible for contracting.
AudioRecording 20170308 12:42:50.m4a	Just tried a new exploration today: balancing on a roller with one leg, and doing a walking/swinging motion with the other leg [in coordination with the singing of the arms] , and as soon that becomes comfortable enough, doing a kind of penchee pose holding on to the leg with hand of same side [dandayamana dhanurasana in yoga terms]. One thing I noticed about the massage action [of the roller on my standing foot]—and it might not just be the massage, it could also just being in an upright position with my feet being stimulated—is that i could feel little clicks in my foot and ankle, and i could feel [the foot and ankle] moving in ways that it hadn't in a while. And then the other: a lot of the discomfort in my lower back disappeared, and it was laterally isolated (i.e., balancing on right leg greatly lessened the discomfort in right lower back just above the iliac crest). It ties it to a few things: 1) the explorations i've been doing with tilting the legs to one side, and feeling little clicks in my feet; 2) the idea—that comes from a feldenkrais thing—that a lot of information comes from our feet or a lot of the stimulus starts with the feet. No wonder that Dean's lentil socks—i mean i haven't tried it myself but it sounds amazing—and the fact that cobblestones seem to increase longevity. The thing with the feet is that it has glabrous skin, and i don't think that the vibrating motors of Haplós wouldn't work well there since they would just be ticklish. But i wonder whether whole body vibration is effective [not because of existing theories like] cleaning out cellular stuff, or that it stimulates the tonic vibration reflex… but what if it's a fascia thing?

AudioRecording 20170308 12:53:52.m4a	I repeated the exploration [in previous recording] and i tested the rolling [inwards] of my legs while LOB. I started with balancing on the R leg, and when LOB my R back didn't necessarily feel flatter—my L did—but when I rolled my R leg inward and it definitely felt more independent of my pelvis than when I rolled my L leg. And then when i did the same exploration balancing on my L leg, both sides felt more equal [when I LOB].

Context	Gym; as above.
Theoretical Implications	1. There are several ways to create more mobility in a certain area of the body—I experienced the same increased in mobility when I did the roller on—and stimulated using Haplós—the TFL. Connectedness. [170308] 2. Possibility of hypotheses for why WBV works: 1) fascia 2) overall there is an increase in ability to attend to muscular movement, which leads to greater coordination and (perceived) isolated strength gains [170308]
Design Implications	1. Haplos could be specifically applicable to areas of the body which are: 1) not covered with glabrous skin; 2) in contact with major fascial structures [170308]

#P0.170308.2.SE.a3

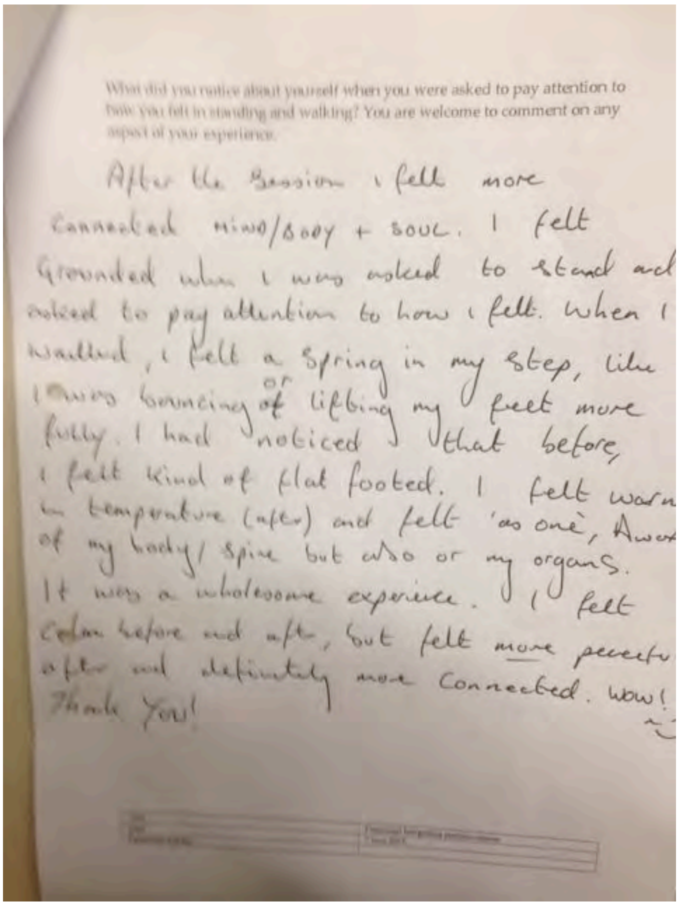
At home, after having gone to the gym twice and done an ISRD session the first time. Feeling calm. Was feeling calm at the gym, too. Slicing halloumi now. I don't need to use my shoulders as much. My legs and feet and torso can help with slicing through. It takes tinier movements but i can use more force. More coordination. It reminds me of when I was doing the calligraphy project with Alvin Tolentino. You have to use your entire body to draw the brushstrokes. It's a pleasurable sensation. An aesthetic one.

Context	Home, everyday activity
Theoretical Implications	Feeling of wholeness creates a feeling of control, mastery, subtlety—an aesthetic experience [170308]
Design Implications	–

Practice-teaching Feldenkrais Method

#P08.160707.tFI.a3

AudioRecording 20160707 18:05:42.m4a	P08: I didn't notice it to begin with, but certainly afterwards, I felt calm, [garbled] i noticed that i was walking with more of a spring in my step. I just felt a lot more, um, [pause] *at one* [emphasis mine]. It did make me realise, yeah i did feel quite kind of… I was fine, previously, but it felt kind of flat, almost flat footed it felt. I felt myself almost lifted onto my toes. So that what's what I felt, the difference before and after. And during… well, your mind is completely active, isn't it, and so… but i was here. Everything that i was thinking was connected to how… where you were touching me, and I was completely aware of not just my physique, my spine, but also my organs, my lungs, my heart, and skin. And i was trying not to medicalise it too much with my problem kind of things. And i was trying to think, I wonder how this relates to chiropractic [approaches] and subluxations that occur in the spine. And so then I thought, "No, don't think about that." But yeah, it was amazing. i'd like to know more about... Me: Absolutely […] A lot of this hinges on a few things. Very gentle small movement can give you a lot of information about how you're structured and how you're organised. [PARTIALLY UNTRANSCRIBED]
Questionnaire Response (see Fig. A3.2, below)	After the session I felt more connected mind/body + soul. I felt grounded when I was asked to stand asked to pay attention to how i felt. When I walked, I felt a spring my step, like I was bouncing or lifting my feet more fully. I had noticed that before, i felt kind of flat footed. I felt warm in temperature (after) and felt 'as one'. Aware of my body/spine but also my organs. It was a wholesome experience. I felt calm before and after, and definitely felt more connected. Wow! :)


What did you notice about yourself when you were asked to pay attention to how you felt in standing and walking? You are welcome to comment on any aspect of your experience.

After the session I felt more connected mind/body + soul. I felt grounded when I was asked to stand and asked to pay attention to how I felt. When I walked, I felt a spring in my step, like I was bouncing or lifting my feet more fully. I had noticed that before, I felt kind of flat footed. I felt warm in temperature (after) and felt 'as one', aware of my body/spine but also of my organs. It was a wholesome experience. I felt calm before and after, but felt more peaceful after and definitely more connected. Wow! Thank You!

Figure A3.2: P8 Questionnaire Response

Participant	P08
Context	FI (one of either lifting the head or bringing the ribs and pelvis close to each other)
Self-Reports	
Observations (DSSM)	How do I provide verbal feedback that I'm listening but not making judgements? Garet has a way of just saying "hm" that sounded encouraging, neutral, but curious. Don't say 'thank you' to the student, say, 'that's great'. It's not a performance, it's not about the teacher. It's about the student.
Theoretical Memos	
Design Memos	

#P42.170325.tFI.a3

Participant	P42
Context	FI Taster session with repeat student, P42. This time i

	did the spine FI and a bit of moving the shoulder from the elbow (while being supported by the hand on the table)
Self-Reports	He said that this was "the best one yet" of the FIs I had explored with him. He described the experience as "subtle" but "amazing".
Observations (DSSM)	P42 is particularly expressive in response to touch. Even touching the middle of his back as i'm tracing his spinous processes elicited a non-worded vocalisations that indicated pleasure. So did the tracing the "grooves" on either side. As I was touching his spine, i realised that i needed to suppress the urge to just keep touching his spine—which as was pointed out in class is because an FM experience is not a massage—and that letting (and myself) rest was an important part of the process.
Theoretical Implications	When he expressed amazement about how such a "subtle" activity could elicit such as response, i said that a lot of muscles attached to the spine via tendons and aponeuroses. But now I'm also wondering whether it's because touching the structure that's in the dead *centre of you* is a powerful experience. We normally experience our body in a bilateral way: we either step with our left foot or our right foot, we hold something with our left our right hand. Rarely do we use our limbs symmetrically. And rarely do we touch ourselves or someone else right in the middle, along the sagittal plane. *Perhaps there's something extraordinary about beyond reminded of your centre.* It reminds me of a professional street dancer who I was in Impulstanz with in Vienna in 2006; he said that he comes to ballet class to help find his centre again. And it reminds me of the sheer somaesthetic pleasure of the slackline.
Design Implications	1. Consider placing the motors right on the spine [170325] 2. Give the user a rest between bursts of stimulation. I kind of imagine it functioning how energy-saving washing machines work. The user needs to feel a bit of themselves in between. This will be a major point in the design features. [170325]

#P47.160727.tFI.a3

Participant	P47, female
Context	FI about finding the diagonals
Self-Reports	[not recorded]
Observations (DSSM)	I began to get a deeper understanding of the idea "asking the student a question". It's not just: it's asking the question continuously: "Can you do this very subtle movement? No? Ok, let's make it subtler. Even subtler still. Ok, i feel it now. Let's expand it now. Ok, that was too big a leap? Let's do it in a smaller increment." And eventually I found the *increment* that made larger movements possible. I found out how it really is a dance, and that my body doing FI is not the same as, say, Garet's body when doing an FI. There's a circularity in my movement that I really have to just honour and follow, so that i can move the student with ease and grace.
Theoretical Implications	Difficult to translate this kind of feedback loop in any kind of current AI/machine-learning-based system. Too sophisticated, too morphologically human a decision-making process. The limits of somatic technologies. [170310]
Design Implications	Give the user the ability to make as fine an increment as possible, on the fly [170310]

#P52.151219.tFI.a3

Participant	P52, female, 86
Context	FI Taster session: tracing the grooves of the spine
Self-Reports	Halfway through the lesson, she said, "Masaheng pang-mayaman ito" (*This massage feels like only the rich could afford it*, suggesting a quality to it that was luxurious, or that it reminded her of clinical treatment that she normally wouldn't have been able to afford)
Observations (DSSM)	She raised her arms overhead repeatedly, seemingly indicating that the activity was more possible now than before, or that it felt pleasurable. She had a smile on her face. Her daughter, who was observing the lesson. Her thoracic spine, which had a noticeable and sagittally asymmetrical kyphosis-like curve to it, seemed

	to me to be noticeably less curved and more symmetrical.
Theoretical Implications	–
Design Implications	This is the FI ultimately what led me to design Haplos for the back.

P33.160828.tATM.a3

AudioRecording 20160828 12:36:43.m4a	P33: That was very interesting. It's like there's an increasing body consciousness. I don't know how I can name it. Body consciousness is the best word i can [garbled]. [garbled] movement [garbled] little sensations. I find this very pleasant, this rotation thingy. It was interesting to see how this changes if I use other body parts. And yeah, wondering how to tr[…] Because if I rotate my arms at the piano, whether I don't know, I can use my foot, to support… it's a very unusual idea. But yeah, just the feeling of trying out movements and see how they feel… Well I noticed when I went back to the piano… well in the beginning i was already… well i guess because i was already lying on the mat first, there was already a bit of more contrast on what my movement feels like. Because usually i mainly listen to how does it sound; i don't… i mean i feel for the keys, because that's what i do. i don't feel so much [garbed] what it *feels* for me, like, "is it a pleasant movement?" I don't know. It's a fascinating feeling. DSSM: I play the piano, too. It's interesting what happens if you use more of yourself to play. So that in doing *this* it's not just *this,* it's more of—as you say—pushing from our foot. Of course the challenge with the piano is you're often using the foot to control the pedal. So we can't do the kind of movement that you were doing on the mat. P33: I guess you can still do it to some degree. With the heel on the floor.

	DSSM: And you still have your other foot. It's not *not* doing anything. It's doing something different but it's always engaged. P33: I feel like I'm curious to try and shake about or not shake, swing the body a bit. DSSM: When I started to trying apply the Feldenkrais Method to piano playing, I realised that I needed to use less of my fingers and my hands to do the force, and a lot of it could be more evenly distributed, and I could play more lightly, and I can play more quickly. It was like my fingers were hardly moving

Participant	P33, male
Context	I gave the Rolling the Fists (161001 - Rolling with fists) ATM lesson.
Self-Reports	He felt that the lesson was appropriately suited to his needs as a pianist.
Observations (DSSM)	I should have given him the opportunity to swing around as he had said he wanted!
Theoretical Implications	It would be an interesting experimental method to do what I did: set up an electronic piano with headphones (but perhaps the participant doesn't realise that their playing will be recorded), have a control and experimental group doing pre- and post-intervention piano playing, then have an audience rate/evaluate their playing. [170310]
Design Implications	–

Training Data

The training data are notes taken from the FM Sussex IX training programme.

#P0.150929.Training.a3 – Catch up Training

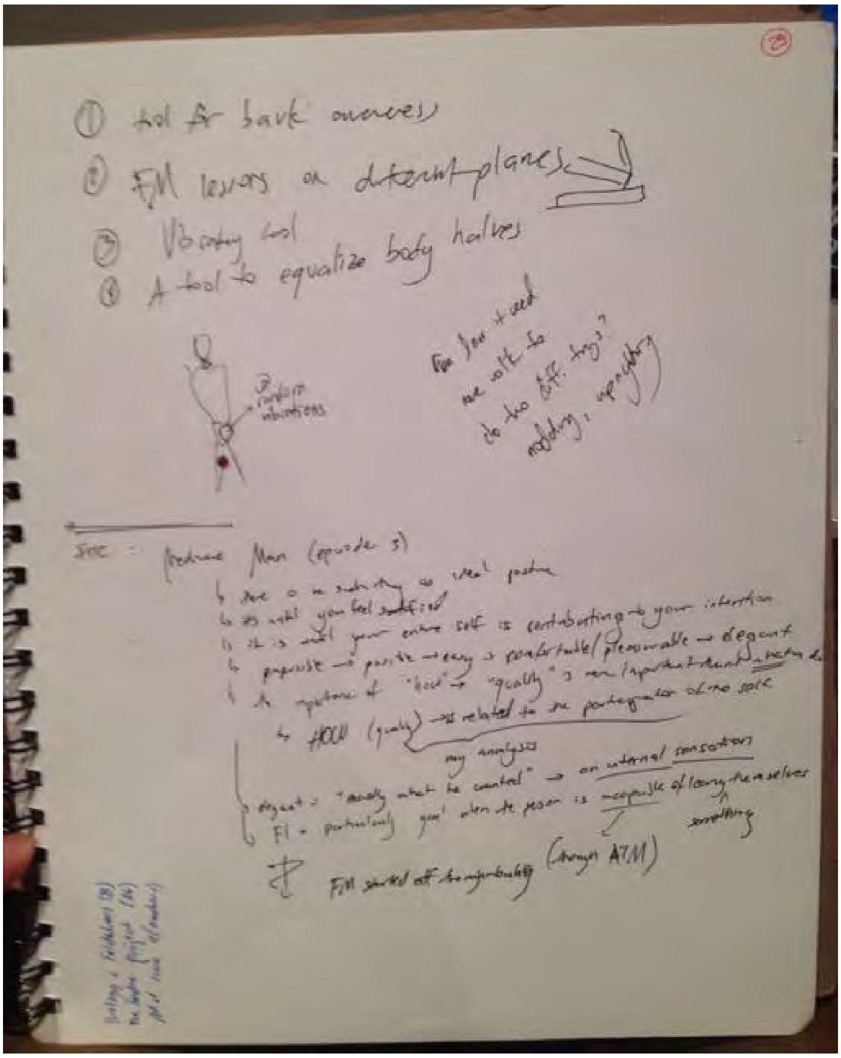


Figure A3.3: Journal entry

1. A tool for back awareness
2. FM lessons on different planes
3. Vibrating tool to remind people of different body parts
4. A tool to equalise body halves

Does it need ? ? ? to do two different things?

Medicine Man Interview (episode 3)

- There is no such thing as ideal posture
- It's until you feel satisfied

- It is until your entire self is contributing to your intention
- impossible -> possible -> easy -> comfortable/pleasurable -> elegant
- The importance of "how" -> "quality" is more important than what
  How (quality) -> is related to the participation of the self (my
    interpretation/analysis)
- Elegant: "Exactly what he wanted" -> An *internal sensation*
- FI: particularly good when the person is incapable (through ATM) of learning something themselves

Moshe started off the ???

Appendix 4. Create Primary Data

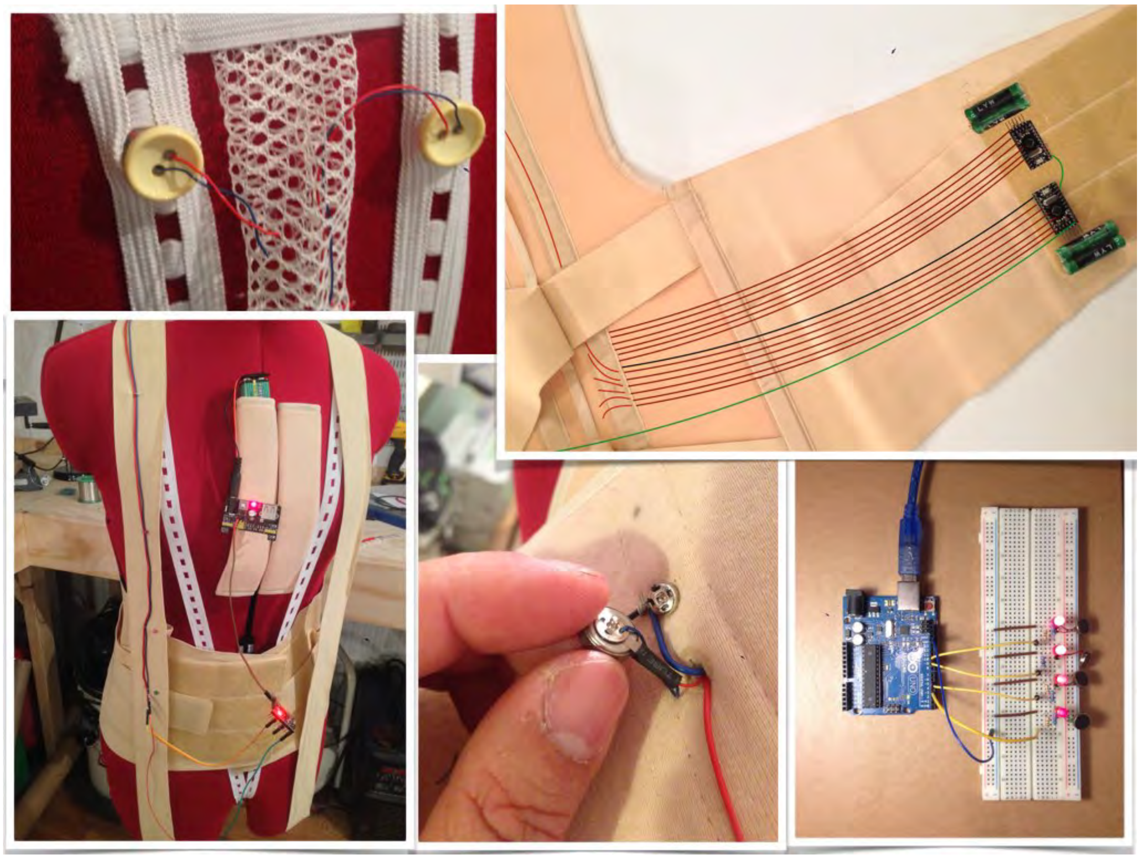
These documents represent a trace of the prototype creation process I underwent in developing Haplós.

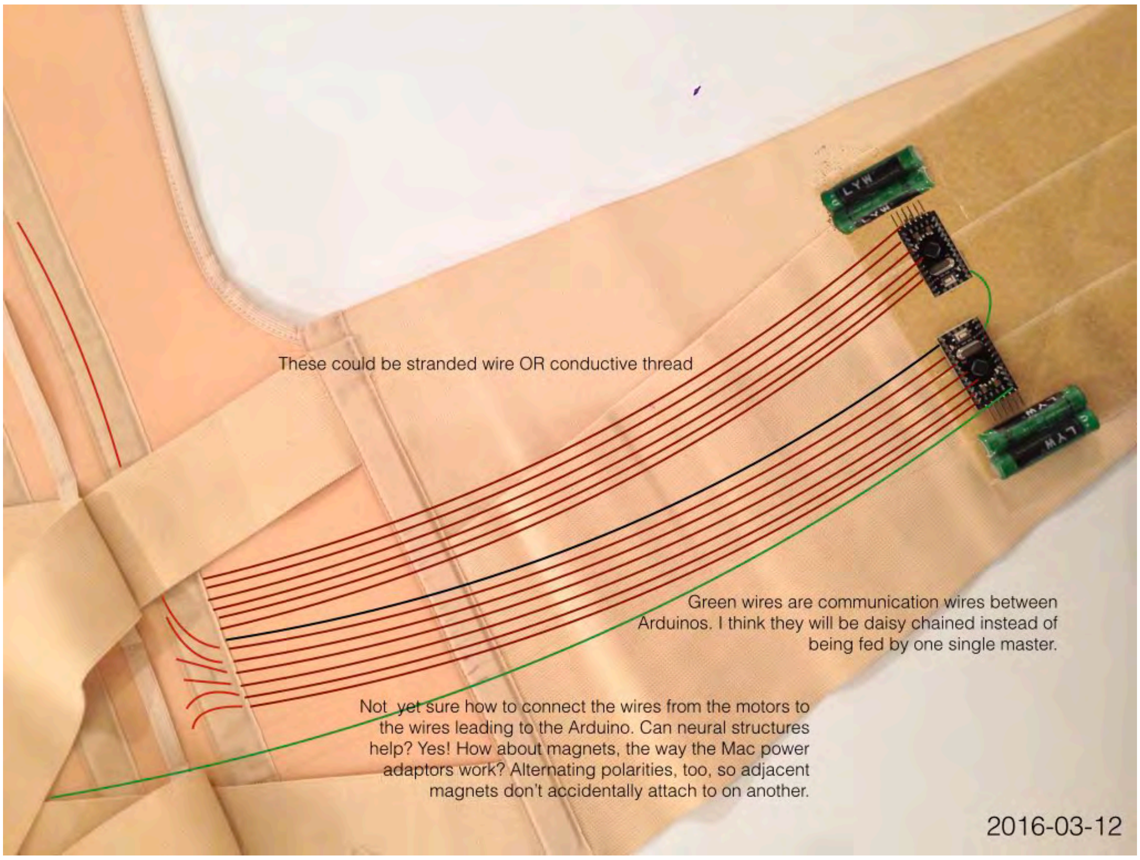
This is the score for the three-minute vibrotactile pattern for the Cravings Study.

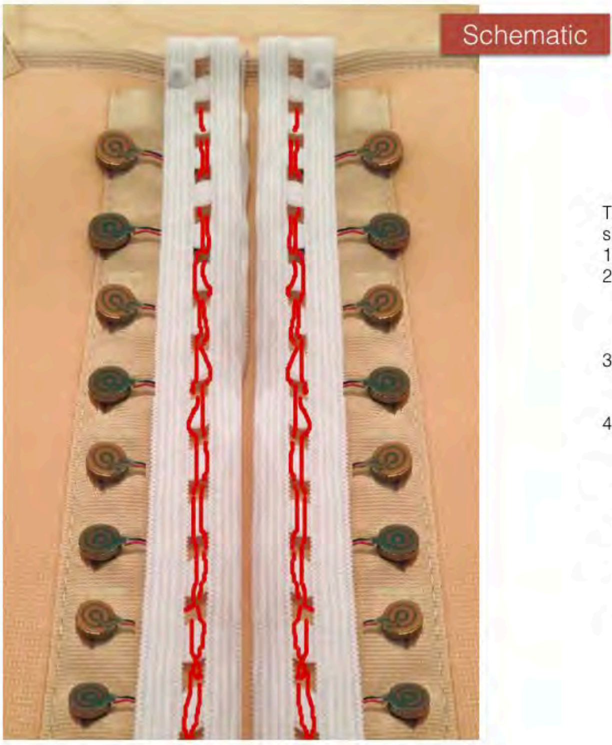
Code #	Code String
1	2097153,2097153,4194306,4194306,1044,2
2	8388612,8388612,16777224,16777224,1044,2
3	67117056,16779264,4194816,128,1044,1
4	524352,131088,32772,1,1044,1
5	2097153,2097153,4194306,4194306,522,1
6	8388612,8388612,16777224,16777224,522,1
7	33554448,33554448,67108896,67108896,522,1
8	134217792,134217792,266338431,266338431,522,1
9	67117056,16779264,4194816,128,261,1
10	524352,131088,32772,1,261,1
11	67641408,16910352,4227588,129,261,2
12	67641408,33817608,4227588,129,261,4
13	33824832,16912416,8454402,129,261,4
14	41024,16910608,67633668,129,261,4
15	68958272,16910352,4242036,129,261,4
16	68958272,219809808,4229782,129,261,4
17	71055425,221906961,6326807,2097153,261,4
18	67647602,85863056,189841924,131217,261,4
19	67778674,68955784,139642404,131217,261,4
20	539382,68955788,139642406,136337,261,4
21	15093,68988556,139646496,5137,261,4
22	178956970,89473024,0,0,261,4
23	48351893,2113536,2113536,2113794,261,4
24	16909191,10567680,10567938,10567938,261,4
25	15093,68988556,139646496,5137,261,2
26	67778674,68955784,139642404,131217,261,2
27	67647602,85863056,189841924,131217,261,2
28	71055425,221906961,6326807,2097153,261,2
29	68958272,219809808,4229782,129,261,2
30	68958272,16910352,4242036,129,261,2
31	67641408,16910352,4227588,129,261,2
32	67641408,16910352,4227588,129,522,2

33	67641408,16910352,4227588,129,1044,1

The following images are excerpted from my digital and physical design journal.



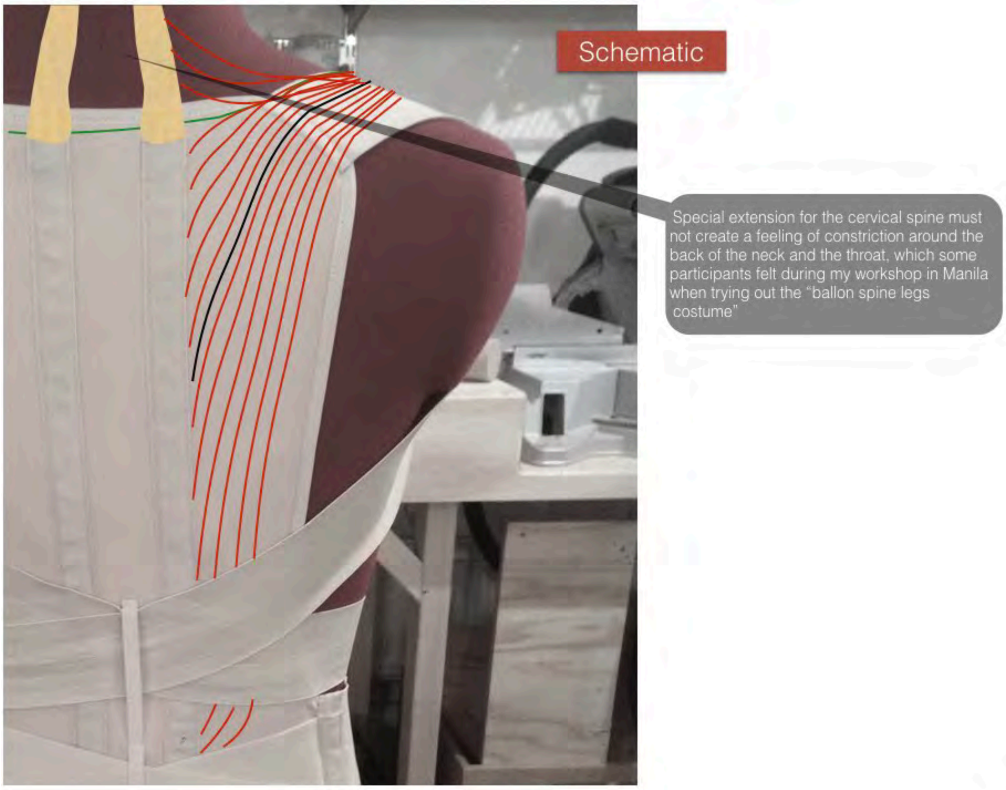




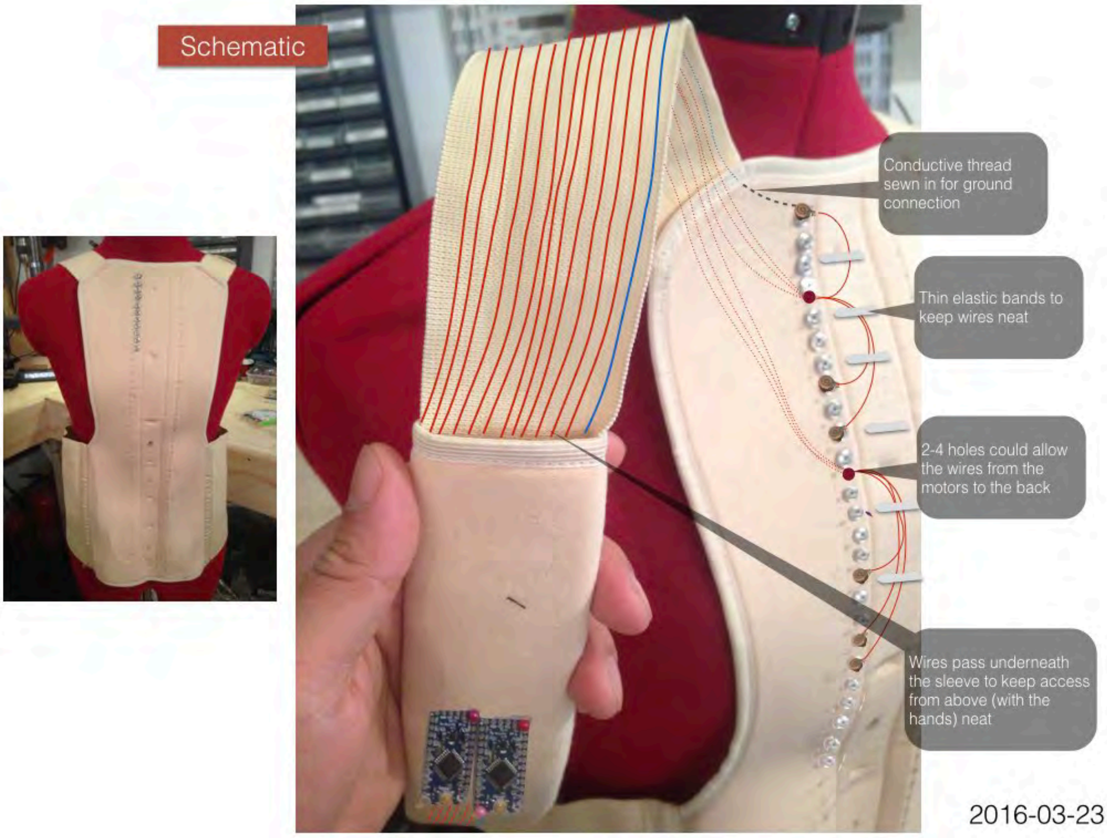
This solution has several advantages over user a a single wire mesh "spinal column":

1) Keeps the wires tight and neat
2) Because of the other features in the back of the brace, i have to bifurcate the spinal column at some point anyway. Better bifurcate now than later.
3) The elastic band has some structure to it (related to point 1). but this also means that i can sew in additional components if needed (e.g., resistors).
4) I could also put the magnet attachment solution here as opposed to the obliques. However, that would mean sewing a lot of conductive thread down the spine. I want to minimise the use of conductive thread. Also, this begins to really limit the number of motors I can put on. I could always just use thinner wires f i decide to increase the number of motors (e.g., half the gauge and double the number of motors, approximately)

2016-03-12

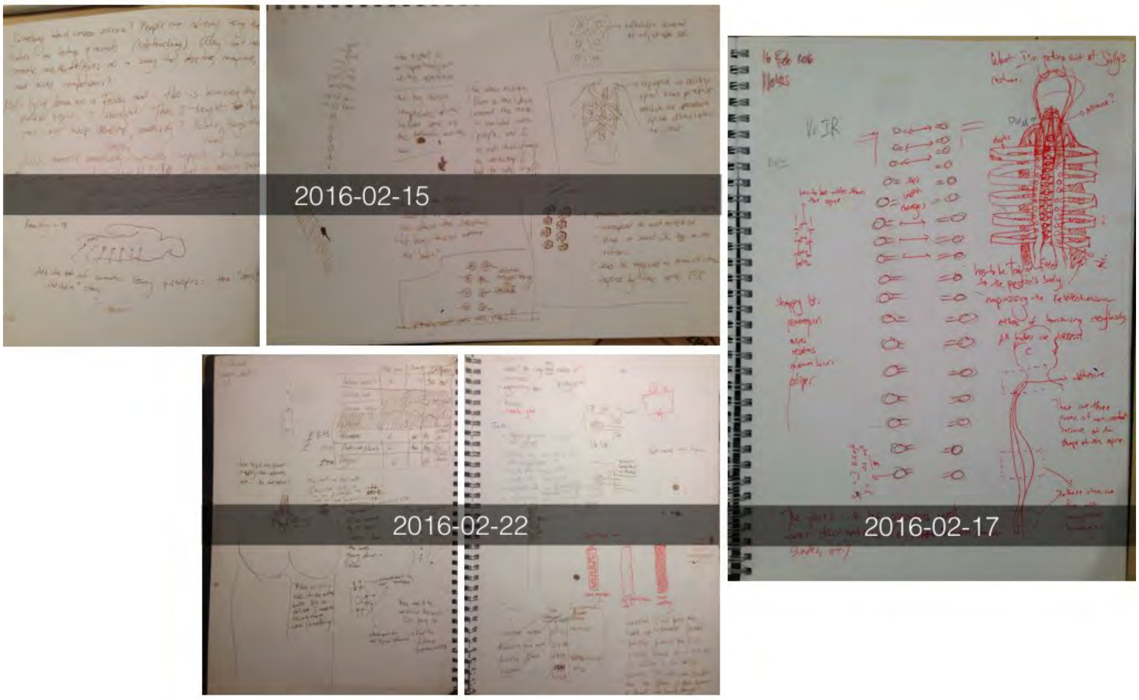


2016-03-14



2016-03-23

Sample paper journal entries



Appendix 5. Evaluate Primary Data

Appendix 5 contains Evaluate primary data for the following research in this thesis: Awaken the Spine (AtS), Prototype Trials (ProtoTrial), the Manufactory workshop (self-explanatory), the Cravings study, and finally, the public demonstrations (Public Demo).

Participant data strings are coded as follows:

#ParticipantNumber.Year/Month/Day.ResearchCategory.AppendixNumber

For example, #P42.170325.tFI.a3 would read as Participant 42 on March 25, 2017, participating in a Functional Integration practice-teaching FM class. Please note that the author is coded as #P0 (Participant 0), e.g., #P0.170304.ProtoTrial.a5.

Awaken the Spine Participant Feedback

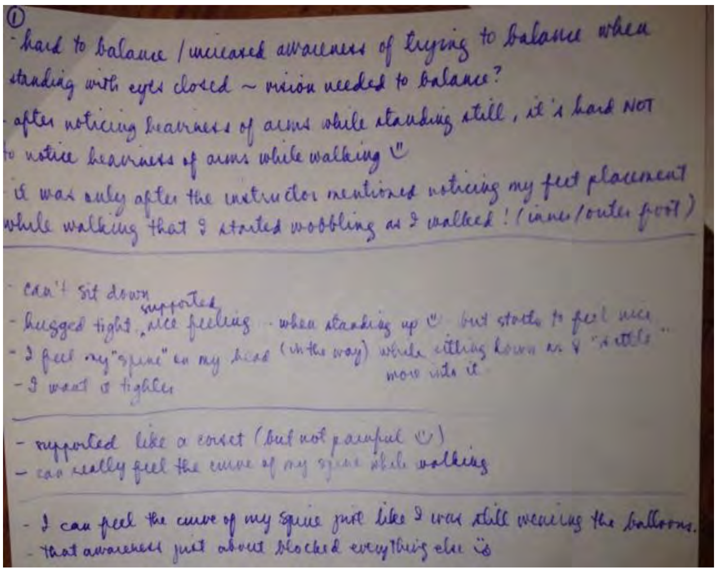
Awaken the Spine was a semi-structured workshop held at the offices of Curiosity in Quezon City, Philippines in January 2016. It explored participant experiences of a derivative of Dean's Balloon-Spine Leg costume (Dean, 2016).

#P03.16109.AtS3.a5

➢ hard to balance/increased awareness of trying to balance when standing with eyes closed — vision needed to balance? ➢ after noticing heaviness of arms while standing still, it's hard NOT to notice heaviness of arms while walking =) ➢ it was only after the instructor mentioned noticing my feet placement while walking that i started wobbling as i walked! (inner/outer feet)
➢ can't sit down ➢ hugged tight, supported nice feeling… when standing up =) but starts to feel nice ➢ I feel my "spine" on my head (in the way) while sitting down as I "settle" more into it
➢ supported like a corset (but not painful =) ➢ can really feel the curve of my spine while walking

- ➢ i can feel the curve of my spine like i was still wearing the balloons
- ➢ That awareness just about blocked everything else :P

Participant	P03, female, 36 yo
Context	Workshop in Manila
Observation (Self-Reports)	[as above]
Observations (DSSM)	1. Recurring theme of hard to change position from standing to sitting to walking but positive attitude towards the feeling of being "supported" [n.d.] 2. Experience of costume persists (momentarily?) after taking of costume, exactly like how it was for me in Sally's workshop [n.d.]
Theoretical Memos	• Interesting aspect of awareness: the "curve of the spine" (i.e, the directional/spatial relationship of the different sections of the spine) [n.d.] • Intensity of experience "blocking" all other sensations [170402] • Importance of bringing something to attention and how that can occupy the landscape of awareness quite fully [170402]
Design Memos	–


① - hard to balance / increased awareness of trying to balance when standing with eyes closed ~ vision needed to balance?
- after noticing heaviness of arms while standing still, it's hard NOT to notice heaviness of arms while walking ☺
- it was only after the instructor mentioned noticing my feet placement while walking that I started wobbling as I walked! (inner/outer foot)

- can't sit down
- hugged tight, supported, nice feeling when standing up ☺ but starts to feel nice
- I feel my "spine" on my head (in the way) while sitting down as I "settle" more into it
- I want it tighter

- supported like a corset (but not painful ☺)
- can really feel the curve of my spine while walking

- I can feel the curve of my spine just like I was still wearing the balloons.
- that awareness just about blocked everything else ☺

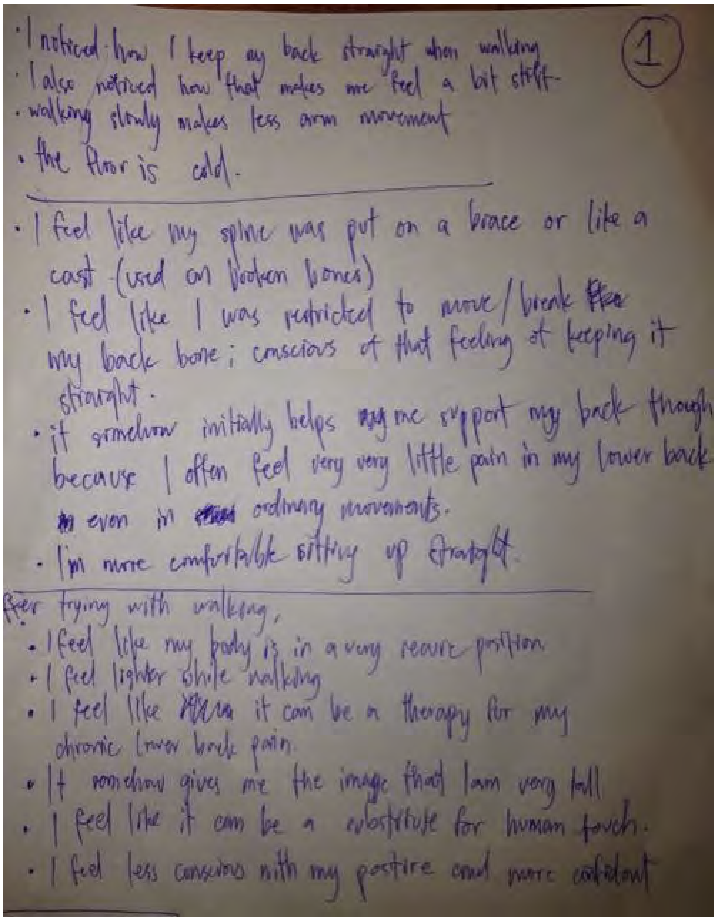
Figure A5.1: P03 Feedback Sheet

#P04.160109.AtS2.a5

• I noticed how I keep my back straight when walking • I also noticed how that makes me feel a bit stiff

• Walking slowly makes less arm movement • The floor is cold
• I feel like my spine was put on a brace or like a cast (used on broken bones) • I feel like I was restricted to move/break my back bone; conscious of that feeling of keeping it straight • It somehow initially helps me support my back though because I often feel very very little pain in my lower back even in ordinary movements • I'm more comfortable sitting up straight
After trying with walking • I feel like my body is in a very secure position • I feel lighter while walking • I feel like it can be a therapy for my chronic lower back pain • it somehow gives me the image that I am very tall • I feel like it can be a substitute for human touch • I feel less conscious with my posture and more confident
After taking off the device • I feel aware of every bone in the spine • I feel lighter when I walk, I used to feel heavy-headed and feel like I have lazy neck and pelvis support • I honestly feel I am in a therapy for spine alignment • I feel great!

Participant	P04, male, 26 yo
Context	Workshop
Observation (Self-Reports)	[as above]
Observations (DSSM)	–
Theoretical Memos	–
Design Memos	How do I design for a supportive feeling that doesn't give a feeling of "a brace or … a cast"?

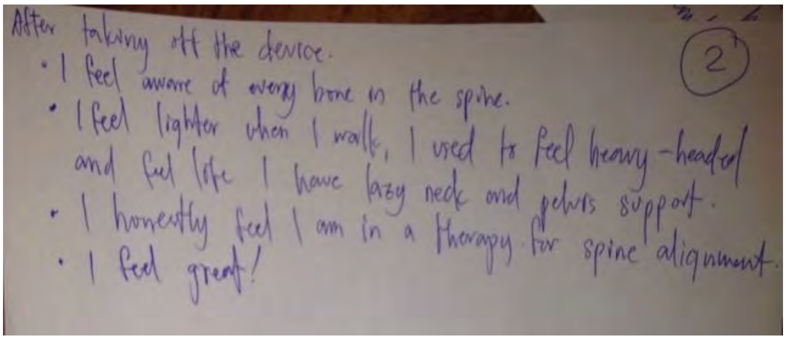

1

· I noticed how I keep my back straight when walking
· I also noticed how that makes me feel a bit stiff.
· walking slowly makes less arm movement
· the floor is cold.

· I feel like my spine was put on a brace or like a cast (used on broken bones)
· I feel like I was restricted to move/break my back bone; conscious of that feeling of keeping it straight.
· it somehow initially helps me support my back though because I often feel very very little pain in my lower back even in ordinary movements.
· I'm more comfortable sitting up straight.

After trying with walking,
· I feel like my body is in a very secure position
· I feel lighter while walking
· I feel like it can be a therapy for my chronic lower back pain.
· It somehow gives me the image that I am very tall
· I feel like it can be a substitute for human touch.
· I feel less conscious with my posture and more confident

Figure A5.2: P04 Feedback Sheet Side 1


2

After taking off the device.
· I feel aware of every bone in the spine.
· I feel lighter when I walk, I used to feel heavy-headed and feel like I have lazy neck and pelvis support.
· I honestly feel I am in a therapy for spine alignment.
· I feel great!

Figure A5.3: P04 Feedback Sheet Side 2

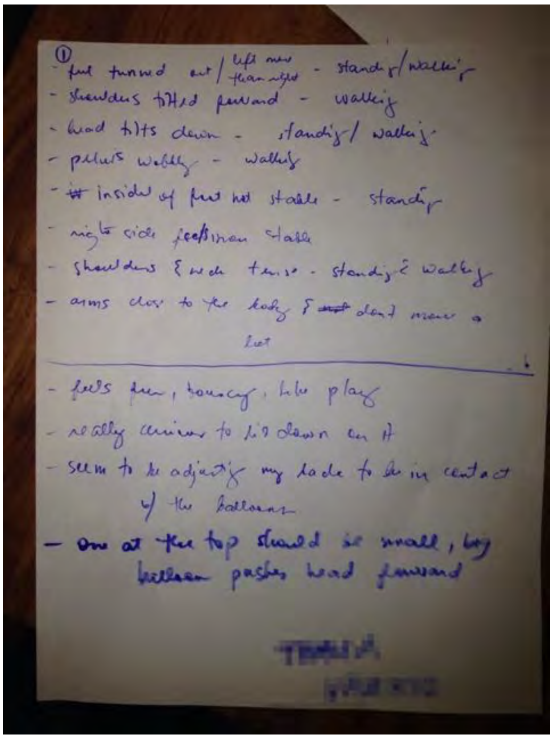
#P05.160109.AtS2.a5

- Feet turned out/ left move than right – standing/walking
- shoulders tilted forward – walking
- head tilts down – standing/walking
- pelvis wobbly – walking
- inside of feet not stable – standing
- right side feels more stable
- shoulders and neck tense – standing walking
- arms close to the body… don't move a lot

- feels freer, bouncy, like play

➢ really curious to lie down on it ➢ seem to be adjusting my back to be in contact with the balloons ➢ one at the top should be small, big balloon pushes head forward
➢ More mindful of how body parts move in relation to my spine ➢ like a corset (support) but with the ability to breathe ➢ tried to maintain contact with the balloons
➢ feet point more inwards ➢ shoulders pull back ➢ head tilts up slightly ➢ right shoulder/arm feels relaxed ➢ while walking less wobbly ➢ feel taller

Participant	P05, female, 35 yo
Context	Workshop
Observation (Self-Reports)	[as above]
Observations (DSSM)	1. Report of top balloon pushing the neck is consistent with my experience. The circle of balloons around the neck in Sally's original design feels to me to be aligned from a tradition of "lengthening the neck" using a physical support (i.e., a structural approach) that is not very Feldenkraisian 2. I remember removing the balloon ring around my neck when I attended the workshop! It felt not freeing but rather restricting.
Theoretical Memos	Movement of the neck is very important for being able scan the horizon
Design Memos	1. Remove the balloon ring around the neck. 2. Do not force neck length if it compromises neck rotation or vertical organisation of cervical vertebrae. Garment should not impede rotation of the cervical vertebrae.

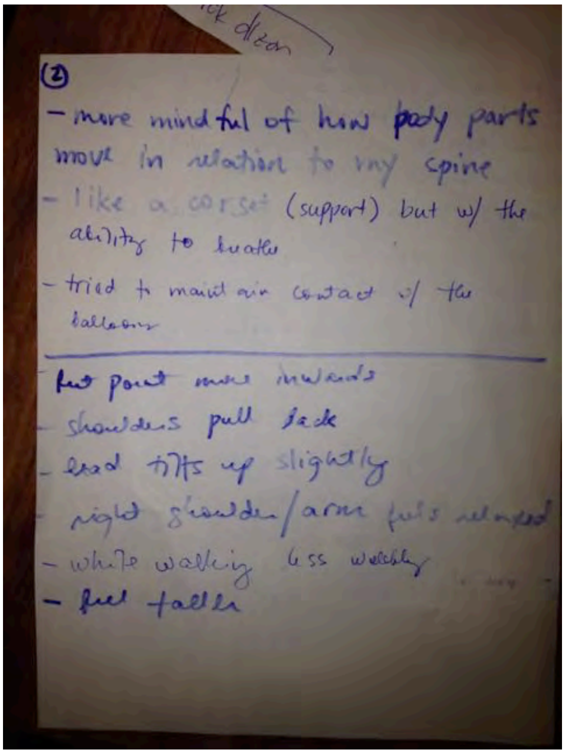


①
- feet turned out / left more than right - standing/walking
- shoulders tilted forward - walking
- head tilts down - standing / walking
- pelvis wobbly - walking
- inside of feet not stable - standing
- right side feels more stable
- shoulders & neck tense - standing & walking
- arms close to the body & don't move a lot

- feels fun, bouncy, like play
- really curious to lie down on it
- seem to be adjusting my back to be in contact w/ the balloons
- one at the top should be small, big balloon pushes head forward

[redacted]

Figure A5.4: P05 Feedback Sheet Side 1



②
- more mindful of how body parts move in relation to my spine
- like a corset (support) but w/ the ability to breathe
- tried to maintain contact w/ the balloons

feet point more inwards
- shoulders pull back
- head tilts up slightly
- right shoulder/arm feels relaxed
- while walking less wobbly
- feel taller

Figure A5.5: P05 Feedback Sheet Side 2

#P06.160110.AtS3.a5

➢ my left side feels heavier while lying; my weight tends to shift to my left ➢ it's hard to lie down flat and still ➢ comfortable sitting cross legged but wonder how much weight I should put on my hips ➢ my eyes move with my hand to the right, but move ahead of my hand when turning to the left ➢ Walking: walk with heel first when moving slowly/relaxed, tend to land middle of feet first when walking fast
➢ i feel animal-like ➢ i feel more playful ➢ smiling more while walking ➢ i feel like i have a tail ➢ i'm thinking of my dog and what it must feel like to have a tail and communicate with another species
➢ I feel more relaxed in my shoulders because the stockings were somehow putting pressure on my neck earlier ➢ I also felt more vulnerable — maybe colder? And the balloon also felt like an entity that protected me from the elements ➢ can't explain it. I was more conscious of the floor. Footsteps felt heavier. Less springy. Maybe because by shedding off the costume it meant shedding off the playful mindset

Participant	P06, female, 36 yo
Context	–
Observation (Self-Reports)	[as above]
Observations (DSSM)	–
Theoretical Memos	Vulnerability and playfulness
Design Memos	Again more complaints about pressure in the neck

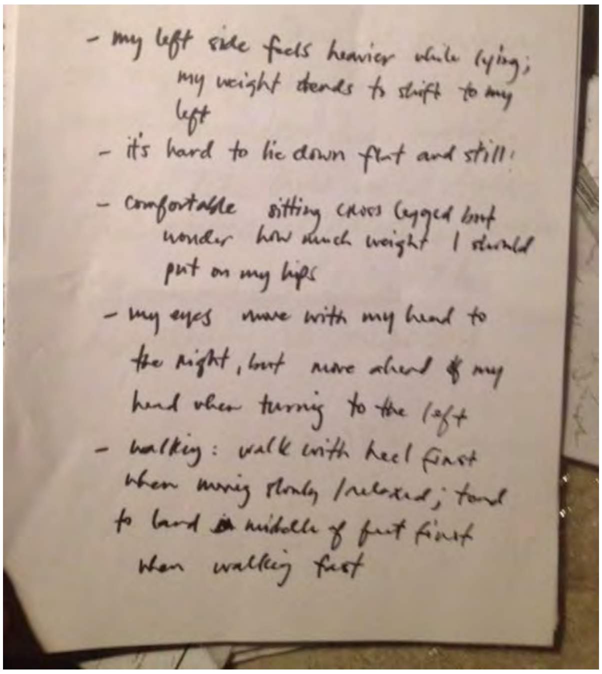

- my left side feels heavier while lying; my weight tends to shift to my left
- it's hard to lie down flat and still.
- comfortable sitting cross legged but wonder how much weight I should put on my hips
- my eyes move with my head to the right, but move ahead of my head when turning to the left
- walking: walk with heel first when moving slowly/relaxed; tend to land middle of foot first when walking fast

Figure A5.6: P06 Feedback Sheet Side 1

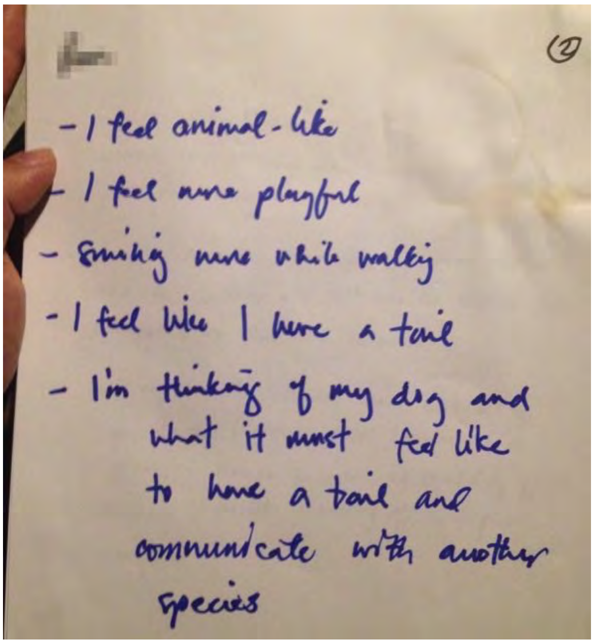
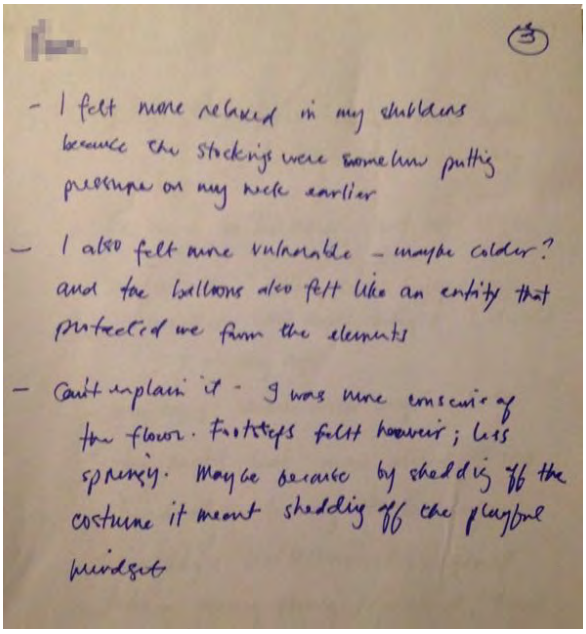

②
- I feel animal-like
- I feel more playful
- smiling more while walking
- I feel like I have a tail
- I'm thinking of my dog and what it must feel like to have a tail and communicate with another species

Figure A5.7: P06 Feedback Sheet Side 2



(3)

- I felt more relaxed in my shoulders because the stockings were somehow putting pressure on my neck earlier
- I also felt more vulnerable – maybe colder? and the balloons also felt like an entity that protected me from the elements
- Can't explain it - I was more conscious of the floor. Footsteps felt heavier; less springy. Maybe because by shedding off the costume it meant shedding off the playful mindset

Figure A5.8: P06 Feedback Sheet Side 3

#P07.160110.AtS3.a5

Feels like something is supporting my back. My neck feels stiffer as though is something is making my head and & neck not move. Dino [?] I did not notice the tail
Lying down: ➢ Earth below ➢ outer space above ➢ My neck feels relaxed Sitting ➢ I feel balanced Walking ➢ The environment around me Standing ➢ It feels normal I became more aware of my surroundings, and how my body reacts to it My left is not the same as my right side of the body Noise [?]
I felt like my back came from a rest There is pressure on my left shoulder, while my right shoulder feels mobile It is like is a ball that makes it rotate or move. When I started feels like something is missing

Participant	P07, male
Context	–
Observation (Self-Reports)	[as above]
Observations (DSSM)	–
Theoretical Memos	–
Design Memos	–

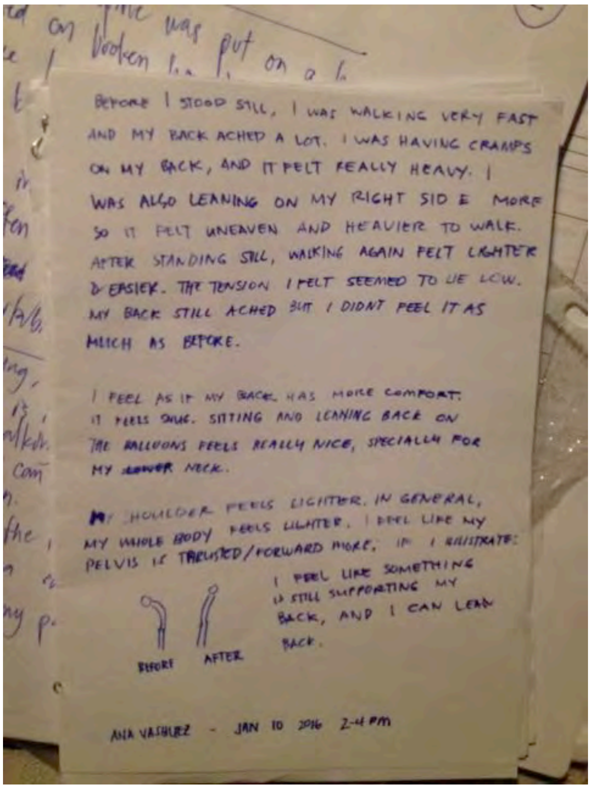
#P17.160110.AtS4.a5

Before I stood still, I was walking very fast and my back ached a lot. I was having cramps on my back, and it felt really heavy. I was also leaning on my right side more so it felt uneven and heavier to walk. After standing still, walking again felt lighter and easier. The tension I felt seemed to lie low. My back still ached but I didn't feel it as much as before.

I feel as if my back has more comfort. It feels snug. Sitting and leaning back on the balloons feels really nice, especially for my ~~lower~~ neck

My shoulder feels lighter. In general, my whole body feels lighter. I feel like my pelvis is thrusted/forward more. [Illustration follows, indicating (also) that the upper torso feels more upright than before] I feel like something is supporting my back, and I can

Participant	P17, female, 22
Context	Workshop
Observation (Self-Reports)	[as above]
Observations (DSSM)	–
Theoretical Memos	–
Design Memos	–


BEFORE I STOOD STILL, I WAS WALKING VERY FAST AND MY BACK ACHED A LOT. I WAS HAVING CRAMPS ON MY BACK, AND IT FELT REALLY HEAVY. I WAS ALSO LEANING ON MY RIGHT SIDE MORE SO IT FELT UNEAVEN AND HEAVIER TO WALK. AFTER STANDING STILL, WALKING AGAIN FELT LIGHTER & EASIER. THE TENSION I FELT SEEMED TO LIE LOW. MY BACK STILL ACHED BUT I DIDNT FEEL IT AS MUCH AS BEFORE.

I FEEL AS IF MY BACK HAS MORE COMFORT. IT FEELS SNUG. SITTING AND LEANING BACK ON THE BALLOONS FEELS REALLY NICE, SPECIALLY FOR MY NECK.

MY SHOULDER FEELS LIGHTER. IN GENERAL, MY WHOLE BODY FEELS LIGHTER. I FEEL LIKE MY PELVIS IS THRUSTED/FORWARD MORE. IF I ILLUSTRATE:

BEFORE AFTER

I FEEL LIKE SOMETHING IS STILL SUPPORTING MY BACK, AND I CAN LEAN BACK.

ANA VASQUEZ - JAN 10 2016 2-4 PM

Figure A5.9: P17 Feedback Sheet

#P18.160110.AtS4.a5

Standing
- awareness of weak right knee
- swaying
- with my eyes closed, the smell of acrylic paint was very strong

Walking
- flat footed
- "outer" sides of my foot fall ["out"]
- elements of the room
- my companions

Second spine experience
- Better posture
- Feels like a comforting experience
- it "massages" your back
- it's like a toy, makes you feel playful
- invites me to experience my environment differently
- i feel my companions look different and balance differently
- makes me smile

Post-exercise experience
- Freer
- the snugness of the "costume" made me less aware of the discomforts of my surroundings of my surroundings, but also made more accepting of them after

Participant	P18, male, 49

Context	Workshop
Observation (Self-Reports)	[as above]
Observations (DSSM)	–
Theoretical Memos	–
Design Memos	–

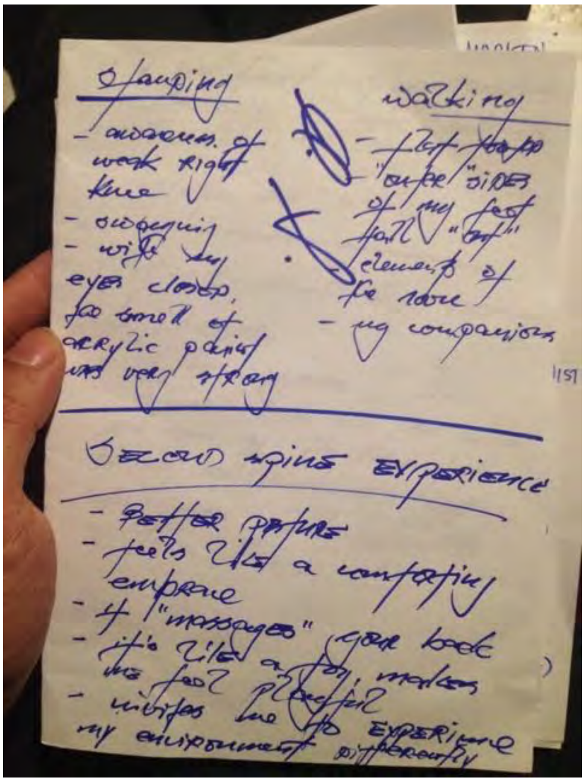
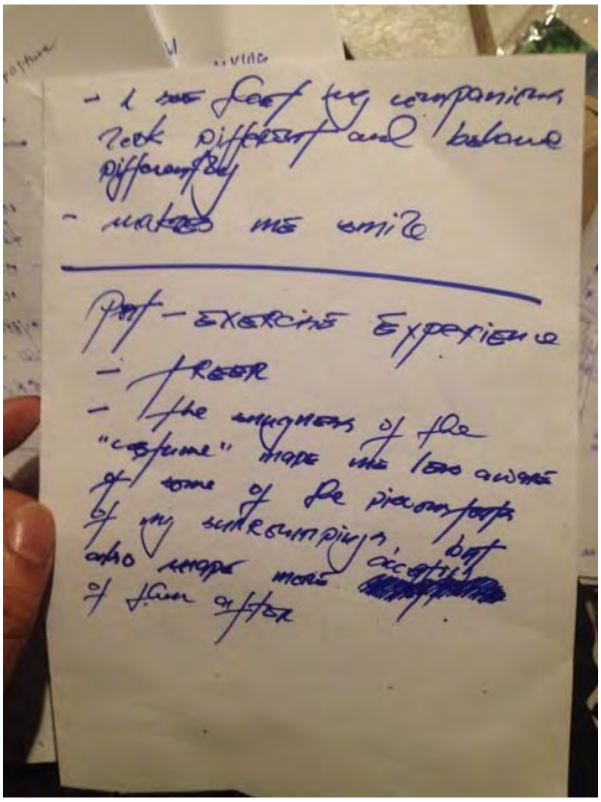


Figure A5.10: P18 Feedback Sheet Side 1



- I feel the companions look different and behave differently
- makes me smile

Post-exercise experience
- freer
- the snugness of the "costume" made me less aware of some of the discomforts of my surroundings, but also made more of them after

Figure A5.11: P18 Feedback Sheet Side 2

#P19.160110.AtS4.a5

Walking
- Look at everything in the room
- Didn't pay attention to how i was walking or to body parts and how it moves. Would only do so when it is mentioned
- After a while i look at things in the room again

Standing
- Even when eyes closed
- But catch myself holding breath (pant waist too tight =)
- Rooster [located somewhere in the vicinity in the area, probably crowing] is quite active

Spine
- Like snug feeling (tight shirt + waist band)
- But disturbed with the one at my nape
- tight collar
- felt better, more relaxed when adjusted

After removing
- less constricted (same feeling as removing a girdle)
- feel lighter but sometimes still have the sensations of the balls

Participant	P19, female, 49
Context	Workshop
Observation	[as above]

(Self-Reports)	
Observations (DSSM)	–
Theoretical Memos	–
Design Memos	–

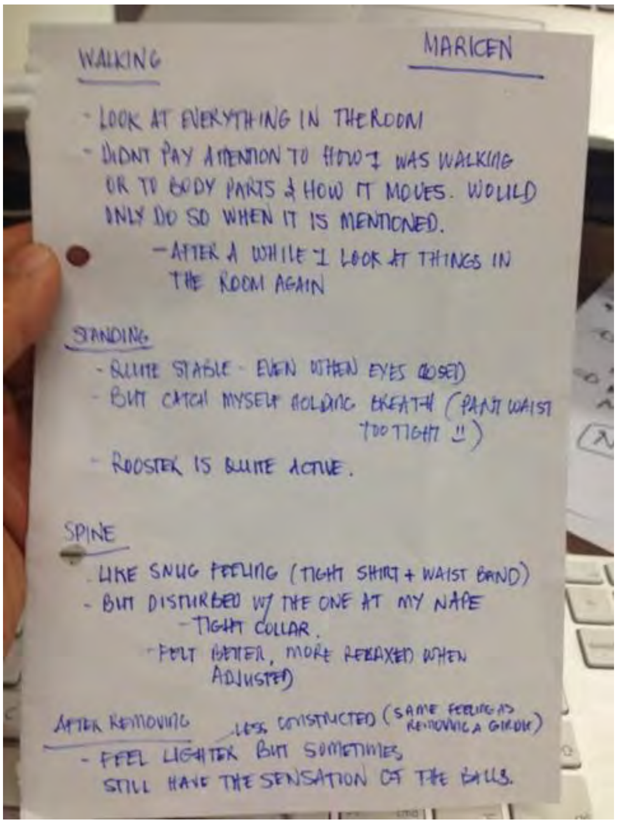


Figure A5.12: P19 Feedback Sheet

#P20.160110.AtS4.a5

1) I noticed that while walking, I would lead with my heels, sometimes they would drag against the ground 2) Standing, I would get a sense that left shoulder is closer to my ear [ear?] than my right 3) While walking or standing, I have this impression that my hips [?] [are?] [this is] out w…, putting a lot of strain on my lower back
4) After applying and securing the balloon strip against my spine, while walking, standing and sitting there was a general feeling of comfort…[???] that my spine has greater support
5) After removing the balloon spine i immediately felt 'lighter' and felt that i had a much smaller frame. After taking a walk and standing still it seemed as if my body missed [?] the [???] support [?]

Participant	P20, male, 34
Context	Workshop
Observation (Self-Reports)	[as above]
Observations (DSSM)	–
Theoretical Memos	–
Design Memos	–

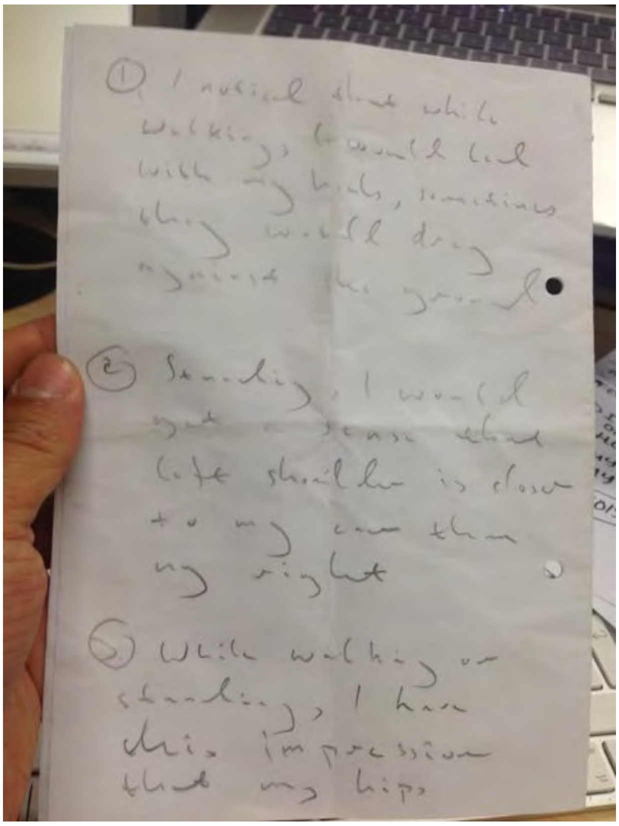


Figure A5.13: P20 Feedback Sheet Side 1

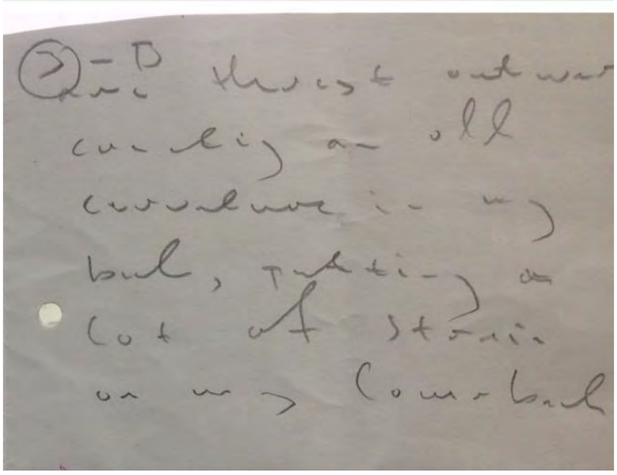


Figure A5.14: P20 Feedback Sheet Side 2

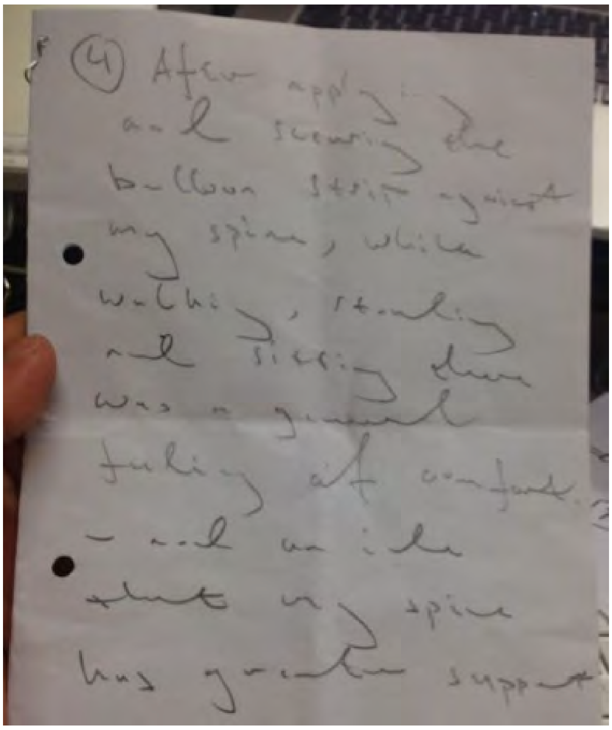


Figure A5.15: P20 Feedback Sheet Side 3

#P53.160110.AtS4.a5

Conscious awareness of my posture
Well-balanced, symmetrical stance
Composed, calculated movement
Cross between massage and a hug
Round, bouncy
Back: relaxed and firm [? free?]
Neck, chest: constricting
1) Clumsy
2) but free [?]
3) more fluid
Extra effort to support back/retain posture

Participant	P53, male, 29
Context	Awaken the Spine Workshop (session 4)
Observation (Self-Reports)	[As above]
Observations (DSSM)	–
Theoretical Memos	–
Design Memos	–

Prototype Trials Primary Data

Prototype trials were informal sessions with colleagues, friends, and on myself that were conducted throughout the entire prototyping and evaluation process of Haplós.

#P0.161006.ProtoTrial.a5

OK I HAVE THE SUIT ON I have 7 equal enough motors in close succession on my upper left lat area [Later on] also, after i tried the cluster of 7 things around my left shoulder, my left hand felt good. ha.

Subject	Author
Context	Unknown
Theoretical Implications	–
Design Implications	–

#P0.170304.ProtoTrial.a5

AudioRecording 20170304 11:28:47.wav	I've just attached Haplós to my right

Subject	Author
Context	At the piano
Theoretical Implications	➢ The conceptual relationships between rhythm, prediction, intent, and attention. When attention to the patterns slip, perhaps the rhythm has become predictable, and thus all that is there to be learned from that rhythm has been learned *for the time being*, so it's time to move on. But (as per the non-linear nature of somatic learning) allow users the opportunity to return to the rhythmic experience. The experience has to be *reversible*. ➢ See the design implications below, which in turn demonstrate
Design Implications	➢ Don't hold users hostage to the rhythm changes. Allow them to go back and forth between the rhythms. Allow them to change rhythm tempo on the fly. Have a go back and go forward button. Maybe even repurpose a bluetooth headsets navigation buttons for that purpose. Or, as John pointed out, use voice activation!

	The reason being that for a controlled kind of experiment on the self, you would like to minimise movement that you don't need to do as much as possible. Although in practice, in FM, often we do disturb ourselves lying on the floor to go to the toilet, for example, or to adjust clothing or the mat. But in order to re-enter the experience, we/I do take a bit of time to return into the experience before continuing the lesson. ➢ Allow the users to STOP THE PATTERNS. This is so obvious that i'm surprised i didn't see before. They need time to integrate.

#P0.170322.ProtoTrial.a5

	Alright, about to try Haplós on my hip flexors. Plan: 1. Feel myself in standing. Shift weight to left and right. 2. Walk around and feel myself in walking. 3. Sit down and feel myself in sitting. 4. LOB, feel contact on the ground 5. Turn legs inwards alternately 6. Bring FotF, legs bent, feel the action here 7. Lengthen one leg and push using foot on other leg. Switch. 8. position motors and turn on
	So this was my last experiment so far: i strung the motors right along the costal spine (?)

#P34-55.160624.ProtoTrial.a5

AudioRecording 20160524 11:05:04.m4a	I'm just going to highlight some of the things that were said here: Diego: "We forget that there's a lot of me in the back" P37: Interesting to see it on different people P35: "Yeah… yeah. That's very good, that one." These were not bicycle inner tubes P34: "It doesn't feel like a massage, like a muscular thing that's working into you… It's more an awareness thing." P55: "There's that thing you can do, where you write letters on people's backs." P38: "Spell out words" Some of the feedback: The straps are not entirely comfortable for everyone.
AudioRecording 20160524 11.35.31.wav	P55's comments are in this audiofile. [untranscribed]

Participant	(Group) P34, P35, P36, P38, P55
Context	Design Critique at Kin

Observations (Self-Reports)	–
Observations (DSSM)	–
Theoretical Implications	P55 points out that If I decide to use music as my peg, there's a whole language that i can appropriate in a certain way: • * tempo • * style (e.g., bravissimo) • * time signature I told him that i had the language of piano specifically in mind. Could Haplós be programmed using musical notation? I could have multiple notes sounding at the same time… but do i want it? And why? Maybe this is something to explore in a workshop? Could Haplós be programmed using musical notation? I could have multiple notes sounding at the same time… but do i want it? And why? Maybe this is somethign to explore in a workshop? *Here's an idea: because the ribbon is rather stiff, parallel increments in multiple sounding notes should be felt as equal lengths by the wearer* **As somatic tool/As musical instrument** Stimulation points | Notes Manipulations/touches | Figure/loop Lesson | Musical puzzle Lesson plan | Playlist/curation
Design Implications	1. The straps are not entirely comfortable for everyone. Ditch them?

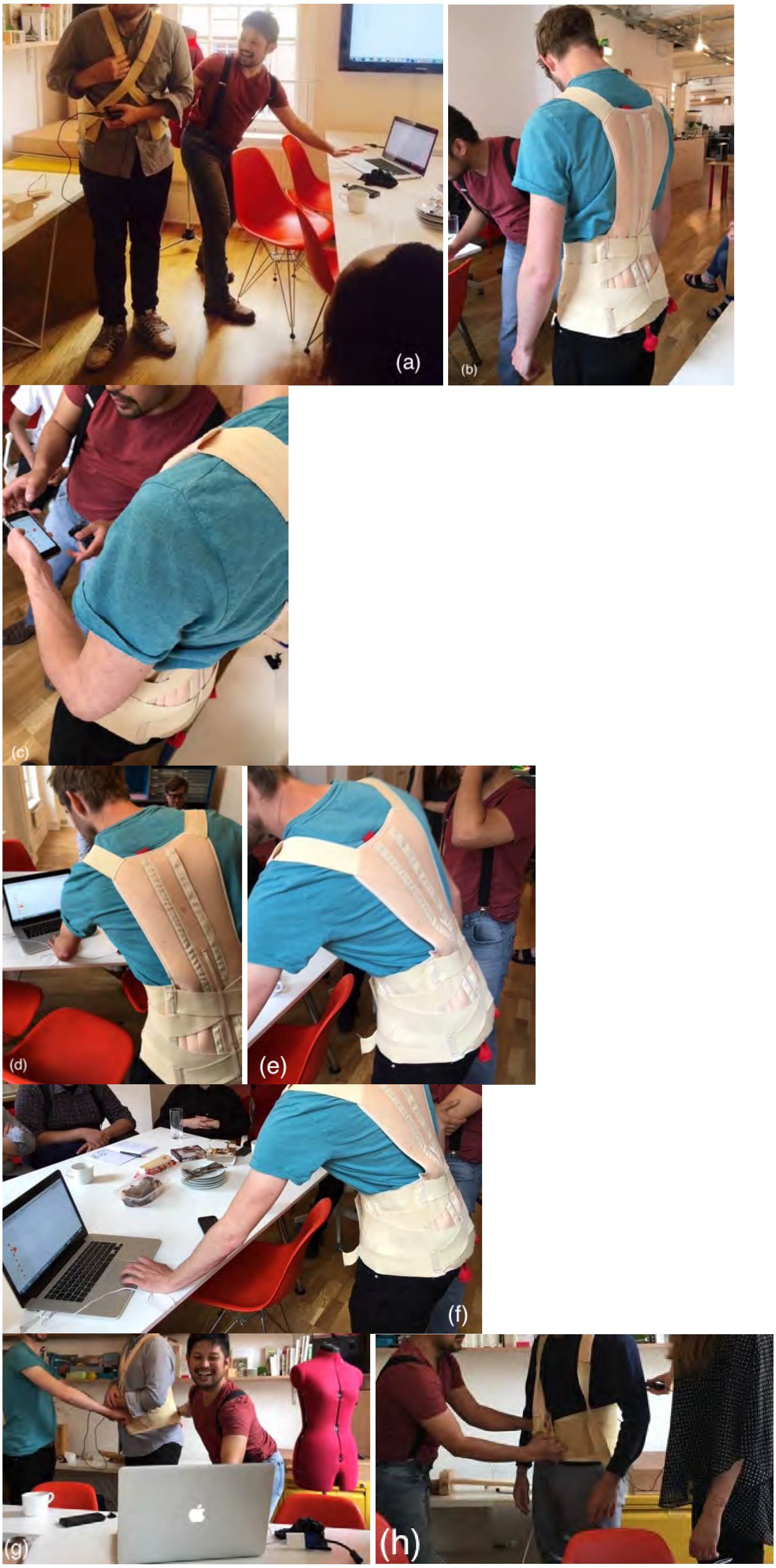

(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)

Figure A5.16 (a-h): Design Critique at Kin

#P43.170121.ProtoTrial-B.a5

#P43.170122.AdHocHaplósTrials.Interview.mp3	Randomly-generated tune. Audio and vibration felt two different things (at first). Maybe too loud?, i asked. But after that, "it sounds like a bass line to the tune that's vibrating along my spine" "It blends in more… before they felt like two different things" "It seems like an electronic tune but it feels like the notes are vibrating through my spinal column" "It feels like there's a theme." He can feel that each of the notes is vibrating in a different place, but "he can't distinguish whether there's a scale, whether the high notes are at the top or the low notes at the bottom"… but then later reverses this opinion (top note = shoulder, bottom note = closer to lumbar spine) I asked him what this feels like to him. "It feels like when you smell and taste something. The taste is kind of unavoidably connected with smell. It's like touch and sound, in a way they can be … touch and sound are a vibration. It feels more like a balance between the sound and the feeling." "The feeling/sensation is nice, it's enjoyable, it feels quite relaxing. I'm enjoying it. It's also kind of interesting." I told him that he can take it off when he was tired of it, and he replied, "I don't think i can get tired of it [laughs]." I paused the pattern. He says, "Now i can hear the white noise" I try a slower composition. "Vibration feels more intense" Trying something quicker. Listening to the recording, I can tell that i gave him a series of three patterns, the first quick, the next two at double time. After about 1 minute of this he says, "I feel like I'm drifting off" and feeling sleepy. "it might have been before, during the slower one, because when i noticed i was drifting off i was already nodding off" After the experience i asked him to stand up and feel himself in standing, then walking. He pointed to the area between his cervical spine and his thoracic spine and said that it felt "different", though he had difficulty describing how it felt different. He says he feels his "spine feels crushed for years now", and he says that the suit made him aware of how "out of shape his spine had become"

	I said that that that wasn't my intention to make him feel like his spine was out of shape He says that it something he felt already… I should have asked him, how does he know that he feels that his spine feels out of shape, or what is he feeling that is making him say that his spine feels out of shape (cf. Petitmengin's interview technique) "That was the biggest kind of sensation, that it was part sound but very much feeling more vibration" "Massage", it felt like a "massage down the spine"

Participant	P43
Context	Ad Hoc Haplós Trials
Observations (Self-Reports)	[As above.]
Observations (DSSM)	–
Theoretical Implications	"Vibration feels more intense"- consistent with prior research that the duration of the vibrotactile stimulus affects its perceived quality and intensity [170419] The end sensation wasn't quite what i was anticipating, and i wonder what would have happened if i just stuck with a one-sided lesson, so that he could feel a difference in sensation and made a judgment about which side he liked better. [170419]
Design Implications	–

#P45.170107.ProtoTrial.a5

Participant	P45, female, ? yo
ontext	–
Observations (Self-Reports)	Participant used the word "technomassage" to descrie the experience lying on the massage table. Exactly.
Observations (DSSM)	–
Theoretical Implications	Actually, when I think about it, really the main thing is differentiation. Variety. And not only sensing that variety, but sensing it as variety and

	differentiating between the different components.
Design Implications	Here are some design patterns: • Differentiation

#P47.160126.ProtoTrial.a5

Said she was surprised that the sensations (vibrations) got stronger over time even though nothing had really changed in the patterns.

#P49.170205.ProtoTrial.a5

Participant	P49
Context	Ad Hoc Haplós Trials
Observations (Self-Reports)	"It's like using your whole body as an instrument" "It reminds me of when you're in a meditation class, and they ask you to pay attention to your toes [and other parts of your body]… it makes me aware of parts of my back that I normally wouldn't think about."
Observations (DSSM)	–
Theoretical Implications	–
Design Implications	–

#P50.170222.ProtoTrial.a5

Says that it's like a nursery rhyme. Felt it was like a Steve Reich piece

#P51.170222.ProtoTrial.a5

Thought it was "brilliant." Was reluctant to take it off.

Manufactory Workshop Primary Data

The Manufactory public workshop was held as two independent 2-hour sessions on the evenings of the 20th and 21st of October 2016 at Plymouth University.

#P09.161020. Manufactory1.a5

Participant	P09
Context	Manufactory Workshop session 1
Observations (Self-Reports)	–
Observations (DSSM)	–
Theoretical Implications	–
Design Implications	–

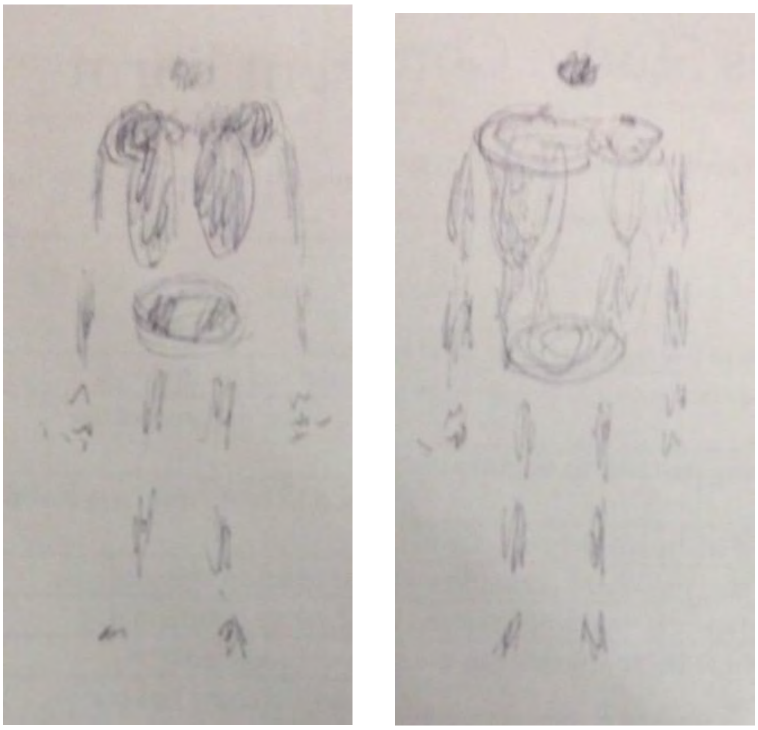


Figure A5:17: P09 drawings before (left) and after (right) wearing Haplós.

#P10.16.1020.Manufactory1.a5

Participant	P10
Context	Manufactory Workshop session 1
Observations (Self-Reports)	He preferred the small, focused vibrotactile sensations.

	He found it interesting that because of crosstalk in data sending, he ended up controlling other people's suits occasionally. "I just notice my back a lot more from doing that… [garbled] helping posture"
Observations (DSSM)	–
Theoretical Implications	–
Design Implications	–

Figure A5.18: P10's drawings before (left) and after (right) workshop

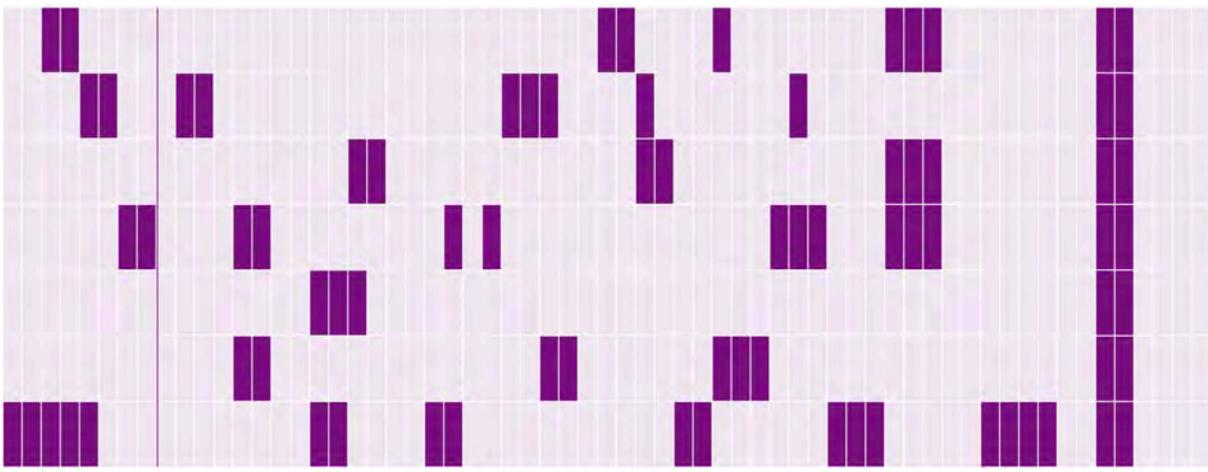


Figure A5.19: P10's Haplós pattern

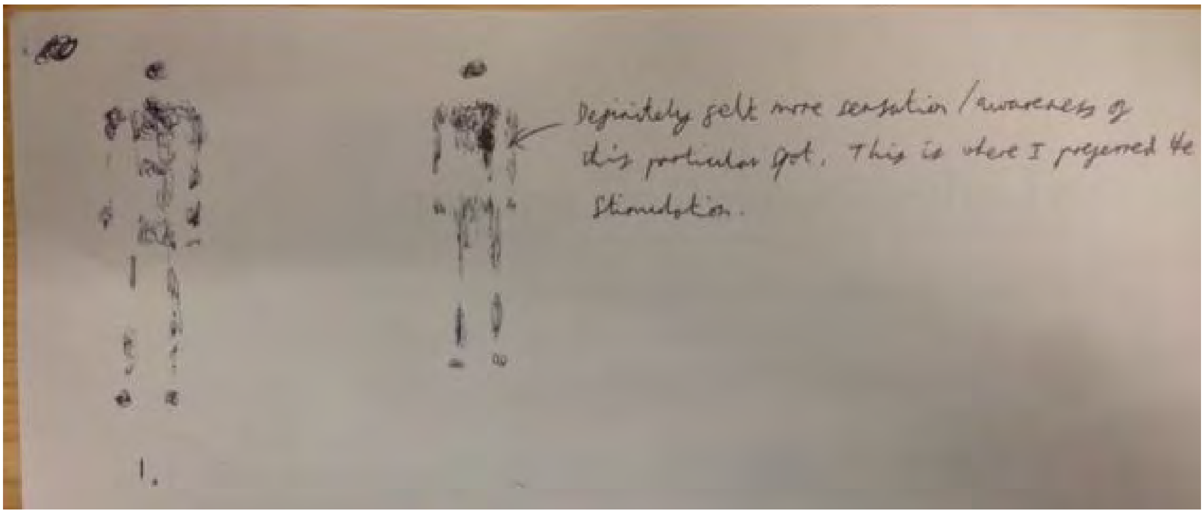


Figure A5.20: P10's handwritten feedback besides the drawings

Transcription: Definitely felt more sensation/awareness of this particular spot. This is where I [preferred?] the stimulation.

#P11.161020.Manufactory1.a5

Participant	P11, female
Context	Manufactory Workshop session 1
Observations (Self-Reports)	After wearing the suit, she said her left hand felt "heavier" (than before? than the right?). But then again I did draw their attention to it.
Observations (DSSM)	–
Theoretical Implications	–
Design Implications	–

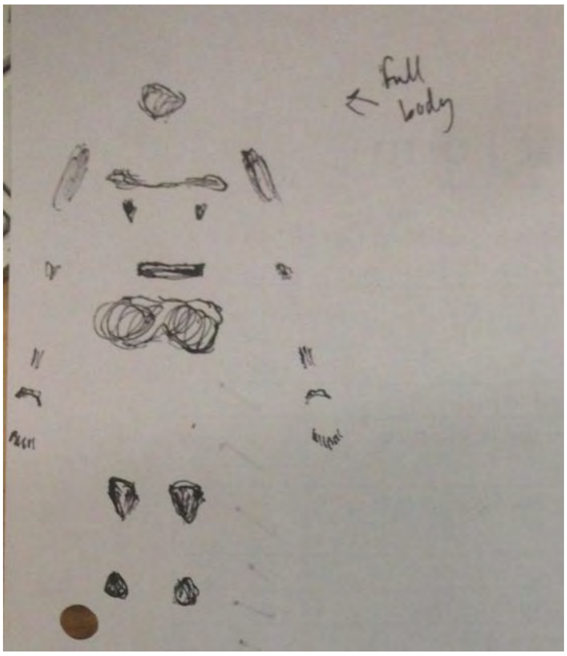


Figure A5.21: P11's drawings before (left) and after (right) workshop

Figure A5.22: P11's Haplós pattern

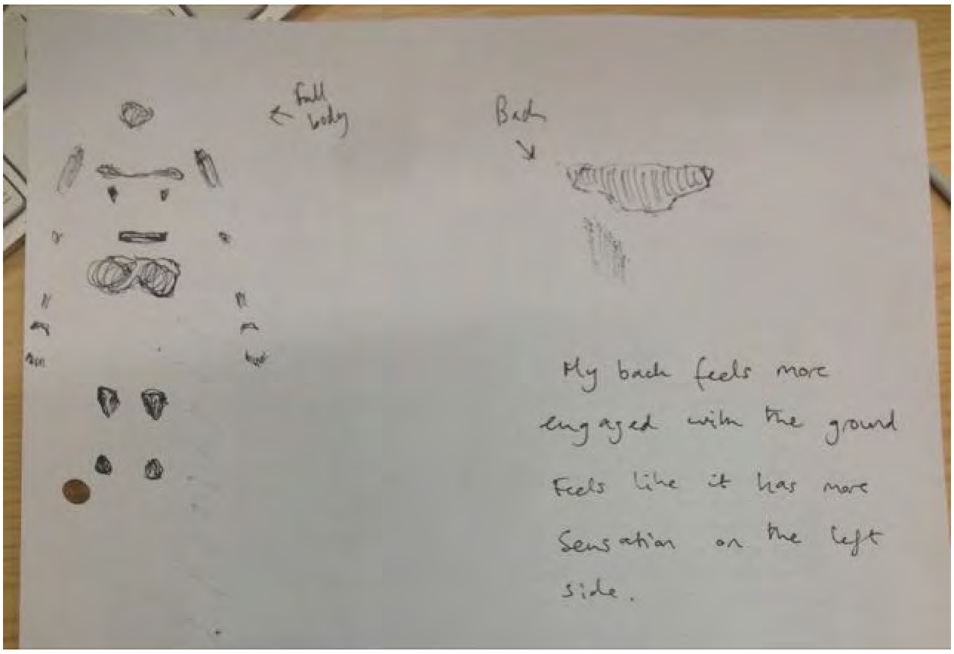
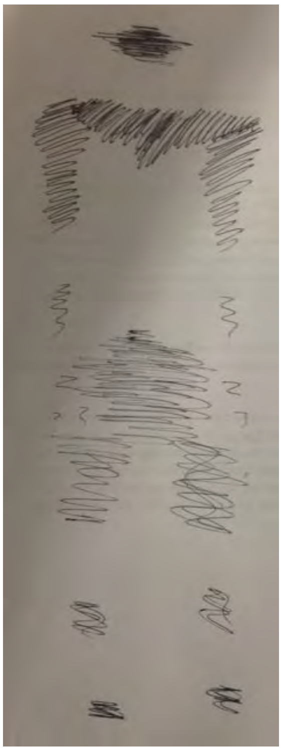


Figure A5.23: P11's handwritten feedback on drawing sheet

Transcription: My back feels more engaged with the ground. Feels like it has more sensation on the left side.

#P12.161020.Manufactory1.a5

Participant	P12, female
Context	Manufactory Workshop session 1
Observations (Self-Reports)	At the end of the session, she says that she felt "relaxed"
Observations (DSSM)	–
Theoretical Implications	–
Design Implications	–



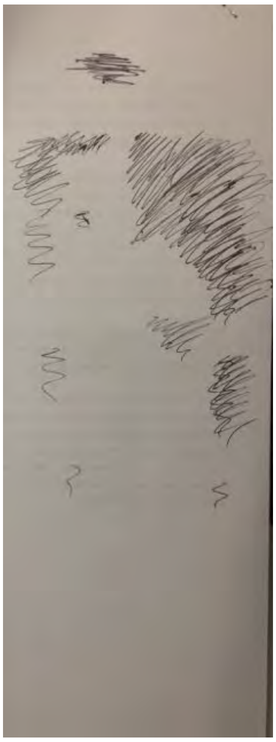


Figure A5.24: P12's drawings before (left) and after (right) workshop

Figure A5.25: P12's Haplós pattern

#P13.161020.Manufactory1.a5

From Clip1.mov	The pitch of the vibration distracted her from the position on the spine. It was incongruous. I can't always predict what the pitch would be based on how the […]

WELL

Participant	P13
Context	Manufactory Workshop session 1
Observations (Self-Reports)	[As above]
Observations (DSSM)	People were laughing and moments of delight when people said, “I like that motor,” “Oooh, i like that one”. There was much more variation in preferences. A preferred point stimulation rather than the big ones. S liked the big ones. Sophie had this great smile like a frisson when all the motors turned on. She liked it fast
Theoretical Implications	–
Design Implications	–

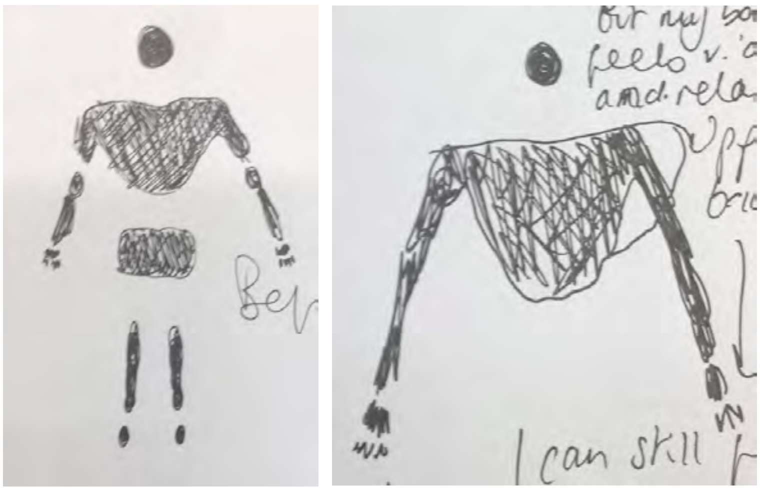


Figure A5.26: P13’s drawings before (left) and after (right) workshop

Figure A5.27: P13's handwritten feedback on the drawing sheet

Transcription: I didn't feel any 'differences' but my back feels v. 'alive' and relaxed. upper back.

I can still feel the sensation of the motors on the LH side of my spine though (a tingling sensation)

#P14.161020.Manufactory1.a5

Participant	P14, male
Context	Manufactory Workshop session 1
Observations (Self-Reports)	(From video recording) After wearing the suit, he said his left hand felt "tingly". But then again I did draw their attention to it. While still wearing the suit and before lying down, he said he felt the experience "underwhelming". He also found it "kind of bothersome" that it was "only on his left" and felt that "it should have been in the middle". (I didn't tell them why the vibrations were one sided) then later on, after lying on the mat, he says that he "was slightly more aware of my left side than i was beforehand... i was more sensitive to its location and which parts were making contact with the floor. so if anything, the resolution with which i can feel my back increased. i feel like i have a sharper image."
Observations (DSSM)	–

Theoretical Implications	–
Design Implications	–

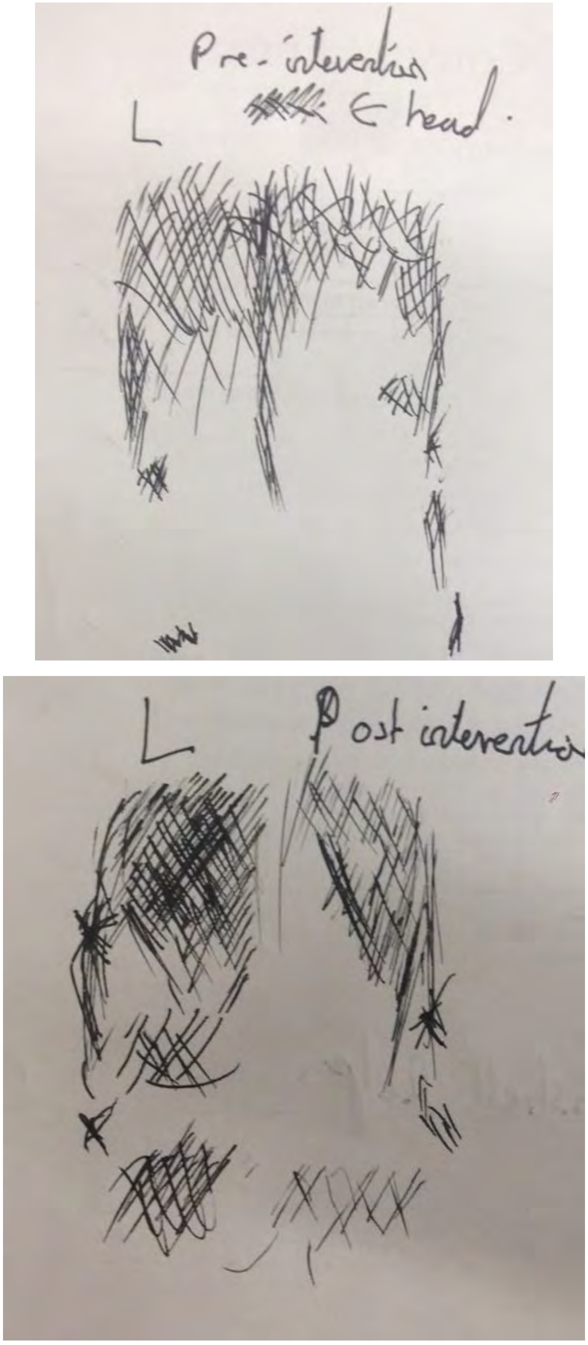


Figure A5.28: P14's drawings before (left) and after (right) workshop

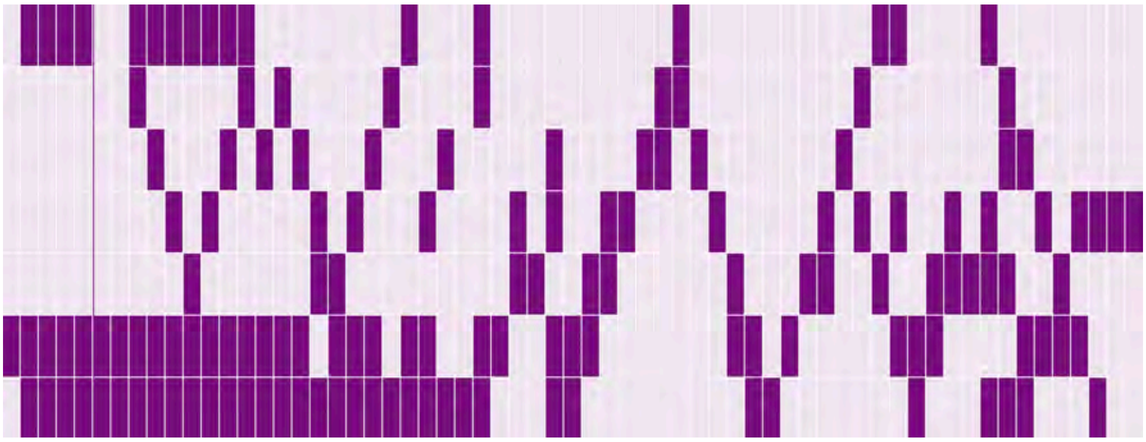
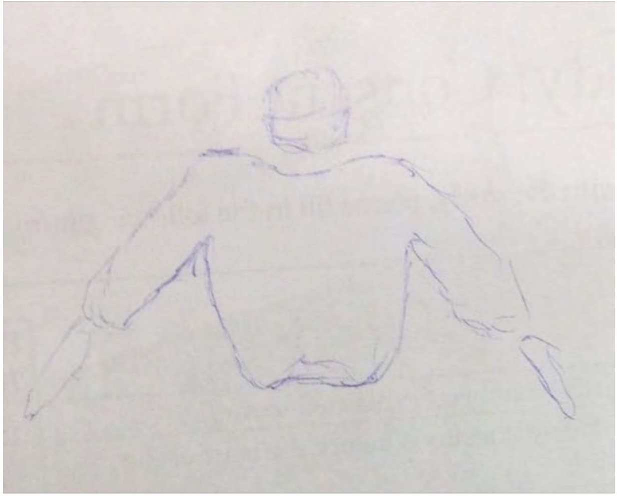


Figure A5.29: P14's Haplós pattern

#P15.161020.Manufactory1.a5

Participant	P15, female
Context	Manufactory Workshop session 1
Observations (Self-Reports)	-
Observations (DSSM)	–
Theoretical Implications	–
Design Implications	–



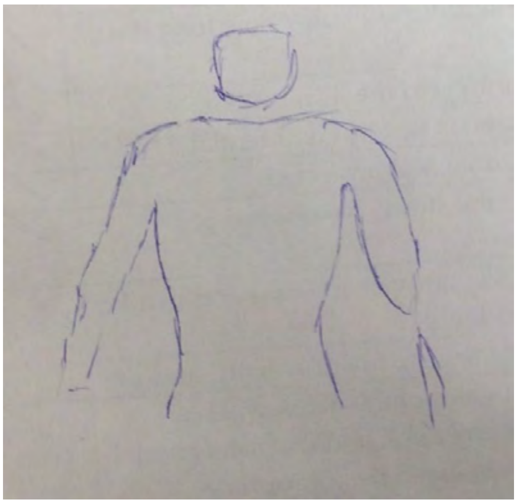
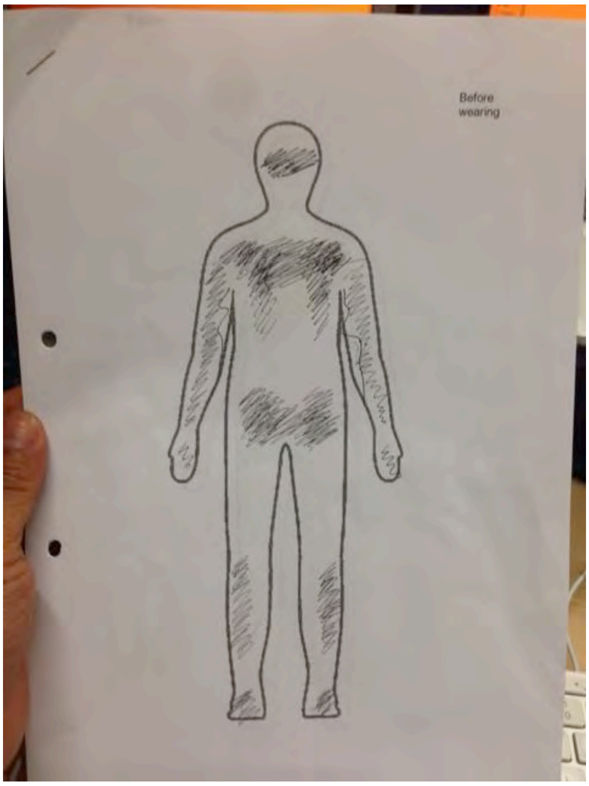


Figure A5.30: P15's drawings before (left) and after (right) workshop

#P21.161020.Manufactory2.a5

Participant	P21, female, 22
Context	Manufactory Workshop session 2
Observations (Self-Reports)	➢ 6:19: After taking off the suit, she made a sound. ➢ When I probed what that sound was, "It's the real me." Me: "Because you don't have this anymore?" Her: "Yeah". ➢ 14:07: Said that arms was interesting. ➢ 14:36: Her gestures showing that her left arm and hand was more outwardly rotated. She seemed surprised. ➢ 15:09: I'm pointing to an area in her drawing, and she gesture using her shoulder to suggest that her shoulders are organised differently so that her chest is wider and her collarbone area is more 'open'
Observations (DSSM)	–

Theoretical Implications	–
Design Implications	–



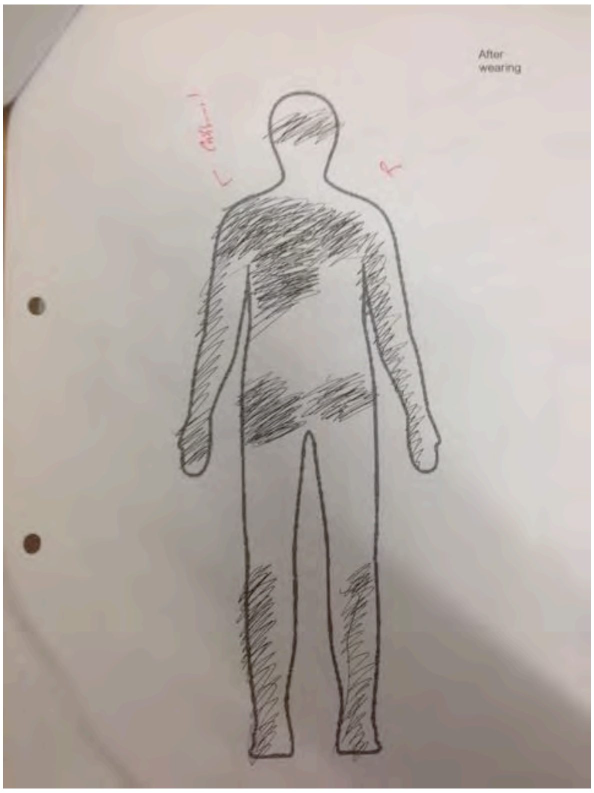


Figure A5.31: P21's drawings before (left) and after (right) workshop

Figure A5.32: P21's Haplós pattern

Cravings Study Primary Data

The Cravings study was a controlled experiment that tested whether the application of short, carefully designed patterns of vibrotactile stimuli from Haplós could reduce intrusive food-related thoughts. The data presented here are from the qualitative questionnaire administered towards the end of the study for the experimental group.

#	How did you feel while wearing the suit?	How did you feel after taking off the suit?	Were there any physical sensations that were interesting to you either while or after wearing the suit?	Where did you feel the vibrations?	Is there anything else you want to say about what the experience of wearing the suit with the vibrating motors was like for you?	Vest pleasantness	Motor pleasantness
E1	The suit was comfortable and the sensations were a little strange, but relaxing	slightly more relaxed	Just the sounds and feeling of the vibrations	Only felt the sensations on my neck and back	[Not answered]		
E2	Tight and uncomfortable but it was easy to deal with because i knew it was a study	relaxed and relieved	the vibrations relaxed my body and after i took it off i felt calmer and ready for a nap	i felt them just on my spine	[Not answered]		
E3	fine, slightly uncomfortable	better, still felt a bit odd	afte I felt as though where the vibrations were I could still feel a tingling sensation	no, just the back	no		
E4	Slightly constrained. It felt quite odd. I became more aware of my breathing and what my body was doing.	More freedom, relaxed. Less focus on breathing.	My fingers were tapping to the rhythm of the suit vibrations. My breathing became deeper.	Neck and shoulders	It was surreal, but became relaxing after a while.		
E5	comfortable, safe, giggly, supportive	cold, wanted the support back on again, more open back feeling?	my back felt very warm during, and after taking it off I had an 'open back' sensation, feeling more loose around my upper back	my shoulders, upper, and middle of the back	[Not answered]		
E6	A bit weird, i didn't know what it was designed to do exactly and was a bit surprised when it started making vibrations, but eventually i stopped thinking about it.	Not too much different really. The questions and test had taken my mind off the suit so other than the obvious difference in feeling, there wasn't too much difference.	The vibrations were interesting, too feel how they moved up and down my spine and back in what seemed like a programmed manor, so i found it interesting to think why is it doing what its doing.	I felt the vibrations predominantly in my upper back, but also the base of the back of my neck too.	I wasn't too sure what to expect coming into the experiment, but after wearing the suit i'm a little more interested in its purpose.		
E7	comfortable, relaxed but unusual	I felt normal. I felt the same as I did before putting on the suit	The upper part of my back was particularly sensitive. The vibrations appeared to be in some sort of a routine	I felt the vibrations on all up my back including my lower back	The vibrations appeared to be making up a song / sequence. Some vibrations felt as if they were chords		
E8	felt really relaxed	to be honest I didn't feel much different	While I was wearing the suit I felt really relaxed	Lower back	It was very interesting and it was very different		
E9	Restricted by the tightness.I enjoyed the vibrations, they were relaxing.	Released, free.	I felt like I was wearing a corset and being held into the suit.	Only felt them in my upper back.	In a strange way it was enjoyable and gave me something else to think about.		
E10	Relaxed and felt like i was getting a back massage. I enjoyed it.	More relaxed then before i wore it.	The sensations on my lower back made me feel ticklish. I also liked the ones on my neck.	Neck, lower back	In enjoyed it it was a pleasurable experience.		
E11	it was slightly uncomfortable because i felt quite restricted, which made it more difficult to relax.	i felt a slight sense of relief which enabled me to relax a bit more.	i noticed that when i was wearing the suit i became much more aware of my breathing and my body temperature felt like it had increased slightly.	shoulders	[Not answered]		
E12	It was weird, but it felt quite relaxing, it was sort of like music was coming from it?	I didnt want to take it off, I felt quite focused on my surroundings afterwards though.	The tingles radiating over my back in areas where the vibrations had been.	No, just in my back predominantly, and a little bit on the under side of my fore arms near my elbows	It felt like music coming from the vibrations and they were playing a song on my skin.		
E13	Comfortable, it was fine, wasn't too heavy or didn't dig in etc.	Not much different to when I had it on.	None	No, just my upper back and occasionally in my lower back.	I found the sound of all the vibrations together quite 'creepy', like a song (sounds strange).		
E14	slightly uncomfortable and restricted	felt more free	during when the motors were on I did feel slightly more relaxed and afterwards I felt calmer than before	felt them in my lower back and hips and running down my spine	it felt like having a massage		
E15	Like I couldn't relax properly, and had to sit up straight.	Relaxed	I found out that I am ticklish around my lower back.	Neck, shoulders, lower back	At first I was very ticklish but I gradually got used to it.		
E16	Confined and weird	relieved	after taking off the suit parts of my back went a little numb for a few seconds	lower back, neck and shoulders	[Not answered]	4	5
E17	Relaxed, calm.	the same.	The motors on my back. They seemed to act in a symetric way	My neck	Nope	4	8
E18	It was ok, i felt a little tired i suppose	normal, it was easier to slouch in my chair once it was off though	The sounds the vibrations made reminded me of like a 1980's scifi computer or something, or like an old theme tune to a TV sitcom or something	i felt the vibrations where they were, i.e. top, middle and lower back	it was ok	6	6
E19	i felt secure and embraced so relaxed	slightly exposed and less relaxed now	my muscles relaxed whilst wearing the suit and now they feel a bit shaky, like my nervousness has returned	i felt the vibrations in my upper and lower back and my neck	I enjoyed the sequential patterns of the vibrating motors, i could predict the next rhythm and it was more relaxing to make the vibrators in a sort of symphony	10	10
E20	A little bit tense because I wasn't sure what the vibrations were supposed to make me feel like but mostly fine	I feel a bit lighter and a bit relieved	I found myself really feeling almost the beat of the vibrations and I started tapping my foot to the rhythm they were performed in.	I felt them on my neck, shoulders, lower back, the back of my legs and my feet	[Not answered]	4	7
E21	it was a little strange to start with but it felt fine after a few minutes	I felt like I wanted to arch and stretch my back	I felt that when the pattern of the sensations changed I was more aware of the different movements.	I felt them in my neck, upper back, middle back and lower back	[Not answered]	4	7
E22	Restricted but relaxed and calm.	More relaxed to how i felt before i wore the suit	my back felt more relaxed and less tense	in my shoulders as well	[Not answered]	3	8
E23	it was a really nice feeling, like a massage. I liked it	it was nice to be unrestricted again but I didn't have a strong feeling either way.	The vibrations made a noise like an old electronic song, something like Kraftwerk. I found that I concentrated on that more than the physical sensations. I did like the physical sensations though.	upper back and shoulders and lumbar area of spine. Felt it in my breathing too, made me more aware of the exhale of breath	I'm not sure if the motor was meant to be randomised but It sounded too much like analogue electro to me to not be designed into a pattern.	4	8

E24	Relaxed, thought free	Still relaxed	my back felt tender, but it was a relaxing sensation	i felt numerous vibrations in my neck and every part of my back, but no where else	I felt as though the vibrations were in the pattern of a song	9	8
E25	It felt strange feeling the vibrations all up and down my back - I noticed the sounds and it felt tight around my body	I felt a lot more relaxed once it was off as it wasn't tight around my upper body and the vibrations/sounds were not there distracting me	The feeling of the vibrations all up my back to my neck - i was very aware of these The vest also felt very restrictive compared to normal clothes	I felt them in my neck and shoulders	[Not answered]	3	3
E26	A bit strange, it was sort of relaxing but at the same time not	The same as before I put it on	The buzzing was a pleasant sensation but I haven't had any physical sensations after taking it off	I felt the vibrations all over my back including the lower back and round the sides, but that was all.	I felt a little bit tense after taking it off	7	8
E27	At first it was quite interesting to feel the movement it made, then as the time dew on, i became more used to the pattern of the vibrations. This made me relax more, and felt quite soothing.	The relaxation felt whilst wearing the suit was 'lifted off my shoulders' as the suit was, so I feel lighter and calmer.	The vibrations were interesting to me as i could feel them move up and down my back, each with varying type of pressure which was very relaxing. I felt my body un-tense.	I felt them in the lower part of my neck, beside my spine all the way down to my lower back.	/	9	10
E28	Comfortable, intrigued and fairly relaxed once the motors were on.	Bit disappointed, would have enjoyed it for longer.	The vibrations on the back and noises were extremely relaxing and kept my focus on them.	neck, shoulders, lower back only.	it was a very interesting experience. I am intrigued of the outcome and found it very very relaxing.	8	10
E29	Relaxed, though the vibrations felt slightly uncomfortable, it felt like they were really relieving tension in the muscles.	Still relaxed	While wearing the suit I found that the vibrations felt really deep into the muscles and felt quite ticklish.	I felt them in my lower back and neck.	No	8	8
E30	Relaxed and comfortable	Warm	It was warm and ticklish	Yes down my leg	It was enjoyable	8	8
E31	Very relaxed, I was able to focus on the rhythm of the vibrations and take my mind off of other distractions which is something I usually struggle with.	was strange taking it back off because I got quickly accustomed to it, my posture felt funny	The vibrations at the lower end of the suit particularly caught my attention and allowed my mind to empty. After taking it off it felt strange- I noticed my natural posture more.	Felt them a little bit in my neck and a lot in my shoulders.	It was quite therapeutic!	7	10
E32	Intrigued	I wanted to know how the suit worked and why I was wearing it	No	Lower back, and shoulders	No	5	3
E33	Comfortable and relaxed	Relaxed	Vibrations on my back	Lower back	[Not answered]	10	10
E34	very relaxed, it was quite theraputic	My muscles and body felt less tense and looser	My back still could feel the sensations left by the vibrations even after it was taken off	My neck and lower back especially noticed them	It seemed like it was a tuneful rhythm and was very enjoyable	7	10
E35	I was a bit apprehensive at first but after it stopped being ticklish it was quite relaxing.	Lighter, it isn't heavy but you notice that its there, I wouldn't have minded leaving it going for longer, it was quite nice.	I can still feel the places where the moters were it's still a bit tingly.	I just felt it where the moters were activating.	I wouldn't mind wearing it again.	3	9
E36	Relaxed, Peaceful, Destressed	Relaxed, Awake, Calm	The vibrations from the suit allowed it to be extremely relaxing and I felt my body untensing and my muscles stayed more relaxed afterwards.	Very slightly in my hands.	Very relaxing.	8	9
E37	Very aware of my back and arms. I felt quite entertained by the musical element. It was easy to focus on just the vibrations but hard to focus on anything else.	Calm, almost like the effect of meditation or actively trying to relax.	My muscles relaxed and felt comfortable.	I felt some on my shoulders and upper arm.	N/A	6	8
E38	it was a strange sensation, obviously not used to a tight vest which gives out vibrations and weird sounds	more comfortable	the sounds it made moire than the vibrations	lower back and shoulders	it felt as it the vibrating motors where supposed to be playing some sort of tune	4	5
	23	21	18	0	12		
	9	12	3	0	2		
	6	1	2	0	1		
	0	4	15	38	23		

Q1 How did you feel while wearing the suit?

Answered: 39 Skipped: 0

#	Responses	Date
1	it was a strange sensation, obviously not used to a tight vest which gives out vibrations and weird sounds	3/3/2017 2:14 PM
2	Very aware of my back and arms. I felt quite entertained by the musical element. It was easy to focus on just the vibrations but hard to focus on anything else.	3/3/2017 11:23 AM
3	Relaxed, Peaceful, Destressed	3/3 /20 17 10: 57 A M
4	I was a bit apprehensive at first but after it stopped being ticklish it was quite relaxing.	3/3/2017 10:18 AM
5	very relaxed, it was quite theraputic	3/2/2017 3:21 PM
6	Comfortable and relaxed	3/2/2017 2:48 PM
7	Intrigued	3/2/2017 2:21 PM
8	Very relaxed, I was able to focus on the rhythm of the vibrations and take my mind off of other distractions which is something I usually struggle with.	3/2/2017 1:47 PM
9	Relaxed and comfortable	3/2/2017 11:46 AM
10	Relaxed, though the vibrations felt slightly uncomfortable, it felt like they were really relieving tension in the muscles.	3/2/2017 11:13 AM
11	Comfortable, intrigued and fairly relaxed once the motors were on.	3/2/2017 10:24 AM
12	At first it was quite interesting to feel the movement it made, then as the time dew on, i became more used to the pattern of the vibrations. This made me relax more, and felt quite soothing.	2/17/2017 3:14 PM
13	A bit strange, it was sort of relaxing but at the same time not	2/17/2017 1:37 PM
14	It felt strange feeling the vibrations all up and down my back - I noticed the sounds and it felt tight around my body	2/17/2017 1:17 PM
15	Relaxed, thought free	2/17/2017 12:19 PM
16	it was a really nice feeling, like a massage. I liked it	2/17/2017 11:17 AM
17	Restricted but relaxed and calm.	2/17/2017 10:15 AM
18	it was a little strange to start with but it felt fine after a few minutes	2/16/2017 2:50 PM
19	A little bit tense because I wasn't sure what the vibrations were supposed to make me feel like but mostly fine	2/16/2017 2:18 PM
20	i felt secure and embraced so relaxed	2/16/2017 1:52 PM
21	It was ok, i felt a little tired i suppose	2/16/2017 1:28 PM
22	Relaxed, calm.	2/16/2017 12:48 PM
23	Confined and weird	2/16/2017 12:12 PM
24	Like I couldn't relax properly, and had to sit up straight.	2/15/2017 2:16 PM
25	slightly uncomfortable and restricted	2/15/2017 1:49 PM
26	Comfortable, it was fine, wasn't too heavy or didn't dig in etc.	2/15/2017 1:26 PM
27	It was weird, but it felt quite relaxing, it was sort of like music was coming from it?	2/15/2017 12:53 PM
28	it was slightly uncomfortable because i felt quite restricted, which made it more difficult to relax.	2/15/2017 11:58 AM
29	Restrained and uncomfortable	2/15/2017 11:38 AM

30	Relaxed and felt like i was getting a back massage. I enjoyed it.	2/15/2017 10:19 AM
31	Restricted by the tightness. I enjoyed the vibrations, they were relaxing.	2/14/2017 3:18 PM
32	felt really relaxed	2/14/2017 2:13 PM
33	comfortable, relaxed but unusual	2/14/2017 12:13 PM
34	A bit weird, i didn't know what it was designed to do exactly and was a bit surprised when it started making vibrations, but eventually i stopped thinking about it.	2/14/2017 11:48 AM
35	comfortable, safe, giggly, supportive	2/14/2017 10:49 AM
36	Slightly constrained. It felt quite odd. I became more aware of my breathing and what my body was doing.	2/13/2017 3:16 PM
37	fine, slightly uncomfortable	2/13/2017 2:44 PM
38	Tight and uncomfortable but it was easy to deal with because i knew it was a study	2/13/2017 1:12 PM
39	The suit was comfortable and the sensations were a little strange, but relaxing	2/13/2017 11:15 AM

Q2 How did you feel after taking off the suit?

Answered: 39 Skipped: 0

#	Responses	Date
1	more comfortable	3/3/2017 2:14 PM
2	Calm, almost like the effect of meditation or actively trying to relax.	3/3/2017 11:23 AM
3	Relaxed, Awake, Calm	3/3/2017 10:57 AM
4	Lighter, it isn't heavy but you notice that its there, I wouldn't have minded leaving it going for longer, it was quite nice.	3/3/2017 10:18 AM
5	My muscles and body felt less tense and looser	3/2/2017 3:21 PM
6	Relaxed	3/2/2017 2:48 PM
7	I wanted to know how the suit worked and why I was wearing it	3/2/2017 2:21 PM
8	was strange taking it back off because I got quickly accustomed to it, my posture felt funny	3/2/2017 1:47 PM
9	Warm	3/2/2017 11:46 AM
10	Still relaxed	3/2/2017 11:13 AM
11	Bit disappointed, would have enjoyed it for longer.	3/2/2017 10:24 AM
12	The relaxation felt whilst wearing the suit was 'lifted off my shoulders' as the suit was, so I feel lighter and calmer.	2/17/2017 3:14 PM
13	The same as before I put it on	2/17/2017 1:37 PM
14	I felt a lot more relaxed once it was off as it wasn't tight around my upper body and the vibrations/sounds were not there distracting me	2/17/2017 1:17 PM
15	Still relaxed	2/17/2017 12:19 PM
16	it was nice to be unrestricted again but I didn't have a strong feeling either way.	2/17/2017 11:17 AM
17	More relaxed to how i felt before i wore the suit	2/17/2017 10:15 AM
18	I felt like I wanted to arch and stretch my back	2/16/2017 2:50 PM
19	I feel a bit lighter and a bit relieved	2/16/2017 2:18 PM
20	slightly exposed and less relaxed now	2/16/2017 1:52 PM
21	normal, it was easier to slouch in my chair once it was off though	2/16/2017 1:28 PM
22	the same.	2/16/2017 12:48 PM
23	relieved	2/16/2017 12:12 PM
24	Relaxed	2/15/2017 2:16 PM
25	felt more free	2/15/2017 1:49 PM
26	Not much different to when I had it on.	2/15/2017 1:26 PM
27	I didnt want to take it off, I felt quite focused on my surroundings afterwards though.	2/15/2017 12:53 PM
28	i felt a slight sense of relief which enabled me to relax a bit more.	2/15/2017 11:58 AM
29	Fine - just felt easier to move around	2/15/2017 11:38 AM
30	More relaxed then before i wore it.	2/15/2017 10:19 AM
31	Released, free.	2/14/2017 3:18 PM
32	to be honest I didn't feel much different	2/14/2017 2:13 PM
33	I felt normal. I felt the same as I did before putting on the suit	2/14/2017 12:13 PM
34	Not too much different really. The questions and test had taken my mind off the suit so other than the obvious difference in feeling, there wasn't too much difference.	2/14/2017 11:48 AM

35	cold, wanted the support back on again, more open back feeling?	2/14/2017 10:49 AM
36	More freedom, relaxed. Less focus on breathing.	2/13/2017 3:16 PM
37	better, still felt a bit odd	2/13/2017 2:44 PM
38	relaxed and relieved	2/13/2017 1:12 PM
39	slightly more relaxed	2/13/2017 11:15 AM

Q3 Were there any physical sensations that were interesting to you either while or after wearing the suit?

Answered: 39 Skipped: 0

#	Responses	Date
1	the sounds it made moire than the vibrations	3/3/2017 2:14 PM
2	My muscles relaxed and felt comfortable.	3/3/2017 11:24 AM
3	The vibrations from the suit allowed it to be extremely relaxing and I felt my body untensing and my muscles stayed more relaxed afterwards.	3/3/2017 10:58 AM
4	I can still feel the places where the moters were it's still a bit tingly.	3/3/2017 10:19 AM
5	My back still could feel the sensations left by the vibrations even after it was taken off	3/2/2017 3:21 PM
6	Vibrations on my back	3/2/2017 2:49 PM
7	No	3/2/2017 2:21 PM
8	The vibrations at the lower end of the suit particularly caught my attention and allowed my mind to empty. After taking it off it felt strange- I noticed my natural posture more.	3/2/2017 1:48 PM
9	It was warm and ticklish	3/2/2017 11:46 AM
10	While wearing the suit I found that the vibrations felt really deep into the muscles and felt quite ticklish.	3/2/2017 11:14 AM
11	The vibrations on the back and noises were extremely relaxing and kept my focus on them.	3/2/2017 10:25 AM
12	The vibrations were interesting to me as i could feel them move up and down my back, each with varying type of pressure which was very relaxing. I felt my body un-tense.	2/17/2017 3:16 PM
13	The buzzing was a pleasant sensation but I haven't had any physical sensations after taking it off	2/17/2017 1:37 PM
14	The feeling of the vibrations all up my back to my neck - i was very aware of these The vest also felt very restrictive compared to normal clothes	2/17/2017 1:18 PM
15	my back felt tender, but it was a relaxing sensation	2/17/2017 12:20 PM
16	The vibrations made a noise like an old electronic song, something like Kraftwerk. I found that I concentrated on that more than the physical sensations. I did like the physical sensations though.	2/17/2017 11:19 AM
17	my back felt more relaxed and less tense	2/17/2017 10:16 AM
18	I felt that when the pattern of the sensations changed I was more aware of the different movements.	2/16/2017 2:51 PM
19	I found myself really feeling almost the beat of the vibrations and I started tapping my foot to the rhythm they were performed in.	2/16/2017 2:19 PM
20	my muscles relaxed whilst wearing the suit and now they feel a bit shaky, like my nervousness has returned	2/16/2017 1:52 PM
21	The sounds the vibrations made reminded me of like a 1980's scifi computer or something, or like an old theme tune to a TV sitcom or something	2/16/2017 1:29 PM
22	The motors on my back. They seemed to act in a symetric way	2/16/2017 12:49 PM
23	after taking off the suit parts of my back went a little numb for a few seconds	2/16/2017 12:12 PM
24	I found out that I am ticklish around my lower back.	2/15/2017 2:17 PM
25	during when the motors were on I did feel slightly more relaxed and afterwards I felt calmer than before	2/15/2017 1:49 PM
26	None	2/15/2017 1:26 PM
27	The tingles radiating over my back in areas where the vibrations had been.	2/15/2017 12:54 PM

28	i noticed that when i was wearing the suit i became much more aware of my breathing and my body temperature felt like it had increased slightly.	2/15/2017 11:59 AM

29	Not really - my waist and back just felt restrained	2/15/2017 11:38 AM
30	The sensations on my lower back made me feel ticklish. I also liked the ones on my neck.	2/15/2017 10:19 AM
31	I felt like I was wearing a corset and being held into the suit.	2/14/2017 3:19 PM
32	While I was wearing the suit I felt really relaxed	2/14/2017 2:13 PM
33	The upper part of my back was particularly sensitive. The vibrations appeared to be in some sort of a routine	2/14/2017 12:14 PM
34	The vibrations were interesting, too feel how they moved up and down my spine and back in what seemed like a programmed manor, so i found it interesting to think why is it doing what its doing.	2/14/2017 11:50 AM
35	my back felt very warm during, and after taking it off I had an 'open back' sensation, feeling more loose around my upper back	2/14/2017 10:49 AM
36	My fingers were tapping to the rhythm of the suit vibrations. My breathing became deeper.	2/13/2017 3:17 PM
37	afte I felt as though where the vibrations were I could still feel a tingling sensation	2/13/2017 2:44 PM
38	the vibrations relaxed my body and after i took it off i felt calmer and ready for a nap	2/13/2017 1:13 PM
39	Just the sounds and feeling of the vibrations	2/13/2017 11:15 AM

Q4 Where did you feel the vibrations? Did you feel them in parts of yourself other than your upper back? (e.g., your neck, head, arms, hands, shoulders, lower back, hips, legs, feet)

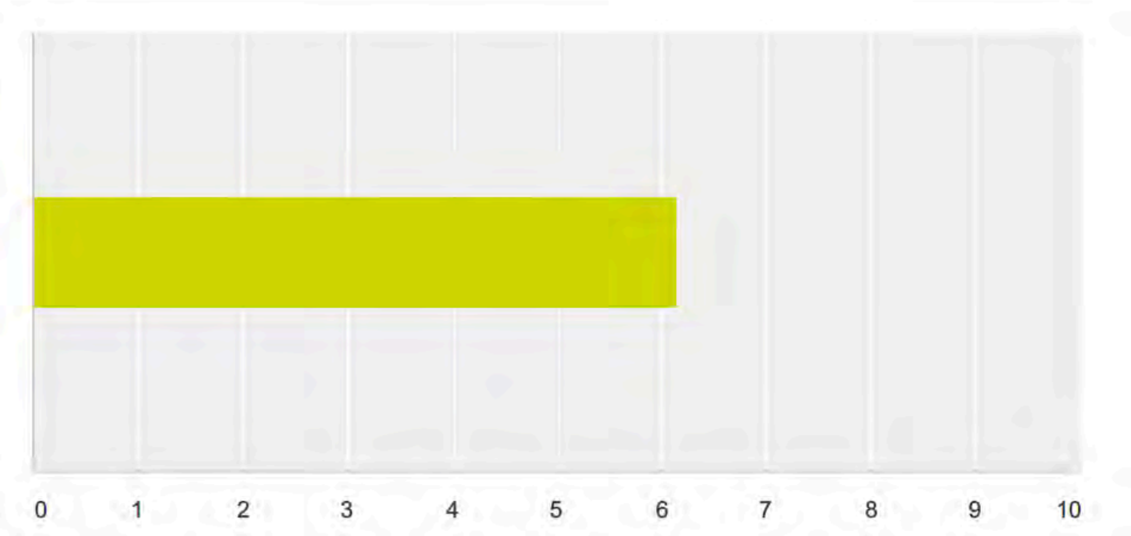
Answered: 39 Skipped: 0

#	Responses	Date
1	lower back and shoulders	3/3/2017 2:15 PM
2	I felt some on my shoulders and upper arm.	3/3/2017 11:24 AM
3	Very slightly in my hands.	3/3/2017 10:59 AM
4	I just felt it where the moters were activating.	3/3/2017 10:19 AM
5	My neck and lower back especially noticed them	3/2/2017 3:22 PM
6	Lower back	3/2/2017 2:49 PM
7	Lower back, and shoulders	3/2/2017 2:22 PM
8	Felt them a little bit in my neck and a lot in my shoulders.	3/2/2017 1:49 PM
9	Yes down my leg	3/2/2017 11:47 AM
10	I felt them in my lower back and neck.	3/2/2017 11:14 AM
11	neck, shoulders, lower back only.	3/2/2017 10:25 AM
12	I felt them in the lower part of my neck, beside my spine all the way down to my lower back.	2/17/2017 3:16 PM
13	I felt the vibrations all over my back including the lower back and round the sides, but that was all.	2/17/2017 1:38 PM
14	I felt them in my neck and shoulders	2/17/2017 1:19 PM
15	i felt numerous vibrations in my neck and every part of my back, but no where else	2/17/2017 12:20 PM
16	upper back and shoulders and lumbar area of spine. Felt it in my breathing too, made me more aware of the exhale of breath	2/17/2017 11:20 AM
17	in my shoulders as well	2/17/2017 10:16 AM
18	I felt them in my neck, upper back, middle back and lower back	2/16/2017 2:52 PM
19	I felt them on my neck, shoulders, lower back, the back of my legs and my feet	2/16/2017 2:19 PM
20	i felt the vibrations in my upper and lower back and my neck	2/16/2017 1:53 PM
21	i felt the vibrations where they were, i.e. top, middle and lower back	2/16/2017 1:30 PM
22	My neck	2/16/2017 12:50 PM
23	lower back, neck and shoulders	2/16/2017 12:12 PM
24	Neck, shoulders, lower back	2/15/2017 2:17 PM
25	felt them in my lower back and hips and running down my spine	2/15/2017 1:50 PM
26	No, just my upper back and occasionally in my lower back.	2/15/2017 1:27 PM
27	No, just in my back predominantly, and a little bit on the under side of my fore arms near my elbows	2/15/2017 12:54 PM
28	shoulders	2/15/2017 11:59 AM
29	No	2/15/2017 11:38 AM
30	Neck, lower back	2/15/2017 10:20 AM
31	Only felt them in my upper back.	2/14/2017 3:19 PM

32	Lower back	2/14/2017 2:13 PM
33	I felt the vibrations on all up my back including my lower back	2/14/2017 12:14 PM
34	I felt the vibrations predominantly in my upper back, but also the base of the back of my neck too.	2/14/2017 11:51 AM
35	my shoulders, upper, and middle of the back	2/14/2017 10:50 AM
36	Neck and shoulders	2/13/2017 3:17 PM
37	no, just the back	2/13/2017 2:44 PM
38	i felt them just on my spine	2/13/2017 1:13 PM
39	Only felt the sensations on my neck and back	2/13/2017 11:16 AM

Q5 The suit is composed of two components: the vest and the vibrating motors. How pleasant or unpleasant was the experience of wearing the VEST?

Answered: 23 Skipped: 16

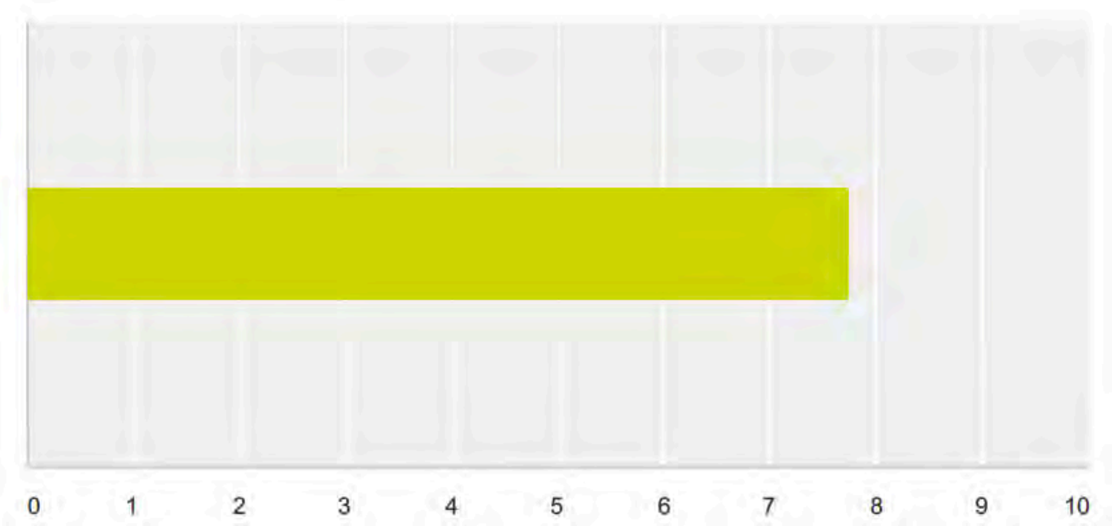


#		Date
1	4	3/3/2017 2:15 PM
2	6	3/3/2017 11:25 AM
3	8	3/3/2017 10:59 AM
4	3	3/3/2017 10:20 AM
5	7	3/2/2017 3:22 PM
6	10	3/2/2017 2:49 PM
7	5	3/2/2017 2:22 PM
8	7	3/2/2017 1:49 PM
9	8	3/2/2017 11:47 AM
10	8	3/2/2017 11:14 AM
11	8	3/2/2017 10:25 AM
12	9	2/17/2017 3:16 PM
13	7	2/17/2017 1:38 PM
14	3	2/17/2017 1:19 PM
15	9	2/17/2017 12:21 PM
16	4	2/17/2017 11:20 AM
17	3	2/17/2017 10:16 AM
18	4	2/16/2017 2:52 PM
19	4	2/16/2017 2:20 PM
20	10	2/16/2017 1:53 PM
21	6	2/16/2017 1:30 PM

22	4	2/16/2017 12:50 PM
23	4	2/16/2017 12:13 PM

Q6 How pleasant or unpleasant was the experience of the MOTORS playing?

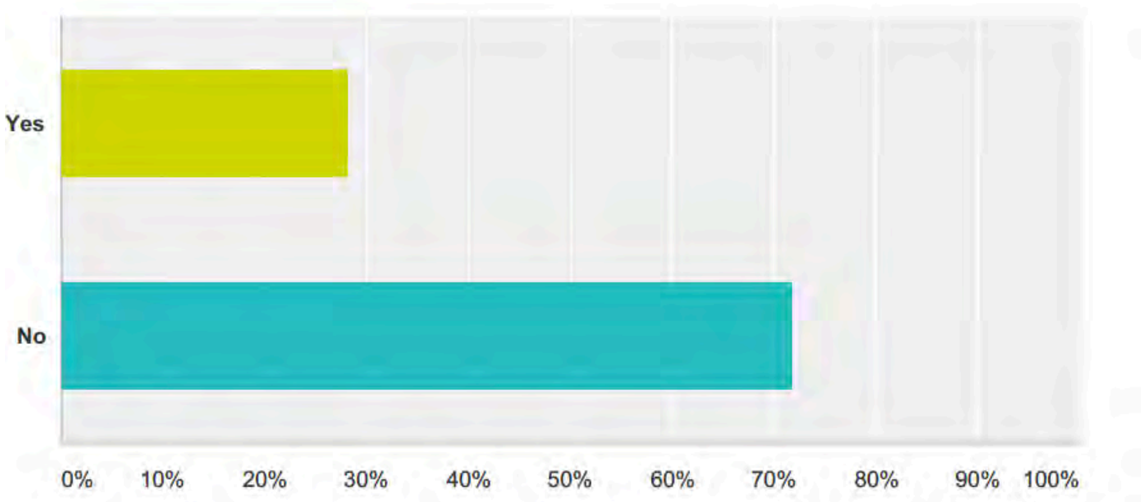
Answered: 23 Skipped: 16



#		Date
1	5	3/3/2017 2:15 PM
2	8	3/3/2017 11:25 AM
3	9	3/3/2017 10:59 AM
4	9	3/3/2017 10:20 AM
5	10	3/2/2017 3:22 PM
6	10	3/2/2017 2:49 PM
7	3	3/2/2017 2:22 PM
8	10	3/2/2017 1:49 PM
9	8	3/2/2017 11:47 AM
10	8	3/2/2017 11:14 AM
11	10	3/2/2017 10:25 AM
12	10	2/17/2017 3:16 PM
13	8	2/17/2017 1:38 PM
14	3	2/17/2017 1:19 PM
15	8	2/17/2017 12:21 PM
16	8	2/17/2017 11:20 AM
17	8	2/17/2017 10:16 AM
18	7	2/16/2017 2:52 PM
19	7	2/16/2017 2:20 PM
20	10	2/16/2017 1:53 PM
21	6	2/16/2017 1:30 PM
22	8	2/16/2017 12:50 PM
23	5	2/16/2017 12:13 PM

Q7 Do you play a musical instrument?

Answered: 39 Skipped: 0



Q8 If yes, which one(s)?

Answered: 11 Skipped: 28

#	Responses	Date
1	piano	3/3/2017 2:15 PM
2	The drums	3/3/2017 11:25 AM
3	Flute	3/2/2017 11:15 AM
4	Guitar, piano	2/17/2017 3:17 PM
5	guitar, bass guitar, ukelele, acordian	2/17/2017 11:21 AM
6	flute	2/16/2017 2:52 PM
7	Piano	2/16/2017 1:53 PM
8	Guitar	2/16/2017 1:31 PM
9	guitar, ukulele	2/15/2017 12:55 PM
10	Guitar, Piano	2/14/2017 12:14 PM
11	Guitar, Bass Guitar, Clarinet	2/13/2017 3:18 PM

Q9 Is there anything else you want to say about what the experience of wearing the suit with the vibrating motors was like for you?

Answered: 29 Skipped: 10

#	Responses	Date
1	it felt as it the vibrating motors where supposed to be playing some sort of tune	3/3/2017 2:16 PM
2	N/A	3/3/2017 11:25 AM
3	Very relaxing.	3/3/2017 11:00 AM
4	I wouldn't mind wearing it again.	3/3/2017 10:21 AM
5	It seemed like it was a tuneful rhythm and was very enjoyable	3/2/2017 3:23 PM
6	No	3/2/2017 2:22 PM
7	It was quite therapeutic!	3/2/2017 1:49 PM
8	It was enjoyable	3/2/2017 11:48 AM
9	No	3/2/2017 11:15 AM
10	it was a very interesting experience. I am intrigued of the outcome and found it very very relaxing.	3/2/2017 10:26 AM
11	/	2/17/2017 3:17 PM
12	I felt a little bit tense after taking it off	2/17/2017 1:39 PM
13	I felt as though the vibrations were in the pattern of a song	2/17/2017 12:21 PM
14	I'm not sure if the motor was meant to be randomised but It sounded too much like analogue electro to me to not be designed into a pattern.	2/17/2017 11:22 AM
15	I enjoyed the sequential patterns of the vibrating motors, i could predict the next rhythm and it was more relaxing to make the vibrators in a sort of symphony	2/16/2017 1:54 PM
16	it was ok	2/16/2017 1:31 PM
17	Nope	2/16/2017 12:51 PM
18	At first I was very ticklish but I gradually got used to it.	2/15/2017 2:18 PM
19	it felt like having a massage	2/15/2017 1:50 PM
20	I found the sound of all the vibrations together quite 'creepy', like a song (sounds strange).	2/15/2017 1:28 PM
21	It felt like music coming from the vibrations and they were playing a song on my skin.	2/15/2017 12:55 PM
22	I didnt feel the vibrating motors - maybe due to the fact of what im wearing? 3 layers	2/15/2017 11:39 AM
23	In enjoyed it it was a pleasurable experience.	2/15/2017 10:20 AM
24	In a strange way it was enjoyable and gave me something else to think about.	2/14/2017 3:20 PM
25	It was very interesting and it was very different	2/14/2017 2:14 PM
26	The vibrations appeared to be making up a song / sequence. Some vibrations felt as if they were chords	2/14/2017 12:15 PM
27	I wasn't too sure what to expect coming into the experiment, but after wearing the suit i'm a little more interested in its purpose.	2/14/2017 11:52 AM
28	It was surreal, but became relaxing after a while.	2/13/2017 3:18 PM
29	no	2/13/2017 2:44 PM

Cravings Data Notes

Five participants remarked that the suit felt “slightly uncomfortable” or uncomfortable, while one (C23) felt “confined”; C23 later on rated the vest’s pleasantness as 4 and the motors’ pleasantness 5. On the other hand, seven participants (C7, C9, C11, C26, C32, C34, C38) reported feeling comfortable while wearing the suit.

In addition, eleven participants found the experience “odd” (C35), “strange” (C1, C13, C14, C18, C38), “weird” (C1, C23, C27, C33), “unusual” (C32), or intriguing (C7), but not always negatively so. One participant (C10) stated that they found the vibrations uncomfortable, but then later on gave the experience of the motors a rating of 8. Only two participants (C7 and C14) rated the experience of the vibrator motors to be less pleasant than that of the vest. Notably, C14 found the vibrations and the sound they made “distracting” and rated the motors’ pleasantness as 3.

Overall, however, twenty-three out of the thirty-eight participants positively rated their experience of the suit. Nineteen participants (C3, C4, C5, C6, C8, C9, C10, C11, C12, C13, C15, C17, C20, C22, C27, C29, C31, C32, C38) reported feeling “relaxed” while two reported feeling “calm” (C17, C22).

Public Demonstration Primary Data

The Bizarre Bazaar event featured public demonstrations of creative and research outputs held at Plymouth University on the 22nd of October, 2016.

#P22.161022.PublicDemo.a5

“feel more of myself" “further down and further up" “lighter" “I couldn’t feel myself as much before" even though part of me wasn’t touching the floor I could still feel that there was something there

Participant	P22, female
Context	Off the Lip, Bizarre Bazaar public event
Observations (Self-Reports)	[As above]
Observations (DSSM)	–
Theoretical Implications	–
Design Implications	–

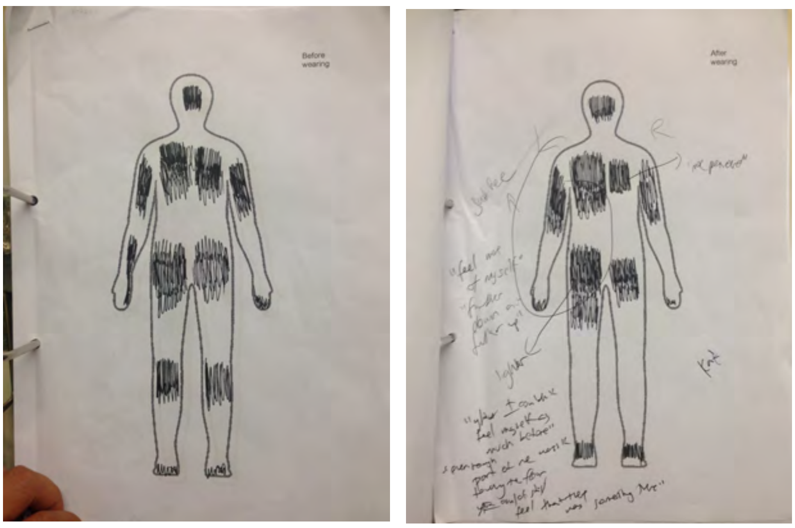


Figure A5.33: P22’s drawings before (left) and after) wearing Haplós

#23.161022.PublicDemo.a5

Participant	P23, female
Context	Off the Lip, Bizarre Bazaar public event
Observations (Self-Reports)	-
Observations (DSSM)	–
Theoretical Implications	–
Design Implications	–

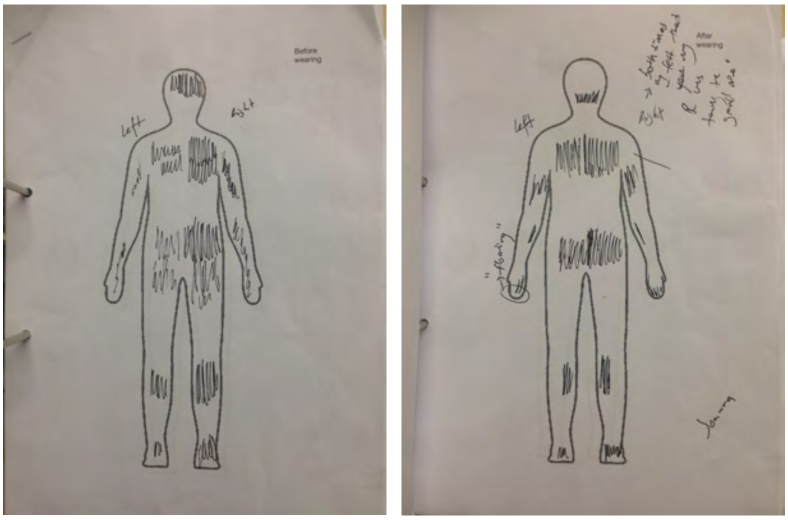


Figure A5.34: P23's drawing before (left) and after (right) wearing Haplós

#24.161022.PublicDemo.a5

Participant	P24, female
Context	Off the Lip, Bizarre Bazaar public event
Observations (Self-Reports)	-
Observations	–

(DSSM)	
Theoretical Implications	–
Design Implications	–

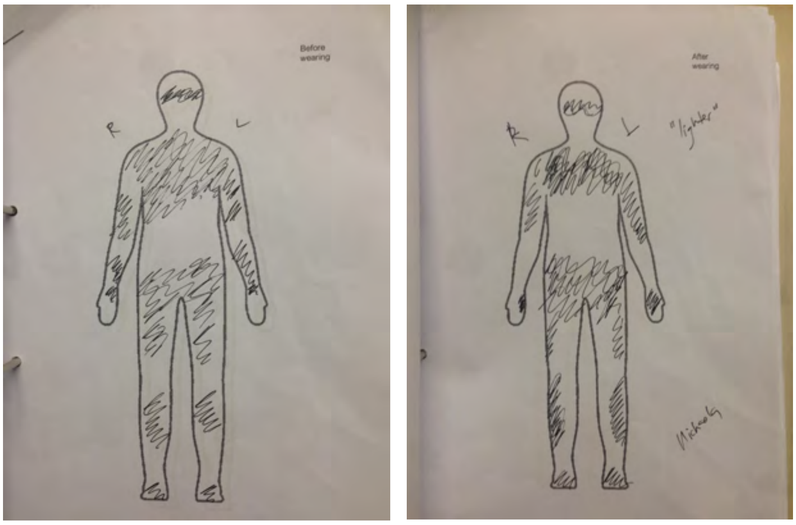


Figure A5.35: P24's drawings before (left) and after (right) wearing Haplós

#25.161022.PublicDemo.a5

Participant	P25, female
Context	Off the Lip, Bizarre Bazaar public event
Observations (Self-Reports)	-
Observations (DSSM)	–
Theoretical Implications	–
Design Implications	–

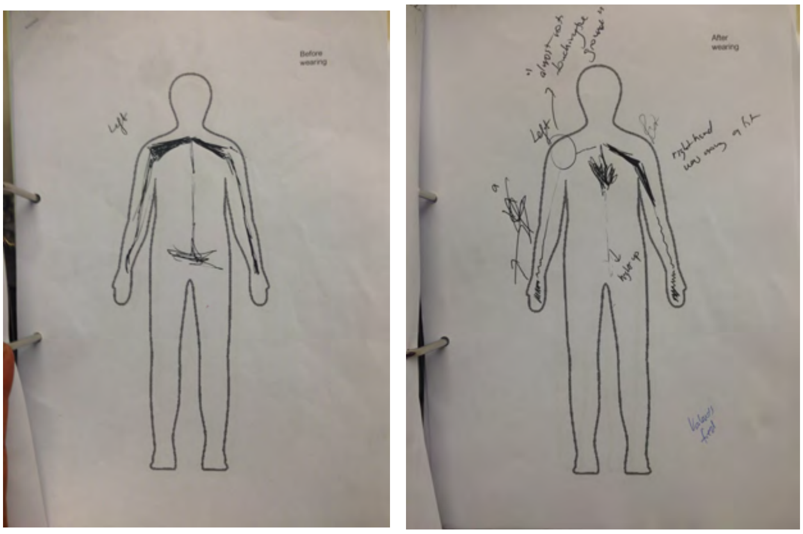


Figure A5.36: P25's drawings before (left) and after (right) wearing Haplós

#26.161022.PublicDemo.a5

Participant	P26, male
Context	Off the Lip, Bizarre Bazaar public event
Observations (Self-Reports)	-
Observations (DSSM)	–
Theoretical Implications	–
Design Implications	–

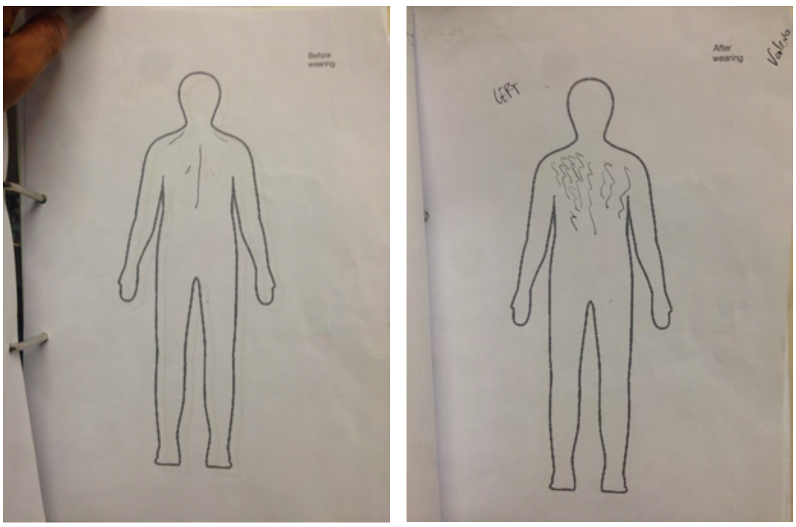


Figure A5.37: P26's drawings before (left) and after (right) wearing Haplós

#P27.161022.PublicDemo.a5

Participant	P27, female
Context	Off the Lip, Bizarre Bazaar public event
Observations (Self-Reports)	-
Observations (DSSM)	–
Theoretical Implications	–
Design Implications	–

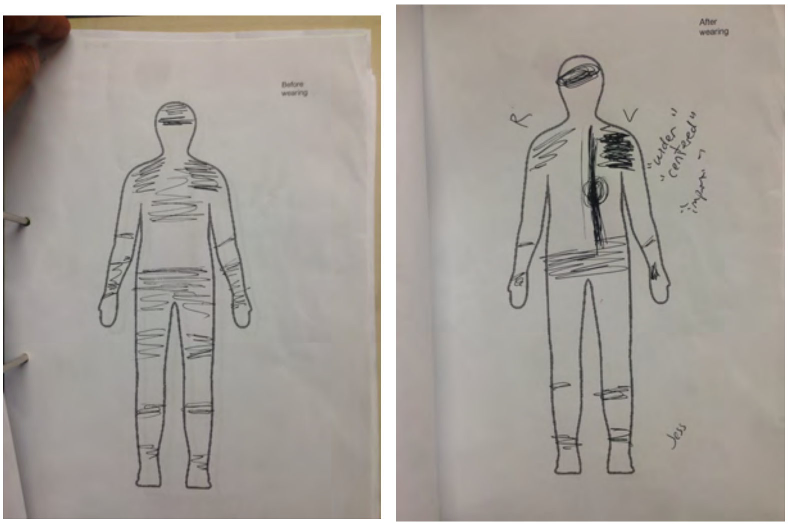


Figure A5.38: P27's drawings before (left) and after (right) wearing Haplós

#P30.161022.PublicDemo.a5

Participant	P30, female
Context	Off the Lip, Bizarre Bazaar public event
Observations (Self-Reports)	She said that she felt irritate that the vibrations were on the left and not on the right
Observations	–

(DSSM)	
Theoretical Implications	–
Design Implications	–

#P40.161022.PublicDemo.a5

Participant	P40, female, ? yo
Context	Off the Lip, Bizarre Bazaar public event
Observations (Self-Reports)	–
Observations (DSSM)	➢ Surprised that the older lady liked it faster ➢ The suit is really cumbersome… do i really need it if it's just the shoulder blade?
Theoretical Implications	She asked about sleeping. She liked it faster. This resonates with #P45's experience
Design Implications	Consider a faster pattern for sleeping

Appendix 6. Cravings Study Analysis Summary

The following summary was prepared by Cravings Lab member Kirsten Woodman.

Summary

The initial cravings for people in the experimental group and control group respectively, were 5.54 and 5.46, a difference that was not significant. The results of the study show only significant results between the experimental group and the control group for the CEQ frequency scores, $t = 2.12(df = 46)$, $p = 0.039$, with the experimental group having an average craving of 2.07 and the control group having an average craving of 3.074, suggesting that those who wore the body vest with the motors in experienced a lower frequency of chocolate cravings. The CEQ is made of 2 smaller questionnaires which rate cravings for different substances on a scale of 0-10, one questionnaire measures strength and the other measures frequency. The strength sub category was not significant between groups, however there is markedly a difference, with the experimental group showing slightly less strong cravings ($m = 2.86$) than the control group ($m= 3.54$). The frequency sub category of the CEQ comprises of 11 questions, of which 6 were significantly different between groups (picture_f: $t = 2.53(df = 44)$, $p = 0.015$, taste_f: $t = 2.29(df = 44)$, $p = 0.027$, smell_f: $t = 2.404(df = 44)$, $p = 0.021$, mouth_f: $t = 2.042(df = 44)$, $p = 0.047$, body_f: $t = 2.09(df = 44)$, $p = 0.042$, intrusive_f: $t = 2.19(df = 44)$, $p = 0.034$). These results mean that the control group, significantly more so than the experimental group, more frequently pictured chocolate, imagined its taste, imagined its smell, imagined what it would feel like in their mouth or throat, imagined how their body would feel and experienced more intrusive thoughts, during wearing the vest. There were no significant differences between the pegboard times, suggesting that the motors in the body vest had no effect on dexterity measures, and no significant differences between any of the 4 mindfulness measures obtained by the Kentucky Mindfulness Inventory, suggesting that the motors in the body vest had no effect on the participant's perceived mindfulness at the time.

Appendix 7. Selected related publications and presentations

Maranan, D. S., Loesche, F., & Denham, S. L. (2015). CogNovo: Cognitive Innovation for Technological, Artistic, and Social Domains. In *Proceedings of the 21st International Symposium on Electronic Art*. Vancouver, Canada. http://hdl.handle.net/10026.1/5076

Maranan, D. S. (2015). Speculative somatics. *Technoetic Arts*, *13*(3), 291–300. https://doi.org/10.1386/tear.13.3.291_1

Maranan, D. S. (2017). *Sensing yourself by sensing the ground: getting intimate with the environment through vibrotactile stimulation*. Poster presented at the Expo' 17: Ecologies Annual Event, Plymouth University, UK. https://doi.org/10.5281/zenodo.1039377

Maranan, D. S. (2016, July). *Haplós: Designing Technologies for Exploring Somaesthetic Experiences*. Poster presented at the Cognition Institute Conference 2016, Plymouth University, UK. http://hdl.handle.net/10026.1/5086

CogNovo: Cognitive Innovation for Technological, Artistic, and Social Domains

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Abstract

CogNovo is a multi-national doctoral training programme offering a research network for cognitive innovation, both as a new field of artistic and scientific investigation, and as a strategy for research and innovation. We summarize the programme's goals, themes, members, partners, projects, and activities in this paper.

Keywords

Cognitive neuroscience, computational modelling, humanities, experimental psychology, creative industries, cognitive robotics, game design, PhD programmes, cognitive innovation, interactive arts

Programme overview

Why is novelty creation and selection so important for cognitive functioning? Is it necessary for autonomous knowledge acquisition in artificial systems? What is the relationship between novelty, usefulness, and creativity? Can a deeper understanding of perception and the generation of ideas help forge new links between cognitive science, technology, the arts, and the humanities, thus creating new opportunities for innovation?

CogNovo[1] is a multi-national doctoral training programme that addresses such questions. Based in the Cognition Institute at the University of Plymouth (UK), CogNovo focuses on interdisciplinary research in cognition, novelty, and creativity. The programme aims to disrupt single-field research and to establish a rigorous basis for cognitive innovation and a research training programme in which new researchers learn to adopt the self-aware, multi-faceted process of cognitive innovation (exploration / speculation, explanation / synthesis, and exploitation / implication), applicable both to their research activities as well as their professional and personal development.

Programme themes

CogNovo is characterized by a wide-ranging interdisciplinary approach, formed by combining the following complementary streams:

The **experimental psychology** stream involves studying perceptual, developmental, and cognitive aspects of creativity as well as developing innovative solutions to problems in alarm design, medical communications, decision-making, and cinema technologies, thus providing new insights into the basis for sustainable social innovation.

The **interactive and creative arts** stream explores the role of and effects on cognition in the creative process within a range of artistic disciplines including digital games, music, interactive sound, and dance. This stream also explores the dynamics of social creativity within interacting groups through direct engagement with creative practices.

The **cognitive neuroscience** stream explores the neural and physiological basis for cognitive innovation and the relationship between cognition, novelty and creativity. CogNovo fellows will apply neuroimaging technologies to investigate creativity in imagery and deception, and how novelty detection helps to shape cognition and inspire creative responses and outputs.

The **humanities** stream takes a transdisciplinary approach to broadening the scientific ear of CogNovo fellows by offering new ways of thinking about problems not normally considered within the scientific community. A particular focus is on the human values important for sustainable innovation in technological applications.

The **computational modelling** stream develops bio-inspired models that provide testable explanations for creative cognitive processes. Computational modelling provides important links between cognitive neuroscience and experimental psychology and a basis for developing novel intelligent cognitive technologies.

The **cognitive robotics** stream tackles the problem of developing human-like cognition in artificial robotic systems. It examines the role of artificial creativity in the development of artificial cognition.

Programme Members and Partners

There are currently 25 doctoral students from 15 countries in the programme. They are supervised by a team of over 45 University faculty members from across a range of disciplines, and by over 25 external academic and private industry partners from Europe, Asia, and North America. Fourteen of the research fellows are funded through the European Commission's Marie Skłodowska-Curie Actions programme, the other eleven directly by the University. The Marie Skłodowska-Curie Actions programme provides generous research funding

[1] Programme website: `http://cognovo.eu`; accessed: 22-OCT-2015

to students alongside ample opportunity to gain experience abroad and in the private sector during the course of their studies.

Example Projects

Each of the 25 fellows works on a distinct project related to novelty, creativity, and cognition. This section describes a selection of the projects to demonstrate the range of concerns tackled within CogNovo.

Shared creativity in dance (Project 7) focuses on group improvisation as a unique way to understand how people collaborate and how new ideas appear from social interaction. It explores the interdependency of individual cognitive strategies and group processes, investigating the role of shared flow experience in improvisation.

Bodyshaping the Mind (Project 8) aims to develop theories, tools, and techniques for exploring how the body shapes the mind. It investigates how physiological states such as muscular tension, range of motion, and quality of movement shapes cognition and affect, and how technology-mediated interventions could facilitate somatosensory sensitivity.

Designing Playful Systems in Mixed Reality (Project 9) investigates notions of play through a series of experimental games and playful interactions that take place in mixed reality environments. The project involves artistic research into aspects of complex systems such as neural network models and social systems theory.

Early Cinema and Cognitive Creativity (Project 10) investigates the temporal resolution and inter-frame nature of analogue and digital film projection and its effect on the cognition of the cinema spectator. It explores whether the cognitive experience of cinema has changed as a result of the transition from analogue to digital cinema projection.

Signs of Alarm Fatigue (Project 12) aims to provide evidence of the pheno-physical correlates of the subjective experience of "alarm fatigue", as well as to outline a framework for a cognitive-methodological innovation in the study of the phenomenon.

Creative technologies for behaviour change (Project 13) translates insights from Elaborated Intrusion theory into novel treatments for unhealthy lifestyles, with a specific focus on social robotics and mobile apps to stimulate imagination and suggest mental imagery to users.

Predicting creativity from spatial ability and personality (Project 15) investigates the qualities of creative people by exploring how individual differences at a fundamental level in terms of temperament can affect cognition and creativity.

Unconscious Creativity: The Eureka moment (Project 16) focuses on the process of creative problem solving by understanding how to overcome impasses and the role of restructuring problems. The methodology includes behavioural experiments using established and newly developed tasks to collect empirical evidence undermining findings from qualitative analysis of interviews with real life problem-solvers. The project will look closely at neural activity in order to develop a model of the emergence of novel insights.

Neural Concept Sampler (Project 17) computes and represents concepts found in musical patterns using neural networks in order to generate innovative pieces of music using neural networks' conceptual representations of musical fragments.

Moral cognition: An interdisciplinary investigation of judgment versus action (Project 19) brings together experimental psychology and state-of-the-art technologies in order to examine 'moral hypocrisy' or the dissociation between moral judgments and moral behaviours. Virtual reality methods utilising virtual headset systems as well as haptic feedback devices are incorporated to allow realistic simulations of moral actions. Both pro-social and anti-social predictors are assessed in order to understand and model real life moral decisions.

Attention and learning about irrelevant cues (project 20) investigates the acquisition of associations for stimuli based on their predictiveness with a particular focus on the paradigm of blocking. In blocking, reduced learning is seen for a novel stimulus (blocked cue) that is paired together with a stimulus within a previously established stimulus-outcome association (blocking cue). This project uses experimental research with human participants and eye-tracking to examine gaze location patterns in order to gain further insights into the process of learning to ignore irrelevant cues.

Creating a voice for engagement and trust (Project 21) aims at creating an artificial voice for a robot that sounds trustworthy, based on phonetic and prosodic characteristics of English accents. A specifically-designed trust game is used to analyse more trustworthy voices and their characteristics in detail.

Understanding the Human Object (Project 24) questions the idea of establishing a working consensus between different disciplines and their views and on the rhetoric within scientific modelling, through the creation of a class of provocative objects that may reconcile or conflate opposing sentiments.

A Framework for Intuitive Remote Robotic Control (Project 25) takes inspiration from human robot interaction, ergonomic principles, and autonomous robotics to proposes a human-centric framework for robot control. Drawing on the current advancements in machine learning, artificial intelligence and autonomous robotics, the project aims to design a flexible, intuitive, and largely reconfigurable telerobotic interface. The interface is realised as a software agent connecting the two end points of the system: human and robot, providing an adaptive and intelligent interface for robot control.

Programme Activities

A variety of activities are programmed in CogNovo not only to support the research training of the fellows, but also to engage both the wider research community as well as the public at large on the programme's streams.

Interdisciplinary training for fellows

One approach that is taken in CogNovo to disrupt single-fields research is the implementation of combined workshops and the creation of designated spaces and times to discuss knowledge transfer between disciplines and evaluate preliminary results in the light of other streams. Five week-long workshops allowed intensive and focused training on selected topics during the first 18 month of the program. A **Research Methods Workshop** in May 2014 introduced methodologies from the different research areas involved in CogNovo. During the **Experimental Methods Workshop** in June 2014 all CogNovo Research Fellows and participants who joined for the week learned about paradigms, advantages, and potential pitfalls of running and analysing experiments. The **Computational Modelling Workshop** in September 2014 instead focused on simulation and gave the participants access to computational and robotic tools. The **Public Outreach and Social Innovation Workshop** in January 2015 trained fellows on how to engage with broadcast media and deliver public presentations to create compelling and understandable accounts of research processes and outcomes. Finally an **Entrepreneurship Workshop** in April 2015 gave some insight into the interplay of science, business, and the law.

Another two workshops are planned for January and April 2016: the **Social Creativity Workshop** will explore the influence of group structures on the creative output while **The Brain Basis for Cognitive Innovation** will focus on the brain as the source of creativity.

Engagement with the wider research community

CogNovo engages with the research community through a number of events. The **Off the Lip** conference[2] held in Plymouth in September 2015 focused on humanities perspectives on Cognitive Innovation. Keynote speakers included Roger Malina[3], Sundar Sarukkai[4], and Amy Ione[5]. Presented papers and posters offered perspectives from a wide range of the humanities on Cognitive Innovation and touched on philosophy, literature, sound design, quantum creativity, psychoactive substances, decision-making during high-stress situations, and many more. Currently CogNovo aims at publishing the proceedings in collaboration with **Transtechnology Research**[6]. Due to its great success and impact on the CogNovo projects as well as in response to the feedback from involved researchers, CogNovo will hold another **Off the Lip** conference in 2016.

CogNovo fellows will be hosting a **Cognitive Innovation Summer School** in 2016. The Summer School will be open to research students outside the consortium. CogNovo Fellows will plan the programme, invite speakers, and develop advertising and fundraising campaigns.

Engagement with the public at large

From the beginning on the CogNovo workshop included at least one event to interact with the local community. This series of events, entitled **CogJam**, emphasises the artistic engagement of the research fellows and their practical approach to artistic creativity and Cognitive Innovation.

As part of the Public Outreach and Social Innovation Workshop, led by former BBC senior producer Malcolm Love and professional science communicator Emily Grossmann, the CogNovo research fellows put together a **Public Science Cabaret Show** which they performed live in downtown Plymouth while it was simultaneously transmitted to the local FM radio station. Podcasts created during the evening are still accessible to a wider audience through the website of **Radio CogNovia**, a digital radio broadcast initiative that was launched during the workshop.

Besides classic ways of scientific publication CogNovo research fellows experiment with different ways of communicating their findings: podcasts have been published to a wide audience on the **new leonardos** channel at Creative Disturbances[7], an international, multi-lingual online platform that publishes conversations, art exhibitions were used present results, and contributions to public events such as the **British Science Week** and the **ESRC Festival of Social Sciences** have been made. While films produced by CogNovo research fellows have been shown at festivals in the past, the upcoming **Workshop on Social Creativity** is expected to create more movies that can be used to communicate joint findings from the streams involved in CogNovo.

Summary

CogNovo aims to develop a ground-breaking training programme in cognitive research for technological, artistic, and social innovation. Our experience from activities that we have already completed provides us with some confidence towards meeting these aims. We look forward to further CogNovo training workshops in social creativity (January 2016) and the brain basis for Cognitive Innovation (April 2016). We expect that these sessions – in addition to the Cognitive Innovation Summer School (July 2016) – not only will develop among CogNovo fellows the advanced expertise and transferable skills that will prepare them for successful careers in academia and industry, but will also strengthen the worldwide network of leading research labs and innovative industries within which CogNovo is embedded.

Acknowledgement

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References

[1] Denham, S. 2014. Marie meets leonardo: A perfect match? *Leonardo* 47(3):202.

[2] Gummerum, M., and Denham, S. 2014. Cognitive innovation: From cell to society. *Europe's Journal of Psychology* 10(4).

[2] Conference website: `http://otlip15.cognovo.eu`; accessed: 22-OCT-2015

[3] Distinguished Professor of Arts and Technology, Professor of Physics, University of Texas at Dallas, USA

[4] Professor and Director of the Manipal Centre for Philosophy and Humanities, Manipal, India

[5] Director of the Diatrope Institute, Berkeley, California, USA

[6] Group website: `http://www.trans-techresearch.net`; accessed: 22-OCT-2015

[7] Network website: `http://creativedisturbance.org/channel/new-leonardos/`; accessed: 22-OCT-2015

Maranan, D. S. (2015). Speculative somatics. Technoetic Arts, 13(3), 291–300. http://doi.org/10.1386/tear.13.3.291_1. **This preprint differs slightly from the published version.**

Speculative somatics

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Abstract

Based on a presentation at The Undivided Mind conference at Plymouth University, this article sketches out speculative applications of somatics, the first person, phenomenological study of sensation, perception and movement. I first introduce the subject of somatics through an experiential exercise for the reader before summarizing theoretical aspects of somatic study. Drawing from the literature in embodied cognition and from personal recollections of embodied experiences, I propose how somatic approaches could potentially be used in working with immigrant communities, living in outer space, and empathizing with non-human animals.

Keywords: *somatics, sensorimotor learning, phenomenology, embodied cognition, physiological empathy, speculative somatics, immigrant somatics, microgravity somatics*

This article sketches speculative applications of somatics, the first person, phenomenological study of sensation, perception and movement. A primary goal of somatic learning processes is to bring aspects of prenoetic, affective experience into consciousness.[1] Since somatics is primarily experiential, it is best to introduce this article by asking you, the reader, to participate in an exercise that I now detail in a set of instructions. To get started, find someone who can read out – over the span of 5 to 10 minutes – the following to you: [2]

- Start by making yourself more comfortable in the current position you are in. If you are sitting, for instance, sit as comfortably as you can.
- Close your eyes. Turn your attention towards yourself.
- Are you aware of your breathing? Which parts of your torso are moving when you inhale? Which parts are moving when you exhale? Don't try to change anything, just lightly direct your attention to your breathing. Throughout this exercise, try simply to observe yourself and resist the temptation to change or 'fix' anything about yourself.
- Notice how your weight is being supported by the chair, table, ground or whatever surfaces you are in contact with. Which parts of you are in contact with

these surfaces? If the parts of yourself that are in contact with these surfaces – for instance, the back of your thighs, your calves, your back – were smeared with ink, can you imagine the sizes and the shapes of the ink blots that you would be making on the surfaces?

- Notice the space between the lower tip of your ear and the top of your shoulder. How far apart are your ears from your shoulders? Is the distance between your right ear and right shoulder the same distance as that between your left ear and left shoulder?
- Notice where your shoulders are relative to your pelvis. Are you leaning forward, or backward? Is your torso balanced on top of your pelvis?
- Notice your fingers. Are they curved inwards towards your palm, or are they extended out flat? Are the fingers of one hand more curved than the other?
- Now open your eyes and bring your attention back to the room.
- Notice if you feel any differences in the way the chair, floor, or table feels to you compared to when you began the exercise. If there is another person in the room with you, notice if anything has changed in the way you feel or think about them. Notice any other differences in what you can sense and feel compared to when you began this exercise.
- Notice if you still feel comfortable in your current position. Would you arrange yourself differently in your current position so that you can feel more comfortable? If so, do it now.

The soma

The exercise that I hope you have just experienced was intended to develop your soma – 'the living, self-sensing, internalized perception of oneself' (Hanna 1988: 20). The soma is contrasted against the externalized, objective, third-person perspective of a body. Because every individual both has a body and is a body (Shusterman 2008: 21), the soma is simultaneously creator, tool, material, product and witness. Somatics is the study of the soma, which places particular emphases on sensation, perception and motor action, and always in the context of the self-sensing self. [3] It does so by training the interoceptive, proprioceptive and kinaesthetic senses (Smyth 2012; Hanna 1988; Schiphorst 2008). Interoception is the 'sense of the physiological condition of the body' with respect to homeostasis (Craig 2003). Proprioception refers to the sense of 'limb position and movement, the sense of tension or force, the sense of effort, and the sense of balance'; kinaesthesia is a related construct that refers more specifically the sense of movement (Proske and Gandevia 2012).

Somatics has many related and subsidiary fields, techniques and approaches, and is closely related to other sets of practices, such as modern and contemporary dance, Eastern meditative traditions, and martial arts (Schiphorst 2008). Somatic practices are generally ameliorative, aiming to heighten awareness of the body – 'somatic connoisseurship' (Schiphorst 2011) – in order to improve the 'use of the self' (Gelb 1990; Shusterman 2008: 8). This is achieved by turning attention inward and using movement as a way to study sensation and perception.

Three speculative applications of somatics

Somatic theories, practices and skills have been extended to and applied in a wide variety of fields, from psychotherapy (Nolan 2014) to the design of new computing technologies (Höök et al. 2015; Lee et al. 2014; Levisohn 2011; Schiphorst 2008). It can also lead to insights in other design disciplines such as urban planning and architecture (see for instance Biggs 2015). In this article, I sketch out further, speculative applications of somatics. Detailed exploration and discussion of each scenario is deferred for the future; my aim in this article is to lay out the foundational arguments for why these scenarios plausibly warrant applications of somatic approaches. My approach builds on Gallagher's (2011) distinction between the body schema (which resides in the cognitive unconscious and is prenoetic) and the body image (which is accessible to awareness and conscious processing). I propose that somatics leverages the plasticity of the nervous system to facilitate the transformation of the body schema, and it does so by making perceptible differentiations in the motor activity and functional organization of the body image (Doidge 2015).

Immigrant somatics

Somatics has been criticized, as Rouhiainen writes, 'for invoking a self-centeredness and for not offering the means of applying the knowledge retrieved from the body to everyday life and social interaction' (2008). In response, researchers in the field have defending the value of somatics in informing social movements, particularly gender and body politics in the West (Curtis 2015; Green 2003). Yet it remains a compelling challenge to somatics. While somatic practices often emphasize the uniqueness of experience, and how embodied experience can differ radically from one person to another, contemporary choreographer and somatics researcher Isabelle Ginot argues that there is an implicit corporeal ontology embedded in many somatic practices and research:

> Somatic discourses are mobilized by thoughts of the universal. They are freighted with innumerable ideologies: the natural…, the transcendent …, the biological difference of the sexes, and cultural hierarchies. … Behind the insistence on the singularity of each corporeality, most somatic methods have as a backdrop a homogenous, universal, ahistorical, and occidental body… Is the somatic body so universal that it transcends this issue?

> Thought to respond to culturally and historically determined ills, somatics has not conceptualized the social changes that accompanied its development; instead, it has remained fixated on the concepts of body and culture current at the time of its advent. How can somatics respond to the needs of a non-Western public, in a time of globalization and massive immigration?... Can somatics help us understand the unique corporality of migrant peoples and contribute to reducing their suffering? In other words, what would somatic knowledge look like when applied to issues of postcolonialism? (2010)

Positionality (England 1994) is relevant here: I am a non-white immigrant to Anglo-American geography and culture, having migrated on my own from the Philippines to the West Coast of Canada in the mid-1990s while I was in my late teens. I encountered somatic practices in my mid-20s in the course of studying contemporary dance. My narrative is, admittedly, markedly different from those of immigrants fleeing war-torn countries. Nevertheless, I suggest that there is still value in foregrounding my subjective experience through autobiographical narrative. Building on this, I offer a tentative, speculative response to Ginot's questions in the form of three potential approaches for how somatics might possibly be applied to immigrant contexts. It relies on embodied ontologies that presuppose precisely the kind of homogenous and ahistoric body that Ginot cautions against; however, these ontologies made sense from both within my own embodied day-to-day experiences, as well as during experience of exploring heightened sensation and awareness through movement in a studio. Moreover, these assertions are consonant with arguments from the embodied cognition perspective within the cognitive sciences (Wilson 2002).[4]

Weber-Fechner law and bodies under stress

The Weber-Fechner Law (Hargrove 2010; Latash 2008; Smyth 2012) is a psychophysical principle that describes the relationship between the perceptibility of a change in stimulus. If the initial stimulus is low, then a small change (call it d) in the stimulus level will be detected; if the initial stimulus is high, then a change by the same amount d will not be as perceptible. This principle applies to the observation of sensory-motor action; it is easier to discern to sense changes in structure and function during movement if the movement is small and gentle, creating what is known in the somatic practice of the Feldenkrais Method® as a differentiation (Feldenkrais 2005). Cortical representations of body parts correspond to how intensely, complexly and finely differentiated those body parts are used (Doidge 2015; Elbert et al. 1995). Hence, deliberate application of the Weber-Fechner law to sensory-motor action (through gentle and slow motion) facilitates increased and more finely differentiated use of those body parts and correspondingly changes cortical representations of those parts in the brain.

In high stress situations, the flight-or-fight response is activated, resulting in an increase in muscle tone. I suggest that the ability to make kinaesthetic differentiations is reduced during stressful periods. Moreover, following the Weber-Fechner Law, the amount of change in one's posture or movements must increase in magnitude in order for proprioceptive and kinaesthetic sensory information to be perceptible. I suggest that individuals who report the feeling of tension in specific areas in their bodies are less able to make kinaesthetic and proprioceptive distinctions in those areas. If there is widespread increase in muscle tonus for an individual, due for instance to constant and high-intensity stress, then strategies for facilitating somatic knowledge must be planned accordingly, as the individual may not be able to sense very small changes as when tonus is less and muscles are closer to their resting state. I suggest that while this is true for most people regardless of their place of origin, this is worth bearing in mind when working with non-western publics, and particularly with immigrant communities for whom the process of relocation can be traumatic.

Embodying self-confidence

As an immigrant to a new country, I found the ability to feel secure and confident within an unfamiliar culture a critical skill to develop. Somatics has played a hand in this. As part of my training as a dancer, I studied a variety of embodied practices, including yoga, Pilates, the Feldenkrais Method® (Feldenkrais 1990), the Alexander Technique (Gelb 1990), Laban Movement Analysis (Davies 2001; Laban 1974; Lamb et al. 2011; McCaw and Laban 2011), and the Franklin Method® (Franklin 1996), either as part of a formally taught curriculum or through self-study. It was my study of these practices that led to me to certain discoveries, which came as anatomically based Eureka moments. For instance, while walking down the street and practicing 'actively pushing against the ground from the balls my feet', I realized that this allowed the front of my pelvis to 'open' and my hip flexors to lengthen. The back of my legs – my calves, hamstrings and my gluteal muscles – also participated more actively in the movement. I could more clearly feel the heft of my pelvis. My stride became longer and I remember clearly registering shock when I realized what I was doing. I was swaggering. Or perhaps more accurately, I was walking the walk of someone who knew exactly what they wanted and was making a beeline towards it with unstoppable determination.

A similarly powerful experience happened in the middle of a Pilates class. I discovered the muscles that pull my shoulder blades down ('scapular depression') and I could feel a concomitant expansion across my collarbone and an upward lengthening of my head, neck and thorax. And I remember suddenly feeling – for what seemed like the first time in my life – utterly powerful. It was both a vulnerable and an empowering sensation, and it was nothing short of a revelation.

It is worth noting that my experiences resonate with studies in experimental psychology, which have suggested a relationship between actively adopting a body posture and feelings of self-confidence and positive mood (Briñol et al. 2011; Zabetipour et al. 2015). Posture has also been found to mediate the content of existing thoughts (Halper 2012), in a process that Briñol and colleagues (2012) have called 'embodied validation'.

Another way in which I have developed self-confidence as an immigrant was to understand that people moved differently in my host culture, and that I had choices on how I could mobilize my physical self either to fit into my host culture with or differentiate myself. I suggest that individuals within a sociocultural group might share not only gestural preferences (Moore and Yamamoto 2012), but also habitual patterns of muscular tonus and other non-gestural movement behaviour that is influenced by similarities in their body schema and body image. If groups and entire societies can share a common language distinguished by variations in dialects and accents, as well as share common sensitivities to spoken phonemes, it is not unreasonable to propose that groups and entire societies can also share common sensory-motor patterns: similar ways of walking, sitting and generally mobilizing the physical self in relationship to the world. The ability to make fine discriminations in movement habits – through observing others and one's self – might lead to the ability for immigrant communities to form strategies for physically relating with their host culture. These strategies might include not just cultural 'integration' but also opposition and counterpoint.

Microgravity somatics

Proprioceptive, vestibular and exteroceptive sensory information are integrated in order to allow humans to shape themselves into functional postures and to navigate through the environment (Feldenkrais 2005; Imai et al. 2001; Latash 2008; McNeill et al. 2010). In microgravity environments such as in outer space, however, the absence of gravity presents major challenges to locomotion and spatial orientation. There is evidence to suggest that the proprioceptive system eventually adapts to these conditions, but slowly (Roll et al. 1998). Research is underway on how to intervene in these situations. For instance, the built environment (i.e., space shuttle interiors) can be designed to provide tactile cues that can aid spatial orientation through stimulating cutaneous and vestibular receptors (Saradjian et al. 2014). I suggest here that somatic training – with its emphasis on increasing proprioceptive and interoceptive sensitivity, and improved kinaesthetic awareness – can potentially be of tremendous benefit to astronauts.[5] Another productive strategy might be to equip astronauts with other interfaces that afford (in the Gibsonian sense of affordance; see Gibson 1979) increased proprioceptive awareness.

Physiological empathy with animals

There has been an increasing interest in understanding the phenomenology of non-human animals (Martinelli 2010), particularly since a compelling case can be made for their sentience (Bekoff and Goodall 2008). Indeed, the conveners of the Cambridge Declaration on Consciousness are certain of it (Low et al. 2012). Other than relying on objective measures and external descriptions of cognitive activity – such as brain imaging data representing neural activity in animals – how can we understand what animals might be experiencing? I suggest that refined somatic capability in sensing subtle muscular and physiological activity can be combined with mental imagery to phenomenologically map animal affective experience into our own bodies. This phenomenological remapping is probably easier done the closer the animal is to humans, taxonomically and structurally. That is to say, an embodied imagining of animal experience is feasible with a chimpanzee, less so with a dog, and significantly even less so with a starfish. While playing with a pet dog in the past and actively imagining what it might like to be in their body, for instance, I have personally experienced muscular sensations in the areas around my sacrum and coccyx (the tailbone) that seemed to me related to the experience of wagging a tail.

Though I have suggested that human qualia is closer to some animal qualia than others, and that phenomenological distance is linked to taxonomical distance, I cannot discount the possibility that through somatic enquiry we might be able to sense vestiges of sensorial experiences of invertebrates. As Grant (2014) suggests, perhaps there is a 'lingering presence or trace of … early sensory systems carried in our [own] nervous and sensory systems'.[6]

Conclusion: From within to between

In this article, I have described three scenarios wherein somatic study and practice is not typically applied but perhaps could be: working with non-western publics; dealing with the effects of microgravity on the body; and empathizing with non-human animals. I have discussed these scenarios in increasing order of speculation. The most speculative of the three, the last scenario also has the most potential to transform our understanding of cognition and consciousness.

These scenarios might appear to be very different from each other. But they are ultimately linked by a common theme: that there is a deep interconnectedness in all lived experience, and that these connections are likely inscribed in our sensory experience (Hackney 2004). Somatics, I propose, might offer approaches for discerning not just what is within but also what is between. It is through somatic methodologies' deep and systematic application of awareness to interoceptive, proprioceptive and kinaesthetic sensation that we might potentially come to understand these connections not just through externalized models and linguistic description, but also through felt experience.

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Endnotes (next page)

[1] Vocabularies for describing the inner landscape of embodied experience are either imprecise, precariously narrow, or at odds with each other. This is to be expected; models – which vocabularies are – necessarily simplify that which they represent, and this is no less true for models of somatic knowledge. I take affect, feelings and emotions to be related but distinct (Shouse 2005). In psychology, affect has been used in the past synonymously with 'mood', which, like the psychological definition of emotion, has an associated valence ranging from positive to negative, and is only partly characterized by patterns of physiological arousal (Bernstein 2006: 429). Other psychologists have distinguished affect from mood; whereas mood is 'saturated in cognitions, especially evaluations', affect is automatic, and can be 'conscious or non-conscious' (Baumeister et al. 2007). Above all, affect is a physiological experience: the heart rate quickening, the 'thousands of stimuli [that] impinge upon the human body' but also the way in which the body's way of 'infolding them all at once and registering them as an intensity' (Shouse 2005). In his notes on his translation of Deleuze and Guattari's *A Thousand Plateaus,* Brian Massumi offers an embodied definition – following Spinoza – of affect; it is not 'a personal feeling' but rather 'the passage from one experiential state of the body to another and implying an augmentation or diminution in that body's capacity to act' (Deleuze and Guattari 1987: xvi). Affect is 'pre-reflective' (Shear and Varela 1999: 135) and 'precognitive' (Thrift 2008).

[2] An audio recording of the exercise instructions is available on https://archive.org/details/speculative-somatics. Borrowing from various somatic practices, particularly the Feldenkrais Method® (Feldenkrais 1990; Rywerant 2003) – this exercise is inspired by one given by Emilyn Claid at a keynote talk at the 2015 Dance and Somatic Practices Conference in Coventry, UK.

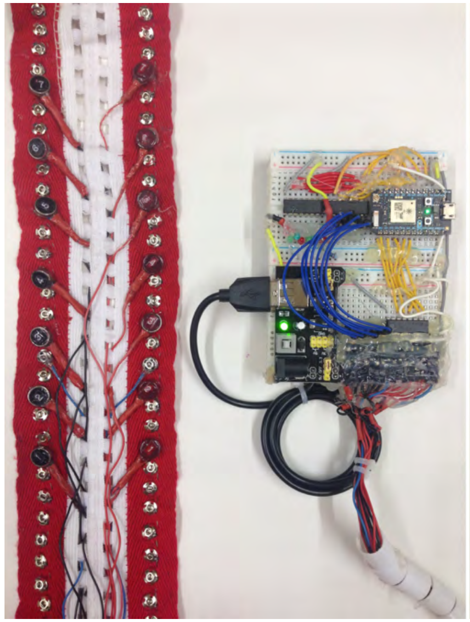
[3] The term 'somatic' is used within other disciplines to signify different concepts. In biology, for instance, somatic is used to refer to particular cells and structures of an organism; additionally, the somatic nervous system refers to the part of the nervous system that is concerned with motor action. Neuroscientist Antonio Damasio's somatic marker hypothesis describes how emotion and affect influence cognitive processes (2004). Other uses of the term abound. In this article, I use it exclusively to refer to the phenomenological study of physiological experience.

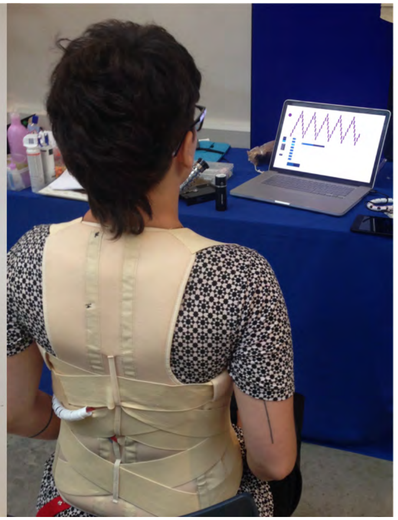
[4] Embodied cognition is an approach to the study of the mind that stands in contrast to positivist, disembodied and reductionist models of human consciousness. Two types of arguments are often advanced in the embodied cognition framework: the first is that the body shapes the mind (Gallagher 2011); the second is that the material world shapes the mind (Ingold 2000; Malafouris 2013).

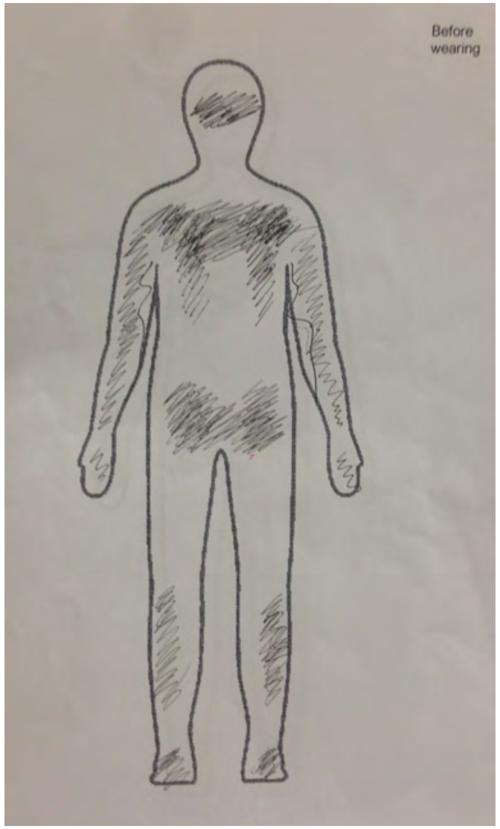
[5] Ideas for how this might be possible could take inspiration from the case of Ian Waterman (McNeill et al. 2010; BBC 1997). Mr Waterman lost all his proprioceptive abilities from the neck down, and successfully trained himself to use his other senses – such as vision, equilibrioception (perception of balance), and thermoception (perception of heat) – intensely as a way to replace his lost proprioception and subsequently close the sensory-motor feedback loop. The closest that typically functioning humans can experience to Mr Waterman's loss of experience is being in microgravity (BBC 1997).

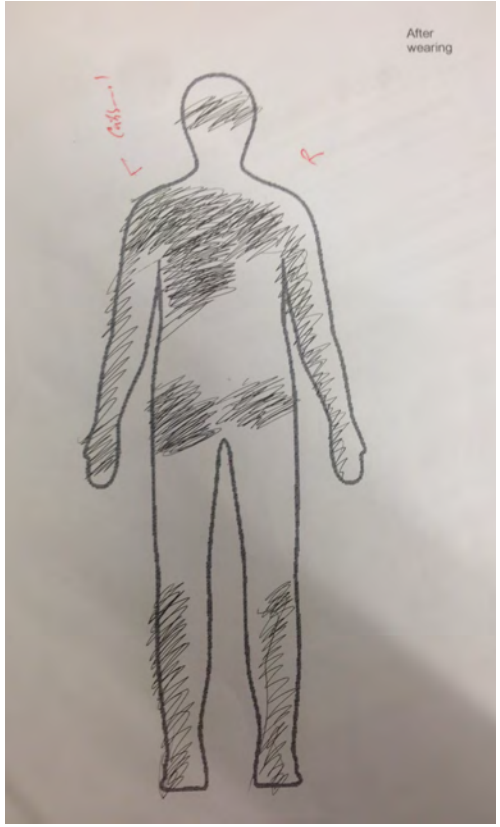
[6] Ventrella has opined on possible implications for our shared neurology with other mammals:

> If we had tails, we'd be wagging them for our dogs when they are being good … It would not be easy to add a tail to the base of a human spine and wire up the nerves and muscles. But if it could be done, our brains would easily and happily adapt, employing some appropriate system of neurons to the purpose of wagging the tail—perhaps re-adapting a system of neurons normally dedicated to doing 'The Twist'. While it may not be easy to adapt our bodies to acquire such organs of expression, our brains can easily adapt. (2014)









Sensing yourself by sensing the ground: Getting intimate with the environment through vibrotactile stimulation

Diego S. Maranan
www.cognovo.eu/project-8

My practice-based research involves the design of wearable technology for enhancing proprioceptive and tactile sensitivity. Haplós is a low-cost, portable device that applies vibrotactile patterns to the skin, can be incorporated in existing clothing and implements, and can be programmed and activated remotely. It is inspired by the Feldenkrais Method (Feldenkrais, 1972), a movement-based learning system for neuromuscular reeducation. I conducted a series of public engagement events and workshops that demonstrate how users of Haplós felt their relationship to the environment—specifically, the ground— more clearly through the application of vibrotactile stimuli. This poster shows two drawings generated by one of the participants. The shaded areas represent portions of the back that the participant could feel in contact with the ground when lying down. After stimulating one side of their back with Haplós, most participants reported that they felt more of that side of their back clearly and in contact with the ground. I thus argue that as a technology for improving self-sensing, Haplós can also be understood as a technology for getting to know the environment more intimately. As Höök et al. (2015) note, "by increasing our body awareness through engaging in various forms of training, we can become more perceptive and aware in the physical world in which we live and act".

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Related work

Maranan, D. S. (2015). Speculative somatics. Technoetic Arts, 13(3), 291–300. https://doi.org/10.1386/tear.13.3.291_1

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Haplós: Designing Technologies for Exploring Somaesthetic Experiences

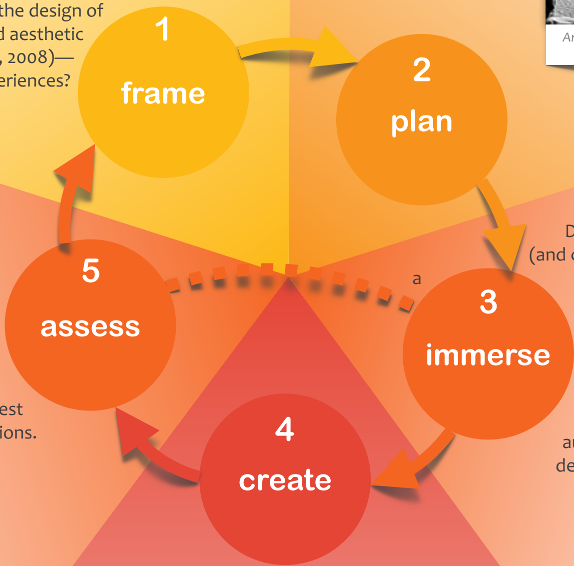
www.cognovo.eu/project-8

From Russell (2014)

Somatics is the first-person, phenomenological study of sensation and perception through movement. The development of somatic knowledge can enhance one's ability to sense and interact with the environment and attain personal well-being. The Feldenkrais Method (FM) is a movement-based learning system and somatic technique that aims to improve the organisation of the body in action by creating increasingly finely-differentiated and integrated cortical representations of the body schema (Verrel et al., 2015). Somatics has been applied to the design of human-computer interaction paradigms (Schiphorst, 2008). How can the neurophysiological and interrelational dimensions of the learning experience within the Feldenkrais Method lead the design of technologies that generate somatic and aesthetic —"somaesthetic" (Shusterman, 2008)— experiences?

This poster shows the iterative and agile design research method we have adapted from typical design thinking processes (Brown, 2008), an approach used by the Project 8 secondment partner Kin (a design studio) and by collaborator Curiosity (a design strategy firm). Immersion in the problem space by practical development of expertise in the Feldenkrais Method is critical, as is the constant development and assessment of prototypes.

An Awareness Through Movement (ATM) class from the Feldenkrais Method



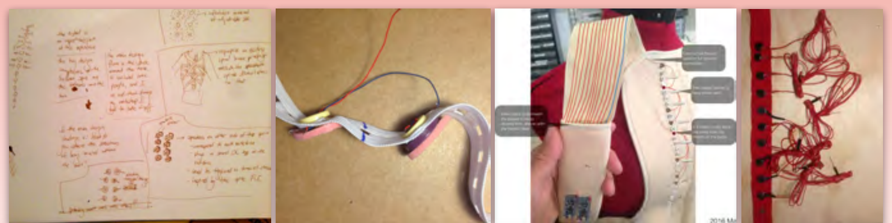
Deep expertise in somatic learning principles is (and continues to be) developed by participating in 4-year professional certification training programme for the Feldenkrais Method. Thick descriptions of phenomenological experience are gathered through conducting FM *Awareness Though Movement* and *Functional Integration* classes on other people and on myself (i.e., autoethnography) to understand FM principles deeply and translate them into design ideas and decisions.

Conducting an ATM class

Prototypes are assessed continuously by the investigators on themselves and other people in structured workshops, through daily use, and in informal events. Results of assessments reframe the problem, instigate adjustments in the research plan, suggest new strategies for deepening immersion in the problem, and suggest new design directions.

Assessing different versions of Haplós

The starting point for the design of the technology is Sally Dean's Somatic Costume™ (Dean, 2014), educational tools that bring awareness to different body areas as well as generate different movement qualities and experiences. We are applying FM learning principles to Dean's work to create **Haplós**, a modular, wearable garment that uses detachable vibratory motors. Haplós will be used in a set of scenarios and use cases in which it can be programmed in specific ways.



Early sketches and prototypes of Haplós

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Curiosity

PhD student: **Diego S. Maranan**. Supervisors: **Jane Grant, John Matthias, Sue Denham, Mike Phillips, Matt Wade**. This project is funded by the Marie Curie Initial Training Network FP7-PEOPLE-2013-ITN, grant number 604764

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