Cultivating kinaesthetic awareness through interaction

Perspectives from somatic practices and embodied cognition

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ABSTRACT

Designing for kinaesthetic awareness, the perception of our body's position and movement, presents a unique set of challenges and opportunities. While these implications are relatively new in the HCI community, they resonate with experiential knowledge from somatic practices and theories in embodied cognition. *Still, moving* is an interactive sound installation designed to support the perception of a person's micro-movements. We elaborate here on findings from a previous study, first emerged inductively from a grounded theory analysis of phenomenological interviews. Tracing the connections between these findings, and existing research in somatic practices and embodied cognition, reveals a range of distinctions and alternatives to flesh out the question: How can we understand and cultivate kinaesthetic awareness through interaction?

CCS CONCEPTS

• **Human-centered computing** → *Interaction design process and methods*; *Auditory feedback*; • **Applied computing** → *Performing arts*;

KEYWORDS

interaction design, auditory feedback, somaesthetics, kinaesthetic awareness, somatic practices, embodied cognition, movement

1 INTRODUCTION

The ease with which we spontaneously move hides a staggering complexity. Even the simple activity of standing in stillness reveals a stream of minute falls and recoveries, the stillness always swaying [35]. Bringing attention to these ongoing processes and associated sensations can reveal the intricacy of our embodied experience. But such a deepening of *kinaesthetic awareness*, the perception of our position and movement in space, is complicated by the elusive nature of our sensorimotor processes: habitually unseen, and difficult to lift into consciousness. With this challenge in mind we created *still, moving*: an interactive system designed to support kinaesthetic awareness, which generates auditory feedback in response to movement and muscle tension data. Section 2 recapitulates information on the system and a qualitative study on it, from a previous publication [16].

We now initiate a broader discussion, drawing from multiple disciplines and perspectives to consider the specific opportunities and challenges of working on *interaction for kinaesthetic awareness*. In section 3 we expand some of the background informing our work, tracing the evolution of embodied approaches in HCI and related ideas from arts-based research and two somatic practices. Section 4 further delineates the importance of detailed somatic considerations to inform design processes, in terms of the system itself as well as how the system is to be practiced. Section 5 considers some of the findings from the qualitative study from the perspective of somatic practices and embodied cognition.

2 INTERACTION FOR KINAESTHETIC AWARENESS

This section recapitulates relevant information on *still, moving* and a qualitative study, from a previous publication [16].

2.1 Our focuses

2.1.1 Proprioception and kinaesthesia. Both terms refer to ways in which we sense our own body, at rest or in motion, but they are used somewhat inconsistently in the literature. Recent clarifications consider that *kinaesthesia* focuses on the senses of the body's position and movement, while *proprioception* is a broader term encompassing the aforementioned and other modalities such

as effort, tension, weight and balance [39]. All these sensory modalities play an essential role in movement execution, which expert movers develop through practice to support precision and nuances. Somatic practices in particular have developed a range of methods to refine proprioception and kinaesthetic awareness (3.2).

2.1.2 Sound and movement. A range of systems use continuous auditory feedback to improve movement performance, foster kinaesthetic exploration, and support learning [7, 17, 18, 40]. We align with this body of research through the lens of kinaesthetic awareness. Two projects share related focuses and are useful to consider here. Bergström and Jonsson apply Höök et al.'s Somaesthetic Appreciation Design [23] to create *Sarka*. The system sonifies subtle changes of pressure on a mat to "support the ability to direct attention" while lying on the mat [3]. Feltham et al.'s *Slow Floor* is inspired by the Butoh practice of slow walking, using pressure sensitive resistors to sonify the subtle transfers of weight of the walk, and support a heightened awareness and agency [14].

2.1.3 Micro-movements and the small dance. We are interested in the small scale of micro-movements, as in Paxton's *small dance* [35]. It is a movement meditation in which one stands quietly and observes the flow of micro-movements underlying the stand. These are postural reflexes happening whether we pay attention to them or not. A slight bending of the knee for instance triggers a stretch reflex, which in turn brings the knee back and closer to vertical alignment [53, p. 25]. This corrective feedback loop is involuntary, but with quiet attention the resulting movements can be observed and experienced. Godard similarly defines *pré-mouvement* as our unconscious relation to weight and gravity, which exists before we even start moving [19]. It is involuntary but conditions and colors all of our gestural expressivity. Godard emphasizes the initiations of movements: transient patterns of organization that anticipate our intentions. If we reach forward with the hand for instance, the first muscles to engage are the postural muscles of the calves. This involuntary preparation is necessary to counter the weight transfer that is about to happen, when the arm shifts forward [19, p. 225].

Both Paxton and Godard highlight the importance of involuntary postural reflexes to organize and coordinate our relation to gravity, ground and space. These processes escape intention but are necessary conditions to its enactment.

2.2 The *still, moving* system

Still, moving is an interactive system generating auditory feedback in response to a person's movements, using two Myo bracelets.[1] These interfaces are well suited to work with kinaesthetic awareness, as they track both *movement information* and *muscle tension* (8 EMG sensors spread around each bracelet). While we developed different versions of the system implementing a range of mappings, including a more complex performative version, for the study we streamlined the system to only use the EMG sensors, as they are ideal to reveal the changes in muscle tension underlying micro-movements (4.3). The system was implemented using Max 7 [2] and the Mubu library [44]. The pair of Myo bracelets are placed on a person's lower legs. Muscle tension is tracked by processing EMG data using a Bayesian filtering technique initially developed for prosthetics control [22]. These forces are rescaled using an 'adaptation level' computed as the maximum of the force over the past 10 seconds. This *adaptive process* provides a 'kinaesthetic zoom' as the system's sensitivity increases when the level of activity decreases. The rescaled forces control the synthesis of sound textures using concatenative sound synthesis, a corpus-based and descriptor-driven technique [45]. There are two sound corpuses: field recordings of water sounds used for the forces from the calves, and recordings of rustling leaves and brushing sounds for the shins.

[1] https://www.myo.com/techspecs
[2] https://cycling74.com/max7

2.3 Qualitative study

We recruited 12 participants, with a diverse range of movement backgrounds. After a short introduction the participants were setup with the sensors. The study consisted mainly in 20' interaction sessions followed by 30' interviews. During the interaction sessions we recorded video, the auditory feedback generated by the system and all the sensor data. During the interviews we recorded both audio and video. In the introduction we informed the participants that the sound was generated in response to their movements and muscular activity, but without further details on the mapping strategy. Table 1 recapitulates the three phases of the interaction sessions, alternating between open explorations (phase 1 and 3), and a guided practice of the *small dance* in phase 2 (2.1.3).

We transcribed and analyzed the interviews, using a grounded theory approach. The process included two coders who collaborated through initial discussions, individual coding, and a final negotiation. Our eventual coding system includes references to sensations and kinaesthetic awareness, shifts of attention, modes of exploration, appreciation of the feedback loop, attention to micro-movements, and reflections on the body and the movements induced by the interaction. Before highlighting some of these findings, we will describe our interview process in more details.

Table 1: The three phases of the interaction sessions

Phase	Activity	Facilitation	Audio source	Duration
1	exploration	open	headphones	5'
2	small dance	facilitated	speakers	10'
3	exploration	open	headphones	5'

2.4 Explicitating experience

The semi-structured interviews are based on Vermersch's *explicitation interview* (EI), a form of phenomenological inquiry developed to access and articulate subjective experiences [51]. While introspection can be problematic, the EI alleviates the difficulty of describing one's own experience by mediating the *first-person* point of view of the interviewee through the *second-person* perspective of the interviewer [10, p. 81]. Petitmengin describes a number of usual challenges, such as a dispersion of attention (the 'monkey mind' of meditational practices), or confusing lived experience and the *representation* of lived experience [38]. To counter these tendencies the EI articulates methods to stabilize attention and shift our focus from 'what' to 'how'. Most importantly, it emphasizes the need to

go beyond general statements, and get deeper and closer to *singular experiences*. The EI is thus ideal to elicit fine grained descriptions of the participants' experiences of interacting with *still, moving*.

Vermersch also emphasizes *temporality* as a defining quality of experience: "All lived experience is a process whose primary universal property is that it unfolds over time and whose seizing must be related to temporality" [52, p. 49]. This is all the more important to study the experience of interacting with a system unfolding through a real-time feedback loop involving movement and sound. We thus focused the qualitative study on delineating the temporality of the singular experiences emphasized in explicitation, while also tracing the longer term evolution of these experiences through the full arc of the interaction sessions.

2.5 The experience evolving through time

A consistent pattern from the qualitative study [16] involves: *a*) an initial sense of disconnection or disorientation; *b*) resolved later on, often through a fairly sudden realization; *c*) which then leads to more complexity and experimentation in the interaction.

a) Even though the participants were told before the interaction session that the sound environment was generated from their movements, most reported an initial sense of disconnection between sound and movement:

> I suspect, it didn't register that those sounds were readings, sonic readings of my movement that was being picked up by the devices. [...] In other words, I think **I had forgotten that those sounds were in response to what I was doing**. (P1)

b) Ten out of twelve participants then experienced a resolution of the initial disconnect, during the first phase of open exploration or during the small dance in the second phase:

> Once I finally just kind of let go of my anxiety and was moving more and, exploring the space and kind of getting used to the sound, it was like: 'oh, **it's linked to my movement** and, the type of movement, or how fast or... directionally.' (P10)

c) In the final phase, the open exploration following the small dance, participants extended their attention to micro-movements and more experimentation. Most reported an increased awareness of their bodies' connectedness, finding for instance that small movements of the upper body would reveberate all the way down to the lower legs and generate sounds. They recounted detailed insights into mechanisms such as balance, weight distribution, or even the interplay between bones and muscles in supporting weight shifts.

> The couple times that I was using my arms swinging, that was the only... only small time that I was consciously thinking: 'ah-ha, my arm is doing this but it's still making sound.' And knowing that... knowing that it was not my arm, but **it was the force that my arm is sending to my feet**. (P5)

> At the very beginning, I thought: 'it's not really capturing the weight, it's just capturing the muscle'. So, if I have my weight, **it could just go through my bones**, right? It's not like... my muscles would be completely relaxed. (P3)

3 INTERACTION AS A TRANSFORMATION OF EXPERIENCE

We trace now the evolution of embodied approaches in HCI, and related ideas from two somatic practices and arts-based research, to consider our findings from these perspectives.

3.1 Fleshing out embodiment in HCI

3.1.1 Embodied interaction. From the '80s on, an *embodied turn* has unfolded in many disciplines, establishing embodiment as a keystone to understand cognition [50]. Third wave HCI has similarly *turned* towards lived experience and the body, drawing mainly from phenomenology at first. The paradigm emphasizes the embodied and situated nature of interaction, and the construction of meaning afforded through interaction [21]. Since the 2000s on especially, approaches such as Dourish's *embodied interaction* have gained traction [13]. Dourish establishes embodiment as the foundation of his methodology, and derives the crucial distinction that "embodiment is not a property of systems, technologies, or artifacts; it is a property of interaction" [13, p. 189]. Design focuses are thus shifted away from systems and objects, to center instead on the 'I' of HCI, *interaction*, unfolding through a circularity between *meaning* and *action*. Action is informed by meaning, but meaning also arises from action [13, p. 206]. The emphasis on meaning making as a characteristic of embodiment is a powerful idea, which Dourish extends by considering the long-term influences between practice and technology, a process which he calls *appropriation* [13, p. 204]. An implication left unexplored however, is that as practice and technology coevolve, our embodied experience is itself transformed. And by this we mean not just the moment to moment changes in the flow of our experience, but a transformation of the modalities in which we can and do experience. This *transformation of experience* is precisely what the somaesthetic perspective foregrounds.

3.1.2 Somaesthetics. Shusterman is a philosopher and somatic practitioner of the Feldenkrais Method. He has developed *somaesthetics* to revive "the ancient idea of philosophy as an embodied way of life rather than a mere discursive field of abstract theory" [47, p. 3]. Like Dourish, Shusterman draws on phenomenology to consider embodiment, particularly Merleau-Ponty's embodied phenomenology. But he also develops a subtle critique of it. Merleau-Ponty's work evokes the felt richness of being and moving in the world [32]. In these accounts, he maintains the strict phenomenological opposition between the spontaneity of lived experience, and any subsequent process of representation or reflection [46, p. 61]. Shusterman points out that this polarization leaves no space for embodiment to be practiced and cultivated, a process which implies a stance both embodied and reflective. In Merleau-Ponty's view, embodiment is thus dynamically situated in the world, yet static at the longer timescales of developmental processes. In resolving this tension, Shusterman complements phenomenology by drawing on *pragmatism* and the works of James [26] and Dewey [11]. He acknowledges the plastic nature of embodiment, and the possibility of cultivating this plasticity through practice. And he proposes a middle ground of *lived somaesthetic reflection* [46, p. 63], as the instrumental modality through which experience can be transformed by long-term practices such as somatics.

3.1.3 Somaesthetic design. The importance of this idea to HCI, an extension of earlier third wave HCI paradigms, has been recognized and advanced by Schiphorst [43] and Höök et al. [23]. Within a growing body of works investigating design practices in relation to movement [15, 24, 31] and sensory modalities [8, 29], the somaesthetic perspective clarifies distinct interests and methods. Schiphorst thus delineates four values: self, attention, experience and interconnectedness [43, p. 86]. And Höök et al. articulate four qualities as guiding design principles: subtle guidance, making space, intimate correspondences and articulating experience [23]. Most importantly, embodied experience is approached not only as a multimodal field to explore, but also as an ability to refine, a potential which Schiphorst characterizes as *experience as skill* [43, ch. 2]. This emphasis encompasses the whole potential range of our embodied experiences. A variety of projects have been developed to investigate for instance the somaesthetics of touch, breath, light or heat [28, 41, 42, 48]. Each of these sensory modalities implies specific affordances to be studied experientially and in relation to design processes. Jonsson et al. for instance highlight the "slowness and 'inertia' inherent to heat interaction" [28, p. 116]. Our work with *still, moving* aligns with this emerging approach, focusing on sound, movement and kinaesthetic awareness. We also aim to complement more synthetic approaches with expansive discussions of specific somatic strategies and practices, as Loke et al. do for instance for the Feldenkrais Method [30].

3.2 Somatic practices

3.2.1 Overview. Recognizing the relevance and commonality of a number of existing practices, Hanna formalized the term *somatics* in 1976, to reference "the field which studies the soma: namely, the body as perceived from within by first-person perception" [20, p. 4]. The actual practices are numerous, going back in one case to the 19th century, and interconnected through a web of influences and direct transmission through practice [43, p. 73].

For *still, moving* we are inspired by somatic practices focusing on a deepening of experience. This deepening is analogous to the refinement of attention developed in meditational practices, with an emphasis on movement, proprioception and kinaesthetic awareness. These practices operate through a range of strategies, from purely observational exercises in which one uses the mind to listen to the sensory echoes of what is already unfolding, to more active and voluntary movement exercises. Two practices in particular have informed our process to develop *still, moving*, as methods to cultivate kinaesthetic awareness.

3.2.2 The Alexander Technique (AT). It was created by F. Matthias Alexander at the turn of the 20th century, initially to overcome a recurrent problem of voice loss which conventional medicine failed to alleviate. Alexander's crucial realization was that *to change how he moved he had to change how he thought.* Our habits of thought are deeply linked to our movement habits. From this pragmatic and experiential investigation, Alexander developed a mindfulness based system to overcome harmful habits of use [1].

The concept of *use* crystallizes the idea that we use ourselves in everything we do. Just like a musician who practices with his instrument to develop his ability to play, we should not take our use for granted, but rather investigate and refine it. This is further articulated in the contrast between *end gaining* — focusing solely on a goal — and considering the *means whereby* we do what we do [2, p. 29]. Two more concepts are relevant here. *Directions* are mental intentions that can be put into words, such as 'let the neck be free' [1, p. 20]. In an AT session these intentions are renewed, while at the same time the student is given an experience of the 'free neck', guided by the hands and touch of the teacher. Gradually, through many repetitions, a connection is thus created between the intention of a free neck, and the embodied organization which makes the free neck possible. This two-step process is what is understood as *non-doing*. Cognitively it is a detachment and letting go from doing things directly. A distinction is made between sending an intention of movement as a voluntary decision, and then letting involuntary sensorimotor processes enact that movement, taking care of the fine coordination necessary for it. So the AT offers a methodology to investigate the interface between conscious thinking and involuntary sensorimotor processes.

3.2.3 Material for the Spine (MFS). It is a postmodern dance technique created by Steve Paxton to "bring consciousness to the dark side of the body" [36]. This *dark side* comprises the more opaque elements of our embodied structures, such as the deep layers of spinal musculature constituted of hundreds of delicate muscles crisscrossing adjacent vertebrae [12, p. 89, 94]. In a pedagogical context, MFS combines open movement explorations with a set of rigorous exercises. These are practice forms including fundamental patterns such as helixes and undulations. They are important for physical training, but even more so to train the mind. The learning process does not aim to define a fixed taxonomy of movements, but rather through repetition and inquiry to sensitize the mind to the patterns. Just like frets on the neck of a guitar, references are created so that the mind can orientate itself with ease and efficiency within a continuum of kinaesthetic possibilities, to make movement decisions in real time. Like the AT, the practice operates at the interface between conscious thinking and involuntary processes. The small dance introduced in section 2.1.3 exemplifies this approach. It takes a deep physical quieting and careful tuning of the mind to reveal the micro-movements underlying the stand. They are easily masked by higher levels of activity, stronger sensations or overriding intentions. We used the small dance in the interaction sessions of the study to bring attention to micro-movements, and the sensitivity of the system to these minute shifts.

3.3 Transformation of experience

The initial disorientation and sense of disconnect experienced by the participants becomes meaningful, viewed in relation to learning processes in somatic practices. Hanna highlights that "somatic learning begins by focusing awareness on the *unknown*" [20, p. 7]. Paxton echoes the same idea when he proposes to "bring consciousness to the *dark side* of the body" [36]. And in the AT, the experience of a shift in the habitual way we organize ourselves can be disconcerting, especially early on when the shifts are more dramatic.

The participants initially report two experiential modalities, sound and movement, felt as disconnected. In most cases the perceived lack of relation stands in contrast to an expectation of what this relation should be. This is not surprising, considering that the sensitivity of the system is tuned to reveal the 'dark side' of a

person's micro-movements, habitually unseen and unknown. The subsequent reconnection of movement and sound then, is an act of *meaning making*, a crucial aspect of embodied interaction (3.1.1). We find the circularity between action and meaning described by Dourish, bridging physical and symbolic levels of description [13, p. 206]. But there is also a second type of circularity between two experiential modalities unfolding in synchronous flow: sound makes sense of movement, and movement makes sense of sound.

We see more at play here than simply an issue of 'learning the system'. As sound and movement mutually define each other, something is learned, but we should question what. The literature on arts-based research provides useful insights. Johnson references Dewey's seminal work on art and experience [11] to argue that we should "stop thinking of knowledge as an abstract quasi-entity or a fixed body of propositional claims" [27, p. 142]. He proposes instead to understand practice-based knowledge as a process of inquiry, a dynamic view reflected in his terminological shift from noun to verb. *Embodied knowing* is then "a process for intelligently transforming experience" [27, p. 142]. This idea translates powerfully to somatic practices and to our work on interaction for kinaesthetic awareness. In the process of interacting with *still, moving*, the participants transform their experiences. And this transformation is expressed vividly in some accounts of singular experiences:

> When I am doing this [standing on one leg], and then when I start to fall forward and my weight shifts onto the ball of my feet a lot a lot! It's… it was just perfect and… **I felt like a wave**. I… and I kind of expected the sound to stop, when, I like, truly felt but… I guess, it continued in a natural way, like an actual wave. […] Yes, definitely **I felt like my body was continuing, even though it wasn't**. And it's actually only now that I look back at it that it's such a stark contrast between what I was doing and what the sound did, but in the moment I felt like I continued as well. (P5)

The intensity of the experience seems to originate in the congruence of multiple sensory modalities. Together they create a synesthetic experience (*"I felt like a wave"*) of such strength that it induces a kinaesthetic illusion (*"I felt like my body was continuing, even though it wasn't"*). The multisensory integration between the dynamics of the movement and the sound, colliding with the underlying metaphor of a wave, induce an altered kinaesthetic state.

4 INFORMING THE DESIGN OF A SYSTEM AND THE PRACTICE OF THE SYSTEM

We consider here how our design choices for *still, moving* are informed from multiple perspectives, while also highlighting contrasts and similarities with other projects who share related focuses.

4.1 Somatic strategies — Details matter

We mention two systems in section 2.1.2: *Sarka* uses a mat to sonify the variations in pressure of a person *lying down* on the mat [3], *Slow Floor* uses force sensitive resistors to investigate the slow *walking* practice of Butoh [14]. Our movement focus is closer to Slow Floor, as we are interested in the micro-movements underlying the unique *verticality* of our biped structure, most obvious in movement patterns such as walking and standing. Both Paxton and Godard highlight the importance of involuntary postural reflexes to coordinate our relation to gravity, ground and space (2.1.3). Godard uses the concept of pré-mouvement as an analytical tool to observe the fine textures that imbue our larger movements with a 'postural musicality' [19, p. 224]. And Paxton initiates a practice to disclose this world of micro-movements to consciousness, which changes in turn our ways of being and moving [37].

The horizontal and vertical affordances leveraged in Sarka and Slow Floor resonate with strategies used in somatic and dance practices. Essentially, these are salient variations to explore how we organize ourselves in relation to gravity and the support from the ground. The authors reference respective inspirations from the floor exercises of the Feldenkrais Method, and the slow walk of Butoh dance. Practices often combine a range of such strategies. In MFS for instance, one might first exercise pointing the sitbones to the heels while lying on the floor, and then transpose this experience into a walk. The AT similarly combines table work (lying down in semi-supine), chair work (sitting), as well as standing and walking.

Experientially, horizontal and vertical patterns are highly differentiated and afford distinct possibilities. In lying down we are fully supported by the floor, weight crosses the skeletal system transversely, skin pressure easily comes to the foreground, and various rolling patterns are available as support from the floor can be found through many body parts. In standing, we first have to enact our verticality from the narrower base of our footprints. At the same time there is a potential lightness, when we fully leverage our postural structures, and channel weight through the skeletal system. The center line of our verticality is then a place of minimal effort, and any deviation from this upright axis propagates through the structure as a commensurate increase in muscle tension. In that quiet suspension of the stand, micro-movements that are otherwise dampened or deafened can be revealed.

This is but a glimpse into the variety of *somatic strategies* developed to access a range of experiences. Within this diversity *details matter*. Differences such as working with eyes open or closed, standing or lying down, are not just mechanical shifts of body parts. Experientially, these shifts can be momentous: affecting our sense of being, determining our possible futures in terms of available kinaesthetic choices, and changing how we organize ourselves.

4.2 The practice of the system

We started by considering the affordances of systems: a mat lends itself to lying on it, a floor to walking on it. Conversely, we also need to consider the affordances of practices, and specifically of the *practice of the system*. For *still, moving* we are interested in drawing from somatic strategies in which the synergy between a range of levels of activity is explored, as opposed to remaining mainly in one state or level. Paxton's *small dance* (2.1.3) was developed not only as a quiet meditation, but also as a preparation to 'survive' the sometimes disorienting and high energy dances of contact improvisation [37]. In this meta strategy, the experience of one state is used to inform other states. It leverages the contrast between the states as a dimension along which to clarify a continuum of possibilities. And it relies on our ability to retain qualities nurtured in a privileged state as we shift into another one. The transitions

can be fragile at first, the reverberance of a quality easily disrupted and lost. But with practice one develops this ability to retain a quality, or imprint the quality in order to retain it.

These considerations inform the alternated structure of the interaction sessions for the qualitative study (table 1). Phase 1 is an open exploration giving participants a first impression of *still, moving* on their own terms. Phase 2 uses the small dance to bring attention to the micro-movements underlying the stillness of the stand, and the sensitivity of the system to these minute shifts. Phase 3 opens up the exploration again, but with the experience of the small dance still fresh and resonant. We took care to walk the participants through the structure before enacting it, to limit interruptions in the flow of their experience, particularly in the transition from phase 2 to 3.

Our overarching goal is to provide subtle guidance while retaining a sense of openness. The small dance is facilitated, but non-prescriptive, in the sense that there are no prescribed movements to enact. Guidance emerges from the act of observing a process that is already unfolding. The structure thus combines open explorations and an open observation, letting the participants determine their own experiences. The interaction unfolds mainly on their own terms: motivated by their curiosity, mediated through their movement patterns, and informed by their sense of embodiment. This approach fosters the very process of inquiry and exploration that Johnson defines as a key component of *embodied knowing* (3.3).

As must be clear by now, the design of this structure, the *practice of the system*, is as important as the design of the system itself, and largely informed by existing practices in somatics. Working with the soma affords a rich and subtle range of somatic modalities. Simply put, we can at any point lie down or stand up, listen in stillness or break into a run. And within each of these physical activities, there is a whole landscape of sensations to explore with our attention. Sensors and interactive systems are usually comparatively limited, more specialized in their affordances. While our attention can shift almost instantly, to observe from a range of perspectives, the Myo bracelets are only sensing from the point of view of the lower legs. Careful consideration of the specific affordances of the system and its practice is then all the more important.

4.3 Unpacking one design choice

Given our emphasis on openness in the interaction, a wearable sensor facilitates a movement exploration that is not spatially bound. Stillness and movement remain possible at any point in space and in time. The Myo bracelets are particularly suited to work on kinaesthetic awareness, as they include sensors measuring *movement information* as well as *muscle tension*, using 8 EMG sensors.

From the point of view of somatic practices, and specifically the AT and MFS, focusing on muscle tension rather than position or movement is advantageous. Muscle tension underlies movement, but the relation between the two is non-linear and not one-to-one. This challenge was already recognized in the '60s by Bernstein, as the *degrees of freedom problem* [5]. When dealing with the moving body we are faced with a system that has high dimensionality [12] and a high level of redundancy, in every aspect: anatomy, kinematics and neurophysiology. So there are multiple muscles acting on the same joints, multiple possibilities of movements to accomplish the same goals, and multiple neural connections that can activate the same muscles. A simple example is that by engaging and balancing antagonistic muscles, one could easily increase tension in a limb with little or no resulting movement.

Conversely, one of the somatic issue that a practice such as the AT addresses is illustrated by the image that we are 'driving ourselves with the brakes on', i.e. impeding our use through some degree of antagonistic interference [9]. The ease which one develops through the practice is partly due to a gradual inhibition of these interferences, retuning the dynamic balance of forces in the body, and shifting tension to flow where it needs to be. Early questions from AT students are often concerned with static positions: 'Should my head be like this or like that'. But thinking of use in terms of privileging one position over another is missing the point.

Embodiment, even in seemingly still positions as in the stand of the small dance, is always *dynamic*. Aiming to attain and maintain an imagined 'ideal position' has the potential to create another source of interference, overriding the spontaneous flow of sensorimotor adjustments, and freezing the body into a fixed shape. A typical example is the stiffening often imposed in response to an admonition to 'stand straight', quite the opposite of the openness and dynamic poise cultivated in the AT and many practices.

In summary, focusing on the dynamic balance of forces in the body reveals a more primary kinaesthetic source. The forces generate movements but conversely, cannot be fully deduced from observing movements. According to the AT master teacher Elaine Kopman, while much can be determined through sight, she wouldn't fully trust her insights until putting her hands on a student, using touch to detect subtle changes in muscle tension [9]. The EMG sensors are similarly suited to work with kinaesthetic awareness. Like the hands of an AT teacher, they can access the modulation of tension underlying movement.

5 NAVIGATING THE SOMA

We return to the pattern emerging from the qualitative study (2.5): disconnection → reconnection → integration and exploration, and our argument that the practice of somatics implies, at least initially, to look into the unknown and the 'dark side' (3.3). Because kinaesthesia underlies everything we do as embodied beings, it is not surprising that shifts in kinaesthetic awareness are potentially disorientating. For Paxton this is a fertile state, and the disorientation or even dizziness "signals that we have reached the borderland between these two aspects of physical control — conscious and reflexive. When we linger in the borderland on purpose, we become our own experiment" [34, p. 257]. Paxton is underscoring the interplay between involuntary sensorimotor processes, and conscious movement intentions, an idea we have traced repeatedly, mainly in terms of somatic strategies to interface these two types of processes.

There is also an abundance of sources in the literature on embodied cognition expanding on similar findings. Moravec speculates that the challenge of accessing sensorimotor processes is linked to the long timescales over which these abilities have evolved and been perfected. Conscious thinking by comparison is a recent development and "the thinnest veneer of human thought" [33, p. 15]. In his research to bridge phenomenology and neuroscience, Varela analyzes time consciousness and distinguishes three scales of duration in neurodynamics. From that perspective consciousness appears

simply too slow to fully register sensorimotor processes [49, p. 273]. Hurley elaborates a model organized through levels of personal, subpersonal, and neural processes, as well as different functional layers, to describe how sociocognitive skills such as imitation and mindreading, can emerge from sensorimotor processes [25].

Experientially, the challenge of working with kinaesthetic awareness has a dual nature. Sensorimotor processes can be characterized as both *opaque* and *transparent*. The apparent contradiction is resolved when considering that in both cases there is an issue of not seeing: opacity prevents us from seeing what we try to see, transparency is not seeing that through which we see.

The latter is a reference to Heidegger's distinction between the *ready-at-hand* and the *present-to-hand*. We tend not to examine what we use, and even less so what we are used to use. A tool is usually ready-at-hand, in the sense that our focus is on the use of the object rather than the object itself. Varela describes this habitual flow as "transparency as disposition for action" [49, p. 298]. Only when the tool breaks down do we shift our attitude to one of inquiry. The distinction echoes Alexander's contrast between focusing on the *end gain* or the *means whereby* (3.2.2), and translates well to somatic practices. They are methodologies to shift our relation to embodiment from ready-at-hand to present-to-hand.

As we turn our attention inward however, sensorimotor processes often resist our attempts to lift them into consciousness. We encounter here the second issue of *opacity*. The musculature of the back for instance comprises no less than five layers of musculature [12, p. 104]. We are familiar with the large muscles of the superficial layers. They are powerful and in a kinaesthetic sense sort of loud, thus easily accessible to conscious experience. Going deeper the musculature becomes smaller and more numerous. The most internal layer, closest to the spine, contains a multitude of small and delicate muscles, all of which have to be coordinated to work in synergy as we sit, stand, walk or run — a staggering complexity. And yet we can practice and indeed deepen our embodied experience, as did the participants in reconnecting sound and movement, and gaining new insights.

Berthoz's concept of *simplexity* is useful to consider here, exemplified for instance in his analysis of the intricate mechanisms through which the challenges of walking are overcome [6, p. 120-140]. *Simplexity* is a ubiquitous principle at work in natural systems, as they evolve simplifying solutions to deal with the complexity of their environment and themselves. Simplex principles operate through many of our kinaesthetic structures and processes, such as the geometry of the eye and extraocular muscles [6, p. 28], or the stabilization of the head which is "a veritable 'inertial guidance system'" [6, p. 130]. By extension there is also a *simplex* principle at work as the participants generate meaning over time.

Their experiences come together in ways emphasizing that the body is both *whole* and *differentiated*. Once the initial sense of disconnection is resolved, the interaction evolves towards more integration, sensitivity and exploration. Notably, this includes a sense of the body's connectedness as a whole, for instance that a small movement of the upper body reverberates throughout the structure and all the way down to the lower legs, as well as a finer sensory appreciation of the differentiated structures of the body (bones versus muscles for instance).

We have mentioned the comparative limitations of sensors. While somatic practices can draw seamlessly from a range of activities and focuses, the sensors' perspective here is narrowed to muscle tension in the lower legs. In practice, it is the intrinsic connectedness of our embodied structures that allows to overcome this limitation. As in Godard's illustration of *pré-mouvement* (2.1.3), an increase in tension in the calves can foreshadow a movement of the arm. Thus while the data accessed by *still, moving* is local, echoes of global patterns resonate through it. Here as well, somatic details are essential to understand both limitations and opportunities.

6 CONCLUSION

The somaesthetic approach in HCI has made vital contributions to 'flesh out' the growing interest in embodiment of third wave HCI. Most importantly, it validates and disseminates experiential knowledge from somatic practices, to ground reflections and practices on related issues. This is not a given, and mostly lacking in other research communities. For instance, a collection of articles focused on the notion of *habits* lists multidisciplinary approaches encompassing 13 fields, but misses any contribution from any of the somatic practices that work directly on habits [4].

The pioneering works that fostered somaesthetic perspectives into the HCI community incorporate synthetic approaches [23, 43]. These processes of abstraction are essential. They reveal unseen commonalities shared across a variety of practices. And by distilling the essence of practices into principles, they disseminate important ideas from somatics beyond the community of somatic practitioners.

We propose to complement these synthetic approaches with more expansive discussions of specific somatic strategies: aiming for fine grained descriptions of existing practices, relating these practices to research from other fields, and tracing the multiple ways in which these somatic nuances inform design choices at every step and every level. This goal is only initiated here and demands to be developed over longer publications. Such contributions are relevant to inform the design of a system, and even more so to consider the *practice of the system*. There is a wide range of contemporary somatic practices to be inspired by, or to derive insights from. The details and somatic nuances within this diversity matter. Differences such as working with eyes open or closed, standing or lying down, are experientially salient and change how we organize ourselves.

In conclusion we offer a set of key questions, raised as we worked on interaction for kinaesthetic awareness: What is the practice of the system? How do we balance guidance and openness? How do we foster agency and curiosity? How do we shift attention to lift the habitual transparency of kinaesthetic processes? How do we overcome (partially) the opacity of kinaesthetic processes?

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