Cultivating Mechanical Sympathy

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Abstract

Moving with a drone can be a captivating and reflective experience. A drone can easily grab my attention, yet its hold is distinctly different to a screen where my body goes missing and my eyes are held captive. Instead, my body feels alive and present. As if every part of it is playing a crucial role in keeping the drone in the air. The sensors on my body enable the drone to be sensitive to my movements, which in turn increases my sensitivity to the drone’s movements. It’s like carrying a cup of hot tea with a book under your arm, any sudden movement from any part of your body affects the tea in the cup and vice versa.

In this thesis, I traced back through this experience and several other first-person experiences with machines to reflect on their constituent moments of sensing and acting. In doing so, I came to realise that these moments were fundamental to making meaning with machines, that is, how you come to understand its function and its purpose in your daily life. I used a combination of soma design and industrial design practice to draw from these first-person experiences and create three systems, *Tai Chi in the Clouds*, *Drone Chi* and *How to Train Your Drone*. Through the design of the first two systems, I attempted to distil the feeling of being a beginner tai chi student into a human-drone interaction. Subsequent user studies of these two systems demonstrated some degree of success, but it was the participants’ own interpretations that sparked my curiosity and drove the creative process for the third system. I was fascinated by the tendency for participants to liken unfamiliar feelings to past experiences when faced with an ambiguous situation with a drone. This prompted me to reflect on the ambiguity that presented itself to me during the design process of *Tai Chi in the Clouds* and *Drone Chi*. There I found rich associations with my past experience racing go-karts and maintaining old cars. This culminated in the design of *How to Train Your Drone*, a more ambiguous human-drone interaction intended to support the participants’ own interpretations and allow their unique constellation of sensing and acting to drive the meaning making process.

The subsequent analysis of a month-long user study led me to describe the unique and tacit relationship that unfolds between a human and a drone as *Mechanical Sympathy*. Mechanical Sympathy is a process of sensing and acting that leads to a cumulative appreciation of human-with-machine. It does not, in the reductive sense, mean being emotionally sympathetic towards a machine, but rather a synergy or bodily understanding between human and machine that shapes how they can act together. This process entails fostering an awareness of your capabilities, limitations, and changing body in relation to a machine and vice versa. It also allows you to craft your own experiences with a machine and explore how that machine, in turn, shapes your aesthetic preferences. Through this process, you can reflect on what kinds of human-machine experiences hold value and meaning.

Whilst analysing the interview data from *How to Train Your Drone* it became clear to me that the participants did not program the drones to perform some action as much as they shaped what the drone could and could
not sense; how reality was presented to the drone. This was an important shift in perspective that led me to propose an expansion of the soma design program that considers designing interactive technology as less of a material to be mastered and more of an agent to evolve with — both for the designer and later for users. Central to this shift was the concept of the Umwelt, first introduced by Jakob von Uexküll which posits that we cannot know what it is like to be anything but human and therefore the realities of other beings are essentially unknowable. However, we can make meaning with them by paying attention, which, fittingly, is something that is required by both the soma design process and its resulting artefacts. Additionally, I looked to the fields of evolutionary robotics and human-robot interaction to bring structure to this expanded soma design program and situate it in the literature. Ultimately, I aimed to afford both the designer and the user novel ways to embrace ambiguity when interacting with machines by providing opportunities for aesthetic appreciation and meaning making. The thesis concludes with a speculative look at the challenges this approach to design faces in the context of daily life.

**Keywords:** Drones, Aesthetics, Design, Human-Computer Interaction, Human-Drone Interaction, Human-Robot Interaction
Sammanfattning

Att röra sig med en drönare kan vara en fängslande och reflekterande upplevelse. En drönare kan lätt fånga min uppmärksamhet, ändå fängar den mig på ett helt annorlunda sätt än en skärm, där min kropp försvinner och mina ögon är lästa. Istället, kännas min kropp levande och närvarande. Som om varje del av den spelar en avgörande roll för att hålla drönaren i luften. Sensorer på min kropp gör det möjligt för drönaren att vara känslig för mina rörelser, vilket i sin tur ökar min känslighet till drönarens rörelser. Det är som att bära en kopp full med te och samtidigt en bok under armen, alla plötsliga kroppsrörelser, oavsett kroppsdel, påverkar teet i koppen och vice versa.

Jag spårade genom denna upplevelse och flera andra första personsupplevelser med maskiner tillbaka för att reflektera över deras konstituerande stunder av att kännas och utföra. Genom detta förstod jag att dessa stunder var fundamentala för att skapa mening tillsammans med en maskin, det vill säga, hur du förstår dess funktion och dess syfte i vardagen. Jag har använt en kombination av soma design och industridesignpraktik för att genom dessa första personupplevelser skapa tre system *Tai Chi in the Clouds*, *Drone Chi* och *How to Train Your Drone*. Genom de två första systemen försökte jag att förmedla känslen av att vara en nybörjare Tai Chi-student in i en människa-drönar interaktion. De följande användarstudierna av dess system visade en viss grad av framgång, men det var deltagarnas egna tolkningar som gjorde mig nyfiken och drev på den kreativa processen till ett tredje system. Jag blev fascinerad av deltagarnas tendens att likna de obekanta känslorna de fick då de interagerade med drönarna med sina tidigare erfarenheter av att ha hamnat i en mängtydig situation. Detta fick mig att reflektera över mängtydigheten som blev tydlig i designprocessen av *TaiChi in the Clouds* and *Dro ne Chi*. Där hittade jag rika associationer till min tidigare upplevelse av att tävla i go-kart och att underhålla gamla bilar. Detta kulminerade i designen av *How to Train Your Drone*, en mer mängtydig människa-drönar interaktion som syftar till att stötta deltagarnas egna tolkningar och låta deras egen unika konstellation av att kännas av och agera driva skapandet av mening.


Medan jag analyserade intervjuer från *How to Train Your Drone*, blev det tydligt för mig att deltagarna inte programmerade drönarna att utföra
särskilda handlingar lika mycket som de formade vad drönaren kunde och inte kunde känna av; hur verkligheten presenterade sig för drönaren. Detta var en viktig ändring av synvinkel, som ledde mig till att föreslå en vidgning av somas designprogrammet som tar i beaktning design av interaktivt material, mindre som ett material som ska behärskas utan mer som ett medel som man utvecklas med — både för designern och senare för användare. Centralt för denna ändring av synvinkel var Umwelts-konceptet, som först introducerades av Jakob von Uexküll, vilket tar ståndpunkten att vi inte kan veta hur det är att vara något annat än människor och därför är andra varelser verkligheter i grund och botten okända. Däremot så kan vi skapa mening med dem genom att vara uppmärksamma, vilket passande nog är något som krävs både i en somas designprocess och dess slutgiltiga artefakt. Dessutom har jag tittat närmare på fälten evolutionär robotik och människa-robotinteraktion för att strukturera detta utvidgade somas designprogram och placera det i litteraturen. Slutgiltigt, så syftade jag att till att tillhandahålla båda designern och användare med nya sätt att anamma mångtydighet vid interaktion med maskiner genom att tillhandahålla möjligheter till estetisk uppskattning och meningsskapande. Avhandlingen knyts ihop med en spekulativ syn på de utmaningar som denna designansats möter i vardagskontexten.
List of Papers

A Tai Chi In The Clouds: Using Micro UAV’s To Support Tai Chi Practice
Joseph La Delfa, Robert Jarvis, Rohit Ashok Khot, Florian ‘Floyd’ Mueller
CHI PLAY ’18 (2018)

My contribution: This was my first paper and was submitted to the ‘Work in Progress’ track at the CHI PLAY ’18 conference. The paper was structured with substantial help from Floyd and Rohit. I had significant help from Robert Jarvis in developing the technical aspects of the work. I performed the design work.

B Are Drones Meditative?
Joseph La Delfa, Mehmet Aydm Baytaş, Olivia Wichtowski, Rohit Ashok Khot, Florian ‘Floyd’ Mueller
CHI ’19 (2019)

My contribution: My second paper was in the ‘Demonstration’ track at the CHI ’19 conference. Again, the paper was structured with significant help from Floyd and Rohit. Olivia, Mehmet and I collaborated on the implementation of the demonstration. I performed the design work.

C Drone Chi: Somaesthetic Human-Drone Interaction (Best Paper Honorable Mention)
Joseph La Delfa, Mehmet Aydm Baytaş, Rakesh Patibanda, Hazel Ngari, Rohit Ashok Khot, Florian ‘Floyd’ Mueller
CHI ’20 (2020)

My contribution: My first full paper would not have been possible without the advice from Floyd and Rohit on how to plan and execute the user study. Rakesh and Hazel provided a lot of extra processing power to read through and categorise the large amount of interview data. The paper was written primarily
in collaboration with Mehmet, with structural input from Floyd and Rohit.

**D Designing Drone Chi: Unpacking the Thinking and Making of Somaesthetic Human-Drone Interaction**  
Joseph La Delfa, Mehmet Aydin Baytaş, Emma Luke, Ben Koder, Florian ‘Floyd’ Mueller  
*DIS ’20 (2020)*

**My contribution:** This paper would not have been possible without the design work of Emma Luke, with whom I collaborated with on the design of the hand sensors and the concept of Drone Chi. Ben Koder, who rendered the metaphorical movement concepts into 3D images. The paper was written and laid out as a collaboration between Emma, Mehmet and myself. I performed the remaining design work.

**E How to Train Your Drone – Defining and Designing for Mechanical Sympathy**  
Joseph La Delfa, Rachael Garret  
*Yet to be published*

**My contribution:** While conceptual and technical development were largely my own, I had significant help from a number of students and engineers who advised me on the feasibility and technical implementation of the system. The mammoth task of processing the data and defining the main concept would not have been possible without the help of Rachael Garrett.
I write a lot about design in this thesis if you haven’t already noticed, about doing design and about the designs that I did. To do either of those things properly took conversations with many kind, clever and passionate people.

I would like to start by thanking the following people for the opportunities they so generously afforded me: Fehmi Ben Abdesslem, Sanka Amadoru, Matiu Bush, Shreyasi Datta, Jonathan Duckworth, Jen Farrow, Larissa Hjorth, Wafa Johal, Gesche Joost, Aleksander Joseski, Enriko Khatchipuridze, Sara Ljungblad, Abdulghani Mohamed, Luca Mottola, Darcy Muller, Kellie O’Callaghan, Marimuthu Palaniswami, Ian Peake, Vasiliki Tsaknaki and Jesse Zanker. Thanks also to those who generously helped me with tasks such as technical design and development, navigating administration, data collection, proofreading, translating and giving various forms of feedback: Tobias Antonsson, Catherine Fist, Tim Fist, Nick Huppert, Stuart Lee, Kimberly McGuire, Sean Morrison, Carl Nilsson-Polias, Sam Nolan, Claudia Núñez Pacheco, Mafalda Samuelsson-Gamboa, Nathan Semertzidis, Olivia Wichtowski, Loretta Pinzone, Kristofer Richardsson, Michael Smith, Han Jin Song, Anna Ståhl and Charles Windlin.

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I am so fortunate to have been supervised by a wise and passionate team with very different working styles, expertise and outlooks. While admittedly it was not always easy to manage such differences, ultimately it strengthened the work and fostered a deep appreciation for cross-disciplinary scholarship. Thank you to Rohit Ashok Khot for supervision during those early days of the PhD, I learnt a great deal from your considered and purpose driven style of research. To Leah Heiss for helping me see my research in a broader context than a single academic field, always checking in on my well-being and for making sure I was practising self compassion. Thanks for the support and level-headed advice as my family relocated from Australia\textsuperscript{1} to Sweden\textsuperscript{2}, I could not have done that without you. Thanks to Florian ‘Floyd’ Mueller for your creativity and enthusiasm, for relentlessly throwing ideas at me, and for pushing my presentations to crystal clarity. Thanks for inviting me to the week-long Dagstuhl workshop in 2018. As a fresh PhD I was very nervous to stand in front of those professors and talk about how much I loved the octopus and how it might mean something to the field of human-computer interaction, but you encouraged me to speak with confidence. To Kristina ‘Kia’ Höök, thank you for warmly welcoming me into the lab (aka the jungle) at KTH, after what was essentially a 10 minute drone demonstration (see Figure 2.2) followed by an hour long conversation. Especially after it became clear that I had a lot of reading to do and even more data to sift through. You entrusted me with ample space and time to do this, whilst also inspiring me to do it well. I look back fondly on the times we got a little carried away and threw our self-imposed deadlines in the bin just to squeeze a little more out of the work. Speaking of deadlines, thanks goes to Airi Lampinen who provided me with the opportunity to finalise the PhD while working as a research assistant\textsuperscript{3}. Thank you Airi for your very calm leadership style.

To my Mum, Dad, two sisters and brother-in-law, thanks for always showing an interest in my work and for celebrating the wins with me. Particular thanks to Mum and Dad who gifted me with those formative track days racing the go-kart from an early age. To my daughter Zelda, not only have you shown me new ways to sense and act in this world since your infancy but you have also grown into a super cheeky, clever, courageous and hilarious child. I love you my little talgoxe! Finally, to my incredible wife Margs, your steadfast presence and support against all that we have faced has been nothing short of astonishing. You firmly took my hand for every leap of faith without a moments hesitation. Thank you for your pragmatic advice and unwavering support during my many moments of indecision and doubt. To think that when I started this PhD we have since had a child, got married and moved overseas during a pandemic. We are the best! I love you to pieces.

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Prologue

“There are professions more harmful than industrial design.
But only a few.” Victor Papanek (1985)

For the vast majority of the time that I have been doing my PhD in design, I have not really been sure as to why I was doing it. I knew I wanted to practice design, but to what end? What problem was I trying to solve? For almost four years, research questions, hypotheses and design frameworks evaded definition. Crumbling in my hands with every attempt to shape them. Literature reviews too, failed to elucidate any logical next step. How then did I know what to design? To answer this question, I open this thesis with an origin story. In doing so, I hope to relate to other disillusioned designers who like me, have run away from their jobs, into the dense forests of academia. Only to become a bit disoriented in the fog of an open-ended PhD.\(^1\) Of course, after the prologue everything will be presented as if I knew what I was doing all along. However, I think it’s worth highlighting that for the majority of the time, my design journey was defined by what I was running away from; and it was only through design practice that it came to be defined by what I was running towards.

Running Away

Figure 1.1 shows a typical hard rubbish pile that you would find in suburban Australia. Every spring, these piles begin to bloom at the front of houses as people de-clutter their homes. They consist of anything that is too big for your bin. Not worthy of your time to resell or re-purpose. Meaningless, bulky junk. For those with the time and the interest, a hard rubbish pile is a bountiful offering of potential value and meaning. When I was an industrial design intern, I had both of these in spades and often rummaged though these piles to harvest the fruits of suburbia. Restoring or remixing can be a very expressive pursuit. You are in effect, taking a single instance of a machine, with its unique constellation

\(^1\)I have striven to write this thesis in an accessible style, whilst trying to maintain academic rigour. I do this in gratitude to other authors and scholars who have done the same. They have allowed me to make inroads into the academic world and deepen my design practice. Throughout this thesis I will highlight these more accessible texts via footnotes.
of dysfunctions, wear and tear; and shaping it to a point where it fits into your
own or someone else’s life. In doing so, aesthetic taste, abilities, limitations and
values are all taken into account; so too is the shape and size of the body. Using
the skills gained from my industrial design degree, I made meaning out of the
meaningless.

This practice was a very enjoyable one. I got to move around, work with my
hands, hear the mechanisms, touch the patina and smell the (sometimes toxic)
smells. All of these were constantly changing as the thing I was working on
revealed itself as a meaningful object. In such a process, the result is something
that is made just for you and your life, or, if you were to perform the same process
with someone else, there is the joy of creating meaningful objects in collaboration
with another person. But there was something else that I personally got out of
the process that remains with me and that lies at the core of this thesis; A deeper
appreciation of both yourself and your relationship to the people and the machines
around you.

Through such projects, I learnt about the inner workings of a given machine
and marvelled at the number of processes that had to align in order for it to exist
in front of me. I also learnt more about myself, what I like and don’t like, what
I can and can’t do and what I could do in the future. If I was doing this with
another person, I begin to understand them in the same way. Part of the reason
for this was the required reflection and self directed learning it took to understand
how to work with the machine and the materials from which it was made from.
The other part was the required constant engagement with these machines and
the people I made them for. In this way, I was simultaneously learning new things
about the machine whilst trying to create something new with it. As such, they
frequently tended to break down. On top of this, the people and environment
around the machine were constantly changing too. So engaging like this was a
commitment, in a way, to ongoing care and maintenance. However, despite my
enthusiasm about this process, my feelings towards the hard rubbish season were
mixed, I was frustrated by how easy it was to waste and the systemic hurdles
that rendered any type of salvaging unfeasible. These design practices dominate
the consumer product cycle and leave little room for generating a use outside of
the narrow bounds set by the machine’s original intended use. Nevertheless, it
did not stop me from taking a meandering route to and from work, browsing at
as many piles as I could find.

In Figure 1.3 you can see me hard at work as an industrial designer, testing
out a prototype that I put a lot of effort into. It is a rubbish crusher. A tool
specifically designed to condense any bulky rubbish you may want to put into your
wheelie bin so that it does not have to sit around your house until hard rubbish

\footnote{Here I am referring to the cost of labour, the fascination with the new or convenient, and
the practice of designing consumer goods that are tricky or even hostile to repair. The books that
shaped my feelings towards this approach to business were Victor Papanek’s \textit{Design for the Real
World} (1985), William McDonough and Michael Braungart’s \textit{Cradle to Cradle} (2010) and Paul
Polak’s \textit{Out of Poverty} (2009).}
season. As you can see from the look on my face the irony of this situation is not lost on me. Why am I designing one of the very things that end up on these hard rubbish piles? To add another layer of irony, why am I designing a tool that literally leverages people’s ability to waste, which would then itself, in all likelihood, end up on the hard rubbish pile? It’s not that I wasn’t proud of the project, we sold the work to the client based on a very lean prototyping stage. I had to work quickly and efficiently, which gave me a nice feeling of competency. I even saved some time by using the telescoping aluminium sections off a couple of kick scooters that I found on a hard rubbish pile. Yes the irony runs even deeper!

The bin crusher encapsulates the frustration I felt towards the systemic, behavioural and cultural issues we have in connection with meaningless consumerism. Often boiling over as an unfocused anger that I struggled to make sense of, let alone do anything about. After three years, I decided to run away from design consulting. No hard feelings of course, I worked with talented, kind and generous people, who taught me valuable skills that I am grateful for. I just needed a new direction in which to apply them, one that did not loop back on itself in cruel irony. The bin crusher became my guiding North Star, except I used it to orient myself due South, into the welcoming arms of academia.

**Running Toward**

Within weeks of starting at the Exertion Games Lab, I had a desk, a laptop and a stack of recommended texts. With instructions to start making whatever I wanted. It was the dream. The fact that the PhD was detached from the agenda of any larger grant structure meant that I was free to explore my own ideas. I relished the ambiguity and started making with abandon.

Typical of an interaction design lab, there were a lot of wacky inventions lying around. Electronically induced vertigo (Byrne et al., 2018), sonified vegetables (Wang et al., 2018), ingestible bluetooth game controllers (Li et al., 2017), and so on. At the centre of these concepts was the body. The body was the place that these games took place, on, in or around. Through making, reading and discussing what we made or read. I was reintroduced to my own body as a “living, purposive, sentient, perceptive body, in which movement, body, emotion, cognition, perception, and sociality are tightly interlinked” (Höök, 2018). It was no longer understood as an instrument which carried out the concepts that appeared on my sketch pad, but a design resource in and of itself, mutually shaped by the very designs that came from it. The catalyst for this re-introduction was *Designing with the Body - Somaesthetic Interaction Design* written by my supervisor Kristina Höök. Never has a book struck a chord with me quite like this one. A uniquely accessible book to me as it used examples from my sphere of consumer product design, except it championed the values of first-person processes, movement, meaning-making and slowness. I realised that I had been practising a kind of soma design for a long time. The book legitimised my decision to run away
from the bin crusher and brought a focused calm to the frustrations that I had carried into the PhD.

However, being baptised into the multi-disciplinary world of human-computer interaction also meant being introduced to the epistemological (what is knowledge?), ethical (what is right?) and ontological (what even am I?) tensions that are currently and will probably be indefinitely grappled with in such an interdisciplinary field. To a practical designer especially, this is an overwhelming prospect. In particular I had trouble on the epistemology front, I was never comfortable arranging my designed experience into a delimited taxonomy, and even less comfortable drawing cause and effect relationships within it. This was primarily due to being married to a medical research scientist, who exposed me to the sheer number of variables that she had to control in order to publish, objectively, a single cause and effect relationship. Not only that, but the kind of person it takes to practically manage such a complex operation of objectivity. I am not that person. My strengths lay in my ability to be at ease in chaos and ambiguity.

I was not going to let these tensions derail my new found design direction, and so, like the protective design program that it is, I used Kristina Höök’s book like a shield\(^3\). I charged through my design process, beating away any epistemological challenges in the form of repeatable study design, hypotheses and evaluative frameworks. It was not that I believed that these other epistemological stand points were invalid, or that there was no “view from nowhere” (Zahavi, 2019) where one could observe a universal truth. I had little interest in these debates. Rather, soma design revealed to me a way of working that I had always found hard to articulate much less justify. Now I held in my hands, a book that not only legitimised this design practice, but laid out a program\(^4\) (Redström, 2017) through which I could explore and enrich it.

I had a direction to move in, a reason to stop running away and start running towards.

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\(^3\)This shield metaphor is be expanded upon in Section 1.3.

\(^4\)I have used this spelling as it is inline with design scholar Johan Redström’s notion of a design program which is covered in Section 1.3.
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Chapter 1

Theory and Method

**World Building** This chapter serves as a prospective landscape of the literature relevant to this thesis. As mentioned in the prologue, when I started, I felt as though I was lost in a dense and foggy forest. When I stumbled upon soma design, the fog began to lift, things started to make sense, at least in my immediate surroundings. This is because soma design championed first-person experience, movement, meaning-making and slowness in the design process. Thus, soma design takes a central place in this landscape. We will first explore soma design and its philosophical foundations. After which we will venture further into the forest to find other points of interest. This time however we take with us a frame through which we can view what we have found and find our bearings so that we can return home. We will do this a number of times, clearing more fog with each expedition. In doing so I aim to reveal to you my *worldview* (Redström, 2017) and how it was revealed to me as I undertook the design work. Then, by following the work in the design process and results chapter we will criss-cross this landscape, learning how this worldview was manifested in my design practice and how it shaped me as a designer. Finally, we end our journey with a discussion and contribution chapter, a tiny outpost on a rocky mountain range, overlooking future work and a generative new design space. Hopefully, the knowledge generated by this thesis will serve as a point of interest for others who have also wandered into the forest.
1.1 A Forest Clearing

Aesthetic Appreciation

Through the design of interactive technology, soma design aims to enhance your capacity to aesthetically appreciate. Think of this capacity as a skill that you train. The more you engage with the world, (be it a machine, people, food, nature) the more attuned you become to it and the more nuanced your capacity becomes to design with machines, communicate with people, cook food or appreciate nature. To explain in more detail and to make the case as to why you would even want to enrich this capacity, let’s start with aesthetics.

Having had an engineering-heavy industrial design education, my understanding of aesthetics was that it was a collection of visual cues that characterised a certain style. This was aesthetics as a noun. For example at design school we were told that the Art Deco style was of comprised trapezoidal wedges and floral prints. We were also told that it was popular in the booming economic period before WWII, and that the lavish materials represented the optimistic outlook of the time. What the lecturer failed to emphasise was how he became attuned to the Art Deco style. What did it mean to him and why did he like it? Granted he was probably using slides from the last person who taught the class, but that is precisely my point. The Art Deco period is not just a collection of historical facts and artefacts, frozen in space and time. It becomes alive when you engage with it, deepen your appreciation for it. Create with it, and in doing so you form your own opinion of what is and is not good Art Deco. That is aesthetics as a verb.

Soma Design

Soma design aims to design interactive applications that facilitate the process of aesthetic appreciation. “Applications where the interactions subtly turn users’ attention inwards, towards their own body, enriching their sensitivity to, enjoyment and appreciation” (Höök, 2018). Interactive is the operative word here, as soma design concerns itself with the design of objects made from “digital materials” (ibid.),\(^1\) that can sense the body and respond to it. Hence, its capacity to facilitate aesthetic appreciation.

The Soma Mat and Breathing Light are often held up as a typical example of soma design (Ståhl et al., 2016). When lying face up on the Soma Mat, it gently applies heat to different parts of your body. A pre-recorded voice invites you to compare the sensations as the heat is applied to each side of the body. Bringing

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\(^1\)The actual term used in soma design is “sociodigital materials”. The social aspect is added to try and capture the idea that we are not only handling the materials themselves but also the social interactions that they facilitate between us. I have perhaps crudely pruned the term down to just digital materials as most of my inquiry was focused on what happened between one person and one machine.
attention to tensions that we may be holding on one side of the body and not the other. When lying underneath the Breathing Light, its large dome and low stooping string curtain create an enclosed space that completely surrounds your upper body. The intensity of the light it synced to the depth of your breath, bringing attention to its cadence and affect. Together they provide you with, an opportunity to become aware of your own body; and develop an understanding as to why it feels the way it does. The benefits are not only in the immediate time scale, a long term field study demonstrated that, “experiences with the Soma Mat and Breathing Light enabled the prototypes to impact people’s lives beyond the ephemeral effects in the moment of use” (ibid.).

To create something like the Soma Mat and Breathing Light, the designers demonstrate an intimate understanding of themselves, the interactive materials and the nuanced experiences that can arise between them. This is similar in many ways to the relationship between a craftsperson and their material or myself and the meaningless materials I talked about in the prologue. Good design requires passionate application, a full bodied, sensory engagement with the world which in turn sensitises a designer to certain aspects of their world. soma design’s main point of difference is the explicit commitment to this sensitisation. It strives to bequeath this to the user, and not have it as some by-product of a designer’s relationship with their materials. Therefore, soma design’s concrete contribution to the design community is two fold. There are the artefacts themselves which “support users’ attention inwards” (Höök, 2018), thereby potentially facilitating the process of somaesthetic appreciation of self, world or others. Then there is the process of soma design, the practice behind the artefacts, which is complemented by an expanding vocabulary that describes how designers aesthetically appreciate and generate ideas (ibid.).

**The Soma and Somaesthetics**

I mentioned previously that soma design presents you with opportunities to become aware of your own body. By body I do not mean everything but the brain. I am talking about a “living, purposive, sentient, perceptive body, in which movement, body, emotion, cognition, perception, and sociality are tightly interlinked” (Höök, 2018). This is what philosopher Richard Shusterman refers to as the soma. A way of understanding our existence that rejects the idea that the mind controls the body and embraces instead “our double status as object and subject.” Shusterman uses the example of touching oneself to demonstrate this, “when using my index finger to touch a bump on my knee, my bodily intentionality or subjectivity is directed toward feeling another body part as an object of exploration. I both am body and have a body” (Shusterman, 2012). This means the body is experiencing the world as much as it is acting on it. Another central tenet of Somaesthetics is the idea that we are always experiencing the world in our own body, we cannot experience the world in another persons body. As Dan Zahavi
puts it in his book *Phenomenology the Basics*\(^2\) “There is no purely intellectual point of view and there is no view from nowhere, there is only an embodied point of view” (Zahavi, 2019). When taken together, a line of reasoning opens up, positing that by tending to our somas and enhancing our capacity to experience the world we are “participating in the highest art of all - that of living better lives” (Shusterman, 2012). That is to say that deeply engaging with the world around us and those in it leads to a more interesting, richer and more meaningful life lived. Shusterman similarly argues that “that rather than rejecting the body because of its sensory deceptions”, i.e. irrationality, emotion or physical limitations, we should rather “cultivate improved somatic awareness and self-use, which can also improve our virtue by giving us greater perceptual sensitivity and powers of action” (Shusterman, 2012).

If we take the word ‘soma’ and combine it with our established notion of ‘aesthetics’, we get *somaesthetics*. Which is the name of Shusterman’s broader philosophical project that began in 1996. In his own words somaesthetics is a “critical and meliorative” practice that “concerns the body as a locus of sensory-aesthetic appreciation (aisthesis) and creative self-fashioning” (Shusterman, 2000). In other words, it is a thing you do (e.g. drink wine), that you critically reflect on (e.g compare wines, talk about wines) so that you can get better at it, i.e., amelioration (e.g. become a bit of a connoisseur). Then creatively self-fashion through this new identity (e.g. declare yourself a fan of Chianti, perhaps buy a decanter to display in your home, or even decide to become a sommelier or a wine producer yourself). This rather toothless simplification does not do justice the far reaching philosophical implications that stretch far beyond the literature landscape I have mapped out in this thesis.

Irrespective of that, it can be argued that soma design is a more concrete off-spring of somaesthetics, as it has formed the foundation to many a contribution to the field of human-computer interaction (HCI) over the years. Not without some effort however, “there is a huge difference between engaging in an existing body practice, such as Feldenkrais, and creatively designing entirely novel interactions, shaping new practices and new experiences,” writes Höök (2018). This huge difference meant that much work had to be done to convert Shusterman’s thinking into a more tractable design process. As Höök explains, “Adapting Shusterman’s approach into a design process took quite a lot of translation work, as well as a long period of massaging ideas through practical design work” (Höök, 2018). Many researchers contributed to this maturation of soma design as a practice, including George Khut (2006), Thecla Schiphorst (2009), Lian Loke (2012) and Marianne Graves Petersen (2004). Maturity was approached through the formulation of academic contributions such as concepts, methods or experiential qualities. Together they constitute a holistic approach to the design of interactive technology that encompasses the people, places and cultures that bring them into being, as opposed to only being understood by their computational abilities, cog-

\(^2\)An accessible text.
nitive load or task performance (Höök, 2018, p.167). This means that the people, the technology and the interactions between them are seen as an ever changing assemblage which can account for the diverse somas we design for. While some design disciplines strive to achieve similar outcomes across people, objects and environment (Milton and Rodgers, 2011), soma design thrives on the differences between, as we will see later in the design process.

Concepts and Methods of Soma Design

Here I will briefly introduce some of the earlier and fundamental contributions to soma design, later I will expand on them by explaining their use in my design work. To simplify, concepts are general characteristics that soma design tries to imbue in its designed artefacts, whereas methods are loosely defined ways of conducting the soma design process. This list is far from exhaustive, rather it contains the concepts and methods that I drew upon during my design work.

Intimate Correspondence

Intimate correspondence is, on the surface, easily understood. It is technology that responds immediately to and in synchrony with the body. This is an important quality if you are going to aesthetically explore an interactive experience. For example, in sonified feedback loops like the ones found in Bergsröm and Jonsson’s SARKA (2016) and Mads Hobye’s Mediated Body (2011), the simultaneous processes of moving and listening form the primary mode of understanding the experience.

When done correctly, feelings of oneness begin to manifest between you and the machine. The machine begins to feel like an extension of the self as opposed to a partner or collaborator. Ingold likens it to the relationship between a musician and their instrument, in that you are not only able to explore but create with it (Ingold, 2017). Windlin and colleagues who also draw from Ingold, describe intimate correspondence as being perceived in unity with one or more people. Adding that it “is not necessarily something that just arises. It needs to be orchestrated by finding processes that allow us to sync — and it is an experience that is achieved. Throughout the interaction, you need to ‘feel’ the unity in order to stay within this experience” (Windlin et al., 2019).

Making Space

Space in this instance refers not just to physical space, but also to time and disposition. Continuing with the musician analogy, think about what is required for practice: physical space to play, e.g., in the form of a studio, and time to practice away from distractions. They also need the right attitude to engage, away from other exhausting emotional aspects of their lives. By making space, a de-
signer strives to facilitate these elements, resulting in a safe and non-judgemental platform from which the user can explore (Höök et al., 2016).

Examples that facilitate the making of space can be found in the concept of slow design (Hallnäs and Redström, 2001), where the interactions with a technology are limited in how fast they can be carried out or are of an asynchronous nature. Slow designs generally make space for a person to reflect on what is meaningful to them (Hallnäs and Redström, 2001; Odom et al., 2012). Slowness however, is not an essential characteristic of making space. Other examples that allow the making of space include counter-factual artefacts (Wakkary et al., 2018), illogical objects that contradict the norms of their context; and counter-functional artefacts (Pierce and Paulos, 2015, 2014), objects that contradict the functional norms.

Change and Interest

When you think about how to become aware of your own body, the most obvious thing to do is to just pay attention to it. This can be hard work though. Focus can often only be maintained for a few seconds at a time (Salehzadeh Niksirat et al., 2017). Change and interest is a method adopted by Shusterman from psychologist William James (1905) and is intended to extend this focus period. The change aspect of this method involves breaking down some coordinated movement into constituent parts before devising and performing activities that shift the focus from one part of the body to another. The interest aspect of this method is experimenting with your movement in ways that interest you. For example, finding and inquiring into why one side of the body feels different to the other side or how one part of the body connects to the other, through the Feldenkrais method (Feldenkrais, 1972; Ståhl et al., 2021).

Subtle Guidance

The process of aesthetic appreciation is somewhat self-guided, nevertheless, there are those who can help you along the way, like a sommelier willing to spend the time tasting wine with you for example. However, in the end, you are the one who tastes the wine and decides if you like it and why. The same holds for interactive technology, it has the potential to grab attention and dominate the experience, which is why “finding the balance between guiding attention but not grabbing it” (Höök, 2018) is an important concept to keep in mind when designing interactive technologies. As a designer you must maintain a balance between providing “changing stimuli that help shift attention between areas or functions of the body” and “support lingering attention and focus on one movement or area, preventing the mind from wandering” (ibid.). Here the subtle guidance concept begins to overlap with the change and interest method.
1.1. A FOREST CLEARING

Estrangement

Have you ever held your knife and fork in opposite hands? Entered an apartment with a layout that is the mirror copy of your own? Tried playing a video game with an inverted right thumb-stick? Focussing on your breathing before trying to forget about it? These are the basic building blocks for the estrangement method, which bring to the surface movements that have become “automatic and tacit” (Höök, 2018). In doing so, you are able deconstruct the daily habitual movements in a way that feels more experimental compared to the more inquiry-driven change and interest method. The method has its roots in dance and choreography, going also by the name of making strange (Loke and Robertson, 2013). In a paper by design researchers Danielle Wilde, Anna Vallgärga and Oscar Tomico (2017), the estrangement method is broken down into its constituent steps of “disrupt, destabilise, emerge and embody”. They state that the longer you take to work through these steps and reach an understanding, the deeper and more detailed your understanding will be (ibid.).

Body Practices and Somatic Connoisseurship

The above methods are typically performed within the context of a body practice, which includes performative or artistic disciplines such as Yoga, Feldenkrais, Tai Chi, contact improvisation and many others. Quite often you perform these soma design methods as a part of the practice itself. Body practices open up to a designer a tacit understanding of their own body which they can then use when designing. In much the same way that a crafts-person is expected to understand their tools and materials such that they can create with them. It follows then that having an expert to guide a designer through their journey of appreciation would be useful to the design process. Enter then the somatic connoisseur, part teacher of body practices and part design collaborator, a somatic connoisseur helps you synthesise your existing material and craft knowledge with all these new and provocative sensations you are feeling from your body practice (Schiphorst, 2011).

Finally, these methods are not only about what you can learn about yourself within the bounds of the body practice. Through learning the rules and norms that govern the practice you open up the possibility of breaking them, within the spirit of the practice, thereby also enhancing your somaesthetic appreciation for the practice. In a paper entitled, Boards Hit Back: Reflecting on Martial Arts Practices Through Soma Design (2023) Luft and colleagues describe the design of Koinryō, a mechanical sparring partner designed by Luft, who practices Bujinkan Budo Taijutsu. When used in a training session with a somatic connoisseur of the same martial art, Koinryō challenged some of the normative movements that were baked into the practice and conversely, highlighted ways that he could improve his training to reinforce others (ibid.). This process has similarities to the Art Deco example at the beginning of the chapter and further demonstrates what I
mean by aesthetics as a verb.

Autoethnography

Regardless of what you have done in your life there is one topic that you are the world leading expert in, and that is your own lived experience. Rather than engaging a somatic connoisseur whose experience lies outside your own, or tending to your own body in the moment, autoethnography is a deep dive into an experience from your past (Ellis et al., 2010). A childhood memory, a performance, a previous sports career or even being the subject in your own study (Ljungblad, 2009). These are rich mines of experiential data ready to be extracted and used to drive a design process. In HCI, these methods are commonly used to serve the understanding of something other than the self, in other words, a design problem, a context or a user (Wright and McCarthy, 2008). However, in this thesis, autoethnography has been used as a reflective and generative tool. In much the same way that Höök and Ljungblad have leveraged their experiences of horseback riding (Höök, 2010) and passive photography (Ljungblad, 2009), respectively. Their studies not only generated ideas on what interactive technology could be, but in doing so they also learnt more about themselves.

Bodystorming

Bodystorming is a broad term for idea generation primarily based in movement. Think of it like sketching, but not on paper. It is the practical and performative exploration of the concepts you will read about below. Often assisted by other people and objects, both as passive and active participants (Höök, 2018). Segura and colleagues have written a terrific overview of the method that includes two detailed examples. There they demonstrate the central role that bodystorming can play in the design process as it “integrate(s) both the physical and the social contexts and that formulate and articulate knowledge in ways that can be used by designers and researchers not only analytically but in a generative way” (Márquez Segura et al., 2016).

Articulating Experience

Articulating an experience is an important part of sharing your own experience with others but it also further deepens your understanding of that experience. This is why providing a means to articulate the bodily sensations and actions within an experience is as important to the designer as it is the user. Shusterman refers to philosopher and psychologist William James to explain how expanding your vocabulary of wine descriptors (as discussed previously) will enhance your ability to discriminate between them (Shusterman, 2008). Similarly, research from the cognitive sciences shows a link between colour vocabulary and perception (Regier and Kay, 2009).
Shusterman points out the that despite many somatic practitioners believing that our experiences lie beyond symbolic language, the process of reflecting and articulating our experiences through symbolic language is still useful to somaesthetic appreciation (Shusterman, 2008). Typical methods of articulation include body maps (Loke and Khut, 2014) and trajectories (Tennent et al., 2021). Both of these methods bring different perspectives to reflecting. Body maps encourage you to reflect on the whole body as you scan the silhouette and reflect on the corresponding parts of the body, whereas trajectories facilitate understanding of the temporal aspects as you define a time axis along which you can plot your experience.

As mentioned previously, the concepts and methods outlined here are not exhaustive, rather they were selected to reflect the aspects of soma design that I found helpful in a generative sense, in other words they helped me come up with ideas. I demonstrate exactly how they were useful in the design process and results chapter and in the discussion and contribution chapter.

Expeditions  I mentioned that the idea of the soma has many philosophical implications, most of which go beyond the scope of this thesis. Some of them however, lie within this literature landscape, just beyond the clearing. So with three expeditions we will explore: the blurred definition between designer and user, the spectrum of knowledge between product and paradigm and the fundamental role of sensing and acting in the meaning-making process. When we return from these expeditions, we should have mapped out a worldview that I will then draw upon in the following chapters to motivate design decisions, interpret results and, finally, make a contribution to the field of HCI.

1.2 Expedition 1 - Designer and User

Soma design asks both the designer and the user to train their somatic sensibilities and tend to their felt experience in pursuit of a life well lived. So much so that Höök even contemplated replacing the term ‘user’ with ‘soma co-creator’ or even ‘designer’ in her book but refrained for clarity. In this expedition we will explore how the soma and the pursuit of “living better lives” (Shusterman, 2012) strain the established roles of designer and user. Again, these aspects will not be dealt with comprehensively, rather I explore only the ideas that pertain to my design practice.

By established roles I am referring to the ones that were instilled in me during my design education. My undergraduate course in product design engineering was “the convergence point for engineering and design thinking and practices” (de Vere et al., 2010). It combined the “maker” and “aesthetic” approaches of an industrial design degree with the “objective” and “formulaic” approaches from a mechanical engineering degree (ibid.). In reality, the mechanical engineering approach was stacked on top of the industrial design approach, meaning that the
projects started with an exploratory outlook, full of sketching, mood boards and mock up prototypes, but all of this ambiguity was squeezed out as the project was pushed through the rational meat grinder that is the classic Double Diamond approach (Rogers et al., 2023). Market needs and brand identity tamed most alien or outlandish concepts (Milton and Rodgers, 2011), human factors determined the proportions that best suited the target market (Tilley and Associates, 2001), usability testing determined the shape and placement of buttons (Nielsen and Landauer, 1993) and product feature matrices balanced manufacturability, cost and functionality (Cross, 2008).

These are exactly the types of things that have to be considered, if you are to design a successful consumer product, public infrastructure or a commercial aircraft for example. Interactions that clearly communicate the state of the machine (Norman, 2016), that are ‘intuitive’ across large proportions of the population. With this clarity though comes a loss of ambiguity. Think about all the types of reflective conversations (Schön, 1992; Schön and Wiggins, 1992) a designer undertakes to confront the ambiguity of a new project, sketching, field interviews, mood boards, brainstorming, stakeholder meetings, mockups and exploratory CAD to name but a few. All of these activities are in service of weeding out ambiguity and bringing structure from chaos. Those who wrote the curriculum for my product design engineering undergraduate course believe that this makes their graduates better equipped to make judgements in the face of ambiguity than is the case for their pure engineering counterparts (de Vere et al., 2010; Owen, 1998). What De Vere and colleagues were referring to has more to do with being comfortable with a lack of control over the design process, and a holistic attunement to the project’s setting, stakeholders, and the design methods, tools and materials. This plurality of working styles, of being able to work with ambiguity and against it, is what makes graduates from this and similar courses well suited to using a Research Through Design approach (Zimmerman et al., 2007), which we will come to in the next expedition.

Similarly, soma design pits the designer against ambiguity, but in a somatic way; What am I feeling? What do I want to feel? How can I enhance what I feel? However, unlike in product design engineering, this ambiguity does not have to be eliminated before the design is in the hands of the user. Perhaps a little more structure, form or facilitation, but nothing on the level of a product design engineer who is expected to deliver something that screams ‘this is what I am and this is how you use me’. The methods and concepts of soma design have made a great start towards building an approach that supports this kind of ambiguity, but there is much more work to be done. I am not writing off the Double Diamond either. As you will see later in the design process, it can still be applied to a soma design project, and even help to move the entire process along.

The birth of soma design occurred in the broader events that make up the ‘third wave’ of HCI (Bardzell and Bardzell, 2016). During this time, questions about “experience, emancipation, domestic life, intimacy, sustainability, and the
good life” came to dominate the field, which was previously occupied by productivity, usability and collaboration (ibid.). Soma design does not replace the theories that preceded it but rather compliments them.

There are many examples of designerly artefacts from the field of HCI that demonstrate this complimentary approach which supports ambiguity (Odom et al., 2012; Wakkary et al., 2018; Helmes et al., 2010; Desjardins et al., 2023). Elsewhere in HCI, designers work with dancers to make creativity support tools which balance the idiosyncratic creative processes of different artists with a user-centred approach intended to facilitate collaboration (Ciolfi Felice et al., 2018; Hsueh et al., 2019). Ambiguity however is not something that always needs to be squeezed out of technology, even if it is done so by the end user. Rather, it can just be lived with and appreciated. Sarah Fdili Alaoui explains what she learnt from creating the interactive dance piece, SKIN. “Making SKIN showed that integrating technology in a dance production challenges the view of technology as either solving artistic problems or supporting artists’ actions. Instead it is composed of layers of intentions, interactions, meanings, interpretations, desires and aesthetics” (Fdili Alaoui, 2019).

Another common element across these examples is that they all recognise the value of embracing a messy and non-linear design process that comes with in-context design and analysis. As opposed to a cleanly extracted experience from a pre-booked appointment in a lab, which only stands to entrench the divide between user and designer. Therefore, the above examples show that my product design engineering education still has some sort of role to play, the double-diamond rational meat grinder and all of its accessories are still on the table. They just need to be used in a way that supports ambiguity for both the designer and the user.

Before we return home. I will share with you a passage from Bardzell and Bardzell’s book Humanistic HCI (2016) which I read long after I had finished my design process, yet I feel, reflects my attitude towards the relationship between designer and user. In this passage, they contrast the author-reader relationship in an essay to that in a scientific paper.

“Lopate writes of the founder of the modern essay, 16th century writer Michel de Montaigne, that he saw himself as an average human being, a typical member of a human condition that is “constantly in flux, vain, ashamed of itself, and contradictory. Rather than condemning people, however, he recommended a generous self-forgiveness” (Lopate and Teachers & Writers Collaborative, 1994, p.44). By rendering his

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3Here I assume the term “the good life” to mean something similar to Shusterman’s term, “living better lives”.

4That being said, I still used the term ‘user studies’ throughout my thesis, despite my engagements with some of the ‘users’ being less clean cut than a lab study. I have done this mostly to maintain clarity for the reader, however I do acknowledge that the term is problematic.

5An accessible text.
De Montaigne’s outlook rhymes well with Shusterman’s resistance to rejecting the body because of what it cannot do, perceive or rationalise. Hence in recognising our fallibility and situating it at the core of any disciplinary pursuit, soma design enables the designer and the user to figuratively sit next to one another (sometimes literally as is the case with Hobye and Löwgren (2011)) and navigate the ambiguities together.

1.3 Expedition 2 - Product and Paradigm

Tending to the soma, the “living, sensing, purposive” (Höök, 2018) body invites with it, all that comes with the human condition, its fallibly, contradictions, biases and vices. Soma design sees this as a design resource, a generative force in both the design process and in use; and like De Montaigne’s take on the essay, constitutes a different kind of knowledge contribution than the scientific paper does. On this expedition we will explore these differences before returning with an idea on what kind of kind of knowledge this thesis is poised to produce.

HCI is a multidisciplinary field, with researchers coming together from a range of academic and industrial traditions, they bring with them wildly different ideas about what constitutes knowledge. In HCI conference proceedings you can find tightly controlled scientific studies, ethnographic field studies, rigorous applications of philosophical concepts, demonstrations of interactive prototypes and rich accounts of design processes full of pictures and video. As such, many PhD students are faced with the daunting prospect of figuring out what form their own work should take and how it contributes to the field. I turned to Johan Redström’s Making Design Theory (2017) to bring some clarity to this task.

Drawing from Erik Stolterman, Redström lays out the tension felt across the field of HCI, that of the particular vs the universal.
“Within the scientific project, the focus is on regularities, mechanisms, patterns, relationships, and correlations with the attempt to formulate them as knowledge, preferably in the form of theories. The intention is to form theories that constitute knowledge that is valid and true at all times and everywhere... ...In contrast to the scientific focus on the universal and the existing, design deals with the specific, intentional and non-existing. Interestingly enough, dealing with design complexity involves almost fundamentally opposite goals and preconditions as does the scientific approach. This is especially true when it comes to the notion of universality. In design practice, the goal is all about creating something non-universal. It is about creating something in the world with a specific purpose, for a specific situation, for a specific client and user, with specific functions and characteristics, and done within a limited time and with limited resources. Design is about the unique, the particular, or even the ultimate particular.” Stolterman (2008)

This certainly struck a chord with me, which is why I have quoted Stolterman at length here. Additionally, it brought back memories from my time at design consultancies. Particularly of my boss cursing at his project management software and exclaiming “we are making something that didn’t even exist six months ago, what does the bloke expect!” whilst trying to stretch project resources impossibly thin.

Designers dream up the new and particular, whether it be in service of a client or scholarly inquiry. So how does design contribute to our knowledge of the world? If biology has revealed to us how our immune system works and physics revealed how electrons conduct electricity, what can design reveal? Redström argues that this is the wrong question. Posing instead something more like “what can design reveal about the world, as it could be?” (Redström, 2017). This calls for theoretical contributions to design that “support conceptualising, articulating, making, communicating, collaboratively creating, and so on” (ibid.). In other words, design theory contributions need to be generative, they need to help designers reveal some of the infinite ways that the world could be. There is a quote from HCI literature that I often repeat to myself when thinking about framing my contributions. It comes from James Pierce who wrote in 2013 that “A concept can be used to rationalise why one design is better than another. Or it can be used to design something else” (Pierce et al., 2015).

With that we turn to the idea of a design program. Something that Redström has placed in between the more widely understood notions of a product (e.g., an iPhone), a project (e.g., the orchestrating of resources to design, manufacture and sell the iPhone), a practice (e.g., the norms and standards of industrial design) and a paradigm (e.g., a broad collection of practices that come to form a definition of what designing is, such as human-centred design). A program is a

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6 This is not to say that designers cannot make use of the scientific method and scientists cannot use epistemic or artistic practice. Far from it, they are deeply entangled.
bit broader in scope than a project and less disciplined than a single practice. It is a protected space in which a designer or group of designers can undertake experimental projects, which probe their idea of the world as it could be. As these accumulate, they begin to form what Höök and Löwgren refer to as intermediate knowledge (Höök and Löwgren, 2012; Löwgren, 2013), they quote Bill Gaver (2012) to state that “the role of theory should be to annotate a string of design examples rather than replace them.” Intermediate knowledge is a primary building block that can transform a program into a practice.\footnote{One critique that has been levelled at looking at intermediate knowledge this way, is that it implies that a general theory is what is being worked toward (Frauenberger, 2019). Whilst I do not agree that this is what Löwgren and Höök are implying, I do agree that the accumulation of intermediate knowledge does not have to lead to a general theory. Rather, as we will see in the discussion, it allows designers and users alike to practice in situ, towards ultimate particulars.}

What is being protected here is a “worldview”, which Redström defines as a “set of basic beliefs or assumptions that constitute the ‘world’ for the design, in the sense that they are not really questioned or challenged but rather assumed as its basic condition.” The literature landscape we are exploring in this chapter and the extent to which I have scoped it constitute the ‘world’ within which I will design — that is, I will ground my work in the somaesthetic commitment to “living better lives” through aesthetic appreciation, as well as a first-person, felt experience approach to design. Then in the design process, I will work based on the assumption that our bodies and the materials we interact with constitute an ever changing assemblage regardless as to whether it’s in a lab, showroom, field or hard rubbish pile.

Operating in a design program typically falls under the term Research Through Design, which is broadly described by Zimmerman, Forlizzi and Evenson as “an active process of ideating, iterating, and critiquing potential solutions, design researchers continually reframe the problem as they attempt to make the right thing” (Zimmerman et al., 2007). Nothing surprising here, just designers doing their job, as we saw in the last expedition. Except that the ‘right thing’ is defined as a “product that transforms the world from its current state to a preferred state.” This can add a distinct ethical vector to the program if the design researcher has strong opinions about the world as it could be, which I have, if you had not already guessed from the prologue. This is why it is important to consider the worldview as a protective belt around the program, to allow the designer to experiment without justification or application outside of the program. However, Redström stresses that it is important for a designer to be able to find themselves “both inside and outside” this world. In the sense that after some time designing within a program, attempting to make this ‘right thing’, they should be able to take a step back to reflect on how the program has drifted (Durrant and Price, 2015) from its core values. This is what we will be doing later in the discussion section.

The landscape that we have explored up until this point constituted my worldview for about half of my PhD. During the first half, I produced work that had
been described as “very much in the lane of soma design” by one reviewer. In other words, safely located inside the protective belt of the soma design program. An apt description considering I took the design program Höök proposed in *Designing with the Body* as my main starting point. However, in order to characterise and support the inevitable drift of the soma design program, I will need to bring in some additional theory. In our final expedition we will explore some ideas that I collected during the second half of the PhD, with the intention of contributing an expansion to the soma design program.

### 1.4 Expedition 3 - Sensing and Acting

In the first half of the PhD I leaned heavily on a first-person, felt experience approach to design. During this time, the way I moved with the drone changed, and so too did the drone itself as I carried out my design work. In the second half, I realised that not only was my body and the drone constituting an ever changing assemblage, but so too were my participants and their drones. This had two major implications on my subsequent design practice. First, there was a shift in focus from the sensitised soma as a generative design resource to instead focusing on how my soma became sensitised. Secondly, I began to see the drones as less of an interactive material to be understood and sculpted, and more of an agent\(^8\) that could grow in ways I could not control. A flying, changing, ambiguous machine. Subsequently, my Research Through Design practice was driven by how I, and those in my user studies came to aesthetically appreciate the drone. From a stage of pre-reflexive sensing and acting all the way to the point where they explained to me what the drone meant to them.

**The Primacy of Movement**

In this expedition, we meet Maxine Sheets-Johnstone’s idea of *The Primacy of Movement* (Sheets-Johnstone, 2011) (which forms another foundational pillar to soma design) and draw connections from it to the ideas of the Umwelt (Agamben, 2004; Yong, 2022)\(^9\), evolutionary robotics (Bredeche et al., 2019) and morphological computation (Pfeifer and Bongard, 2006). In doing so we enter risky territory, as these concepts are best understood with a complete grounding in both biology and robotics. I will therefore be using them with caution and within the protective belt of the design program because defending and substantiating such groundings are beyond the scope of this thesis. Finally, these connections only need to be made on a superficial level at this stage; we aim to return to them in

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\(^8\)Where I understand agent to mean “anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors” (Russell and Norvig, 2009)

\(^9\)Here I cite an English translation of an early text by von Uexküll, as well as two more recent interpretations that I will lean on more heavily in this thesis.
the discussion chapter to explore them more deeply and use them to expand the soma design program.

The main idea of *The Primacy of Movement* is that movement comes before language, and that through movement we understand the world, ourselves and those around us (Sheets-Johnstone, 2011). Sheets-Johnstone uses the development of a baby to illustrate this point, by moving around and watching others move, a baby comes to understand things such as what her own body is and what the world is (ibid.). Before moving onto more nuanced learning such as foreground, background, being on a mat or under a table (ibid.). These bodily experiences are the prerequisites for all language and meaning (ibid.). It is important to note here that it is movement coupled with perception that is the driving force behind meaning-making. I draw from psychologist Barbary Tversky to illustrate this recursive coupling.

“Babies start disconnected. They don’t link what they see with what they do and what they feel. The connections are learned, slowly over many months. Ultimately, what unites the senses foremost is action. That is, the output – action – informs and integrates the input – sensation – through a feedback loop. Unifying the senses depends on acting: doing and seeing and feeling, sensing the feedback from the doing at the same time.” Tversky (2019)

The importance of situated and improvised movement to meaning-making has long since existed in design literature. Don Norman advocated for the need for a human’s gestures to have immediate feedback such that a user can understand that their actions have been sensed (Norman, 2010), while Lucy Suchman’s seminal work *Plans and Situated Actions* (1987) highlighted the pitfalls of a machine that relies too heavily on models of its environment to operate.

It comes as no surprise then that the human ability to discern different types of movement is highly nuanced. In a landmark psychological study in 2005, researchers recruited pairs of friends and recorded point-light videos of them doing various activities such as walking, dancing, jumping and playing ping pong. A point-light video is one in which you dress in black and stick small lighted dots on your head and your joints, then when you stand in front of a black background, all that can be seen are the point lights. When paused, these videos are a meaningless constellation, in motion however, participants were quickly able to recognise the activity (Fadiga et al., 2005). Not only that, they were able to recognise their friends amongst a group of strangers performing the same activity. What was most surprising to me was the fact that they were able to recognise themselves most accurately! (ibid.) It is both through our own way of moving as well as watching others move, that we are able to experience and discern between these unique movement signatures and make meaning in the world.

These signatures, are an example of what Sheets-Johnstone refers to as a *kinetic bodily logo*. That is the structure of our bodies, our morphology, determines
our movement and behaviour. For example, our genetics, our bipedal form, the construction and location of our eyes. All of these elements determine how we sense and act in the world. However, they are not set in stone. They are also subject to change, under circumstances both within and beyond our control. Genes switch on and off, limbs become stronger or weaker, eyesight deteriorates and so on. This bears obvious similarities to Shusterman’s notion of somaesthetic appreciation, where the soma is voluntarily changed through engaging with the world; while the inevitable changes within our bodies are embraced and celebrated.

The idea of the kinetic bodily logo can be stretched to include extensions of the body, Dag Svanaes’s Human Tail Project (2019) is a great example. When you wear this highly manoeuvrable mechanical tail, you can wag it left and right, droop it or point it upwards (see Figure 1.8). The tail is able to sense the speed and orientation of the hips and uses this information to act as an extension of the spine. The way you move when wearing the tail is starkly different, it is characterised by this temporary change in your morphology. As such, your felt experience, that always on, recursive loop of sensing and acting is also greatly influenced. Together, these aspects playfully highlight certain bodily expressions as shown in Figure 1.8, thereby modifying your kinetic bodily logo. This affect is also experienced after taking the tail off, in an interview with Dag, he explains feelings of “being tailless” and “longing for his tail” (Höök, 2018).

The Umwelt

Sheets-Johnstone’s kinetic bodily logos rhyme with another concept which I now want to draw a connection to, that of Jakob von Uexküll’s Umwelt. Whilst it may seem excessive or laborious to bring in another concept, I am doing so because it serves a purpose different to that of the kinetic bodily logos. The former is used to support the notion that our morphology determines a large part of our experience of the world and that there is a degree of flexibility and adaptivity within that (as exemplified by the Human Tail Project). The latter is characterised by a sense of inquiry into how the world might present to organisms with radically different morphologies to our own (e.g. a jellyfish, or a tick). This carries with it the implication that the realities experienced by such organisms are radically foreign and unknowable to us.10

In his book An Immense World - How animal senses reveal the hidden realms around us (2022)11 science writer Ed Yong quotes von Uexküll’s poetic explanation of the Umwelt where the body of animal was compared to a house.

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10 An apparently clear distinction between the body and the world in this thesis is made for readability and to maintain a manageable scope. The large body of work on bodily extension in HCI (Mueller et al., 2020) highlights the arbitrary line we draw between self and world or human and animal. Drawing this line will only become even more arbitrary as we continue to make advances in fields such as bio-engineering and brain-computer interfaces.

11 An accessible text.
“Each house has a number of windows, which open onto a garden: a light window, a sound window, an olfactory window, a taste window, and a great number of tactile windows. Depending on the manner in which these windows are built, the garden changes as it is seen from the house. By no means does it appear as a section of a larger world. Rather, it is the only world that belongs to the house — its [Umwelt]. The garden that appears to our eye is fundamentally different from that which presents itself to the inhabitants of the house.” (ibid.)

Uexküll, broke from the biological tradition of sorting all living organisms in order of their complexity and instead “supposes an infinite variety of perceptual worlds” that are “all equally perfect and linked together as if in a gigantic musical score”, at the centre of which lie familiar and, at the same time, remote little beings [such as] *Echinus esculentus* (the sea urchin), *Rhizostoma pulmo* (the jellyfish), *Anemonia sulcata* (the sea anemone), *Ixodes ricinus* (the tick), and so on” (Agamben, 2004; ?). Uexküll and subsequently Yong wrote extensively on the Umwelt of other animals, together constituting an overwhelming collection of mind bending and well written “excursions into unknowable worlds” (Agamben, 2004).

In one such account, von Uexküll describes how meaning is made by the common tick, from only three experiential elements, despite these animals being typically understood to be at the “fringes of experience” (Ingold, 2011). Here, philosopher Giorgio Agamben, paraphrases von Uexküll.

“. . . this eyeless animal finds the way to her watchpoint [at the top of a tall blade of grass] with the help of only its skin’s general sensitivity to light. The approach of her prey becomes apparent to this blind and deaf bandit only through her sense of smell. The odour of butyric acid, which emanates from the sebaceous follicles of all mammals, works on the tick as a signal that causes her to abandon her post (on top of the blade of grass/bush) and fall blindly downward toward her prey. If she is fortunate enough to fall on something warm (which she perceives by means of an organ sensible to a precise temperature) then she has attained her prey, the warm-blooded animal, and thereafter needs only the help of her sense of touch to find the least hairy spot possible and embed herself up to her head in the cutaneous tissue of her prey. She can now slowly suck up a stream of warm blood.” (Agamben, 2004)

Whilst these evocative accounts make for admittedly great ideation material, it is not exactly the reason the Umwelt plays a prominent role in this thesis. It is rather the curiosity that von Uexküll and Yong exhibit through their inquiry, their interest in the existence of the other\(^\text{12}\) in and of itself is what is valuable here.

\(^{12}\text{By the other I am referring to the difference that we see in other beings and machines, its otherness. This is not immediately understood and takes time and engagement to make meaning with it (Eriksson et al., 2019).}\)
Somaesthetics requires a similar curiosity in order to ameliorate the soma. The difference being that in somaesthetics you have access to your own felt experience, where as von Uexküll, a renowned zoologist and Yong, a respected science writer, rely on external sources in the form of scientific observation.

**Evolutionary Robotics**

Unlike von Uexküll and Yong, my curiosity is not motivated by repeatedly observing the other (a primary mode of the natural sciences) but by iteratively building the other (a primary mode of Research Through Design) (Zimmerman et al., 2007). The latter also being an approach taken in evolutionary robotics where the common phrase “understanding by building” points to a connection to Research Through Design. In their book *How the Body Shapes the Way We Think* Rolf Pfeifer and Josh Bongard explain this a little further, “by building artificial systems we can learn about biology, but also about intelligence in general. An exciting prospect is that this enables us not only to study natural forms of intelligence, but to create new forms of intelligence that do not yet exist; ‘intelligence as it could be’.” Putting aside the thorny question of what intelligence actually is, the parallels between both evolutionary robotics and Research Through Design as design processes start to become apparent.

By taking an evolutionary approach to robot design, roboticists build a robot, have it perform some task, evaluate its performance, then feed the results into an evolutionary algorithm. Then through some process of artificial selection and evolution, the algorithm proposes some new designs which then repeats the task in the same environment. This process repeats until the evaluation score is sufficiently optimised (Matsunaga, 2023; Bredeche et al., 2019). This process can occur across both virtual and physical realms. Simple and interactive examples of this process can be found online, in Figure 1.10, a number of randomly generated ‘2D boxcars’ are dropped onto a start line to see how far they make it down a bumpy road. All the cars are different shapes and sizes, with different weight distribution and different sized wheels. Some wheels are powered, some wheels are not. After some time, cars that went the furthest and the fastest are selected and combined to inform the (slightly less random) generation of the next cars.

So far this looks like a very objective way to approach robot design. Application, evaluation and optimisation all standing at odds with the kind of design practice I have outlined so far in this chapter. However, this process becomes relevant when a human gets involved, when an expert enters the loop. An evolutionary algorithm needs some sort of direction to optimise in, some boundary conditions. Otherwise it will take too much computing power or time to find a

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13 An accessible text.
14 I do not plan to wade into debate on the definitions of intelligence or consciousness for that matter. This expedition is only to collect enough information to expand the soma design program later in the thesis. I kindly ask you, dear reader to see this thesis instead as an exercise in design generativity.
solution (Pfeifer et al., 2005). Therefore the roboticist would design the general structure of the agent, its initial conditions (e.g. max number of wheels or polygons) as well as the way in which it’s evaluated (max speed, distance covered or energy used). I like to consider this as the engineer and the agent (in this case a 2D boxcar) working together to shape the agent such that it can negotiate through its environment (in this case a bumpy 2D track). So in this sense the evolutionary algorithm can be seen as a generative design partner (ibid.), requiring expertise and intuition that are provided by the roboticist both before and during the evolutionary process (ibid.). It is this input from the roboticist that I am interested in here. I believe this kind of process, particularly when the robots are being built and evaluated in the physical world, has great potential for aesthetic appreciation.

Morphological Computation

I mentioned before that during the second half of this PhD, my attention turned to how myself and others came to appreciate the drone, how we made meaning with it. During this period, it quickly became clear that drones have a very different body to our own and so sensed and acted on the world in very different ways to us. It is here that the evolutionary robotics approach will exhibit its potential as a generative import into the soma design program. We will not be considering this in any great depth until the discussion and contribution chapter, so for now I will introduce its most relevant concept in order to tie this final expedition neatly back into soma design and set the scene for the conclusion of the thesis.

The type of evolutionary robotics that we will be focusing on in this thesis is the *New Robotics* approach, which crystallised in 2003 with a seminal paper by Rolf Pfeifer, Fumiya Iida and Josh Bongard (2005). However, it can trace its roots as far back as the early 90’s when roboticists began to realise that not every action had to be computed in terms of ones and zeros and that the “intelligent” actions by biological organisms had as much to do with the shape and layout of their bodies as they did with the size and “power” of their brains (Brooks et al., 1991). At the core of this approach lies the concept of *morphological computation*. The idea that the body of a robot mitigates a large amount of computation it would have to otherwise do in order to sense or move about in the world. Pfeifer and Bongard, use the example of imagining how much harder it would be to manipulate objects if your fingertips did not deform or provide friction (Pfeifer and Bongard, 2006) (see Figure 1.11).

In Figure 1.12, the different types of legs, demonstrate three of an infinite number of ways a leg can be constructed to navigate uneven terrain. The *Sprawl* robot is controlled by simple oscillating motors that only need to change their rhythm to produce a different gait. ASIMO’s movement on the other hand is modelled based on recordings of human movement and as such is computationally expensive to reproduce in a morphology comprised of wires and servomotors as
opposed to nerves and muscles (Pfeifer et al., 2005). Another example, this time where a robot was built as an inquiry into the construction of an eye can be seen in Figure 1.13. Researcher Lukas Lichtensteiger, together with his colleague Peter Eggenberger built the *Eyebot* to investigate the arrangement of light receptors in the eyes of insects and its affect on the experience of motion parallax (Pfeifer and Bongard, 2006). “Motion parallax is just a fancy name for a phenomenon that is very familiar to all of us. Assume that you are sitting on a train looking out the window in the direction in which the train is moving and, still far away, you see a tree. As long as you are far away, this tree will move slowly across your visual field. When you pass close by the tree it will move much more quickly across your visual field, even though the train is moving at constant speed” (ibid.).

They *Eyebot* consists of a number of tubes with light sensors at the ends to register the light that travels down them. It is possible to sweep the tubes to the left and right so that they assume different positions. The effect of motion parallax stems from the equidistant positioning of the light receptors at the back of our eye. Therefore the light bulb running past the robot configuration in the top right of Figure 1.13 will appear to move faster as it approaches because the time between each tube receiving light will get smaller. As an insect has a high concentration of these tubes (i.e. light receptors) towards the front of its body, the light bulb running past the robot configuration in the bottom left of Figure 1.13 will appear to have a constant velocity. An evolutionary algorithm was run to see if this was the optimal arrangement to compensate for motion parallax and indeed it was (Pfeifer and Bongard, 2006). This arrangement makes it “computationally” inexpensive for the fly to avoid its predator, it only needs to keep a constant “optical flow” i.e. a constant time between each cell firing. In the human arrangement, this time varies depending on which pairs of sensors are fired, with each pair requiring a different “computation” or neural circuit to determine the time difference (ibid.).

Morphological computation broadens the conception of what “thinking” is and where on the body it could be conducted. Additionally, it highlights the meaning-making processes demonstrated in kinetic bodily logos and the Umwelt. In this respect, meaning stems fundamentally from the body you are in and how it acts on and perceives the world. Pfeifer and Bongard explained this clearly by stating, “if we transfer models of human emotional expression directly to robots, the neural control will certainly not match the dynamics of the robotic system in terms of its physical dynamics, and therefore the expressions and/or emotions will not be grounded — will not be meaningful — for the robot” (ibid.).
Returning to the Clearing I have one final example from soma design that will tie together all that we have covered in this third expedition, but before doing that, let’s take stock for a moment.

- Sheets-Johnstone places movement at the root of all meaning-making, claiming that our kinetic bodily logos shape how we sense and move in the world. The somaesthetic project seeks to enrich your life through the process of appreciation and modification of these logos.

- The Umwelt is the acknowledgement that all living organisms have some kind of experience of the world (again putting aside questions of intelligence and consciousness). Thus decentralising the human as the way in which to experience the world and instead fostering a curiosity for the experience of the other.

- Design assisted by evolutionary algorithms place a roboticist and an agent in a kind of partnership, whereby both offer guidance but also need to be guided throughout the design process. This process has great aesthetic potential.

- The evolutionary approach to robot design bears a strong resemblance to Research Through Design in that they both investigate “what could be” through a process of “understanding by building”. The core concept of morphological computation, could also be seen as a close relative to the Umwelt, with the design of each agent offering the opportunity of making an excursion into an unknowable world.

What is missing here is a somaesthetic engagement with the machine, away from a laser like focus on task environments. One that primarily exists to ameliorate the soma. Kristina Höök got close to this kind of engagement in a paper entitled Transferring Qualities from Horseback Riding to Design. In it she describes her experiences learning to ride a horse in a style she was not used to. In her account she highlights the major differences between the human bipedal body and the equine quadruped body and how they manifest in movement. Through the mutual adaption of their kinetic bodily logos, they learn to ride together, “To make this happen, true sympathy is required. You have to recognise the otherness and difference in the horse and create a lived experience together. You have to forget about your own human self and instead turn yourself into a centaur self – consisting of two agents acting together” (Höök, 2010). Through a shared lived experience the two became one, their centaur self.

Höök explores the many facets of this union in the paper, such as rhythm, reciprocity and tacit knowledge. However it is her reflections on the paper later on in her book that are most relevant at this point. “There is a longer discussion to be held here about whether I can really be perceiving and acting in the horse’s world, or if I am always restrained by my morphology, stuck in what is “available” to humans — or, vice versa, if the horse can be in my world. What best characterizes
my experience is a mutual sympathy, meaning-making grounded in our joint movements.”

This thesis forms part of that longer discussion. Where I eventually come to ponder, how could we come to a similar union, yet in a more radical way. Not just a mutual adaptation or shaping of kinetic bodily logos, but a reflective conversation with an agent as opposed to a material. A physical shaping of morphological computation, guided by your sensitised soma and aesthetic preferences. To put it simply, why does it always have to be a horse? What if it was any arbitrary agent? But you do not know what agent it would be until you spent some time as two agents, sensing, acting and evolving together. In the coming chapter we will be “tracing the rhizomatic lines” (Pierce et al., 2015) between my design projects and build towards this design opportunity, criss-crossing this newly revealed landscape to do so. Taking us closer to the final contribution of the thesis.
Figure 1.1: Bulky rubbish that does not fit in the regular bins, sitting on the street ready to be collected. Credit: Bayside City Council (2023).

Figure 1.2: Bicycles were a particularly fun machine to creatively restore. This one was done for my friend. Together we shaped how the bike should look and ride.
1.4. EXPEDITION 3 - SENSING AND ACTING

Figure 1.3: The rubbish crusher prototype in action, hook it under the handles, push down and *poof!* More space in your bin. Unsure how I got those jeans on. Credit: Graeme Marshall.
Figure 1.4: The literature landscape rendered as a fictional world. A larger version of this map can be found on the inside of the dust jacket.
Figure 1.5: Ways of articulating aesthetic experiences in soma design. Top: Trajectories. Bottom: Body Maps. Credit: Tennent et al. (2021).
Figure 1.6: The little arrow that expanded my design practice. Who knew you could challenge what designing even is? How exciting! This figure is a reproduction (with permission) of a figure found in Johan Redström’s book *Making Design Theory* (2017).

Figure 1.7: By recording point light videos (similar to the ones depicted above) of people doing various activities, Maas, Johansson, Jansson and Runeson demonstrated our innate capacity to make meaning from motion. (Maas and Johansson, 1971; Johansson, 1973).
Figure 1.8: A depiction of the kinds of bodily expressions that are playfully evoked when wearing the human tail. Credit: Svanæs (2019).
Figure 1.9: Four creatures and their unknowable worlds that Jakob von Uexküll grappled with in his writings. Clockwise from top: *Echinus esculentus* (sea urchin) Credit: Rigels/Unsplash. *Rhizostoma pulmo* (jellyfish) Credit: Niko-
lay Kovalenko/Unsplash. *Anemonia sulcata* (sea anemone) Credit: Allan Pick-
Figure 1.10: A screenshot from “HTML5 Genetic Car Thingy” an online interactive tool that offers a limited but practical introduction to the ideas behind genetic algorithms. Credit: Rafael Matsunaga.
Figure 1.11: Wearing thimbles on your fingertips changes how you sense and act on the world. Credit: Bone Dry Music.
Figure 1.12: Morphological computation. Left: Sprawl robot exploiting the material properties of its legs for rapid locomotion. The elasticity in the linear joint provided by the air pressure system allows for automatic adaptivity of locomotion over uneven ground, thus reducing the need for computation. Middle: An animal exploiting the material properties of its legs (the elasticity of its muscle-tendon system) thus also reducing computation. Right: A robot built from stiff materials must apply complex control to adjust to uneven ground and will therefore be very slow. This figure and its description has been reproduced (with permission) from Bongard and Pfeifer’s book, How the Body Shapes the Way We Think (2006).
Figure 1.13: Morphological computation through sensor morphology. Left: The Eyebot has adjustable hollow tubes with light-sensitive cells at the base, thereby mimicking the facets of an insect eye. Top Right: If the facets are evenly spaced, a point of light, depicted by the running light bulb, moves slowly across the visual field if the light bulb is in front and far away, but moves fast as it passes by the side of the robot. This is the phenomenon of motion parallax. Bottom Right: If, however, the facets are more dense toward the front of the robot, a point of light will move at the same speed across all of the tubes, no matter whether it is in front or to the side of the robot; the motion parallax is therefore compensated for by this particular morphology. This figure and its description has been reproduced (with permission) from Bongard and Pfeifer’s book, How the Body Shapes the Way We Think (2006).
Meeting the Robotic Material  I am looking around the Exertion Games Lab for the first time, it looks like a workshop and a toy store except all the toys are covered in breadboards and wires. My jaw is on the floor. I am visiting to discuss starting a PhD with lab director Florian 'Floyd' Mueller. “What kind of technology would you want to work with?” He asks me. “You know those kilo-bots?” I ask, “the ones they use for swarm robotics research? They’re pretty cool,” Floyd walks over to a nearby tool chest and pulls open the top drawer full of ten small drones. “Those robots only work in two dimensions, what about three?” he suggests with a glint in his eyes. “Uh, seems a bit complicated.” I reply hesitantly while project complexity and scope creep alarms beep asynchronously in my head.

After a few weeks, I eventually come round to the drones. Deciding to adopt the technology agnostic “lucky dip” attitude, I typically took to a hard rubbish pile. However, I had no idea what to do with them. “Just try to make a game with them and see where you end up,” said Floyd, “the CHI PLAY conference is coming up, perhaps you can submit a demonstration.” I make some lame obstacle course game for the drone, working within the bounds of the factory supplied software because I didn’t really know how to code anything more complex than an Arduino. “I need help programming these things,” I complained. Within 72 hours Floyd had conjured up a group of undergrads interested in drones and told us again to make a game, but this time added “Joe you are interested in mental health, do something crazy like drones and yoga or something.” “Drones and yoga?” I thought “Why would I want to be still in front of a drone, you’d want to be moving like in Tai Ch...” (see Figure 2.2)
2.1 Tai Chi in the Clouds

*Tai Chi in the Clouds* is a simple movement exercise performed with a drone. It was designed to explore the role of drones in the practice of tai chi and other types of meditative movement (La Delfa et al., 2018). Here’s how it works. A cloud like drone slowly moves back and forth around your body as you perform a simplified tai chi movement known as ‘cloud hands’. The drone does not respond to your body, rather, you are instructed to synchronise your movements with it. As such, the drone sets the pace and the rhythm.¹

*Tai Chi in the Clouds* is a product of that unbridled enthusiasm to ‘make with abandon’ mentioned in the prologue. It was my first attempt at designing from a first-person perspective. Except that if you had asked me anything about first-person methods at the time, I would not have been able to give you an answer grounded in literature because I was barely reading any. I was too busy taking tai chi lessons and trying to learn enough about python, git and bash terminals to get the drones in the air. This was perhaps due to the fact that I had scared the undergraduates away by asking them too many basic questions. Luckily I had tech savvy lab mates around to help and figured I needed to be hands on if I was to do anything meaningful about the epiphany in Figure 2.2 anyway.

During my tai chi classes, I really enjoyed coordinating and orchestrating my body through a slowly morphing form. There was something magical about moving through space while exerting fine motor control over almost every joint in my body simultaneously. Getting to this point, however, required a bit of technical work. When learning the moves, my attention was oscillating between the pace, rhythm, position, balance, breathing and posture of my own body, and synchronising all this with the teacher’s movements. Not to mention those times when I found myself in the front row because the class has turned through 180 degrees, which made me go from self-aware to self-conscious.

Once the basic movements were under my belt something else came to the fore, the imagery. Each movement in a set has specific names like ‘stroke the horses mane’, ‘grasp the birds tail’ or ‘strike the tigers ears’ (Wayne and Fuerst, 2013). These names play multiple roles in practice. They help you remember the order of the moves, the general movement and in some cases the manner in which you perform them. For me, the more dramatic the names the more performative their role. ‘Move hands like clouds’, ‘creeping low like a snake’ and ‘twin dragons rush out to sea’ are some of my favourite examples as they are more evocative and open to interpretation. When it came to demonstrating *Tai Chi in the Clouds*, the experience made a lot more sense to those who could already perform ‘cloud hands’. If you understood the basic shape of the movement, then you did not have to concentrate so much on the technical details. Plus, thanks to the drone taking care of the pace and the rhythm, you could enjoy the performative aspect.

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¹For video footage please visit https://github.com/cafeciaojoe/mechanical-sympathy alternatively you and find my channel ‘Joseph La Delfa’ on YouTube.
a little more. Appreciate being in the clouds, or on them, or just being a cloud. It was up to you.

When it came to publishing however, I was scrambling to ground my work in the literature. Which framework could this work extend? What are the related works and how did they inspire the design of this artefact? Why are we even doing this work? How will it help designers? What will it help them design for? These were questions I admittedly reverse engineered the answers to in my first two papers (La Delfa et al., 2018, 2019) in an attempt to look like everyone else who apparently knew what they were doing. “The demonstration relates to an expansion of the attention regulation framework, which is used to inform the design of interactive meditative experiences and human-drone interactions.” I wrote in the second paper and continue “Meditative movement (MM) can be described as regulating attention to the body whilst moving to reach a meditative state. A well studied example of meditative movement is Tai Chi, where a large body of research suggests that tai chi can have positive effects on balance, attention, depression and perceived quality of life.” In other words, the attention regulation framework (Salehzadeh Niksirat et al., 2017) was going to help me design drones to help you do meditative movement, which is a catch all term for all kinds of non-static meditation. Furthermore, by committing the design work to the expansion of the attention regulation framework, the rich imagery I experienced in my tai chi classes was no longer intrinsically valuable; rather it was reduced to “improving a student’s technique, focus and willingness to continue learning” (La Delfa et al., 2018). The only problem was, once I actually got the drones responding to my hands, none of that made sense.

Five months in and I finally have a drone responding to my hands, Floyd really pushed me to use the motion capture system, and in hindsight it was a good decision. The fidelity of my movements that the drone could respond to was a delight to behold.2 There was definitely something meditative about it, as we suspected from building Tai Chi in the Clouds, but this was definitely not Tai Chi. Unlike a tai chi teacher, the drone grabbed my attention and kept it. Its hold over me was distinctly different however, to a screen where my body goes missing as my eyes are held captive. Instead, my body felt alive and present. As if every part of it was playing a crucial role in keeping the drone in the air. I felt captivated, but not under control. The sensitivity of the drone to my body was matched by my body’s sensitivity to the drone. It was like carrying a cup of hot tea with a book under your arm, any sudden movement from any part of your body affects the tea in the cup and vice versa.

After this experience, it was clear to me that frameworks such as the attention regulation framework (Salehzadeh Niksirat et al., 2017) were not going to help me describe what was happening here. Furthermore, even if I did find some other drone-related framework that got close to what I was feeling, what would I do with

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2For video footage please visit https://github.com/cafeciaojoe/mechanical-sympathy alternatively you and find my channel ‘Joseph La Delfa’ on YouTube.
it? Verify it? Disprove it? Reformulate it? I was not interested in doing science. I needed support exploring this design space not categorising it. Looking back now I understand that this kind of research has been a characteristic of good Research Through Design for decades (Gaver and Martin, 2000). I considered deepening my knowledge of tai chi as a way of exploring this design space, there are move sets that are performed with objects like a sword or a fan. Perhaps this was a good jumping off point?

I interviewed my teacher Master Han Jin Song on the idea and also got him into the lab to try the drones. While he definitely saw the potential in moving with a drone in a manner like Tai Chi, our discussions revealed to me that my access to tai chi as a generative design resource was always going to be obscured by some western translation of it. This made sense, because when I really drilled down to find the source of the imagery that ‘cloud hands’ and ‘twin dragons rush out to sea’ evoked in me, I found scenes from a Japanese anime, which did not sit very well with me. So if I were to properly study the martial art of tai chi and use it as a design resource, I had a lot to do in order to not only learn the rules but also know when and how to break them. I refer back to Luft’s work designing Koinryō in the previous chapter to demonstrate what I mean here. I also would have probably needed an extra 4 years to finish my doctorate.

However, Master Han did leave me with a piece of advice that he gives to all his beginner students, which was to take the movements of tai chi and integrate them into every day life. There are opportunities to practice your posture while stepping through the line at the supermarket or your balance when putting your underpants on. This parting message was an important one for two reasons. Firstly, it gave me a kind of licence to remix the teachings of tai chi through the first-person. This expanded my narrow understanding of tai chi according to which it should only be practised in a wholesale manner, as a martial art. Secondly, it acted as a primer to the idea of cultivating the soma through bodily practices. Fortunately it was around this time that I read an article in the academic magazine Interactions entitled The Somatic Turn in Human Computer Interaction (Loke and Schiphorst, 2018) which highlighted HCI’s growing interest in somatic body-based practices which “train awareness of self and environment through directed attention to bodily sensing, feeling, and moving.” (ibid.) Perhaps if I had carried out a proper literature review earlier, as advised, this would all have been understood sooner.
2.2 Drone Chi

*Drone Chi* is a human-drone interaction experience that is designed to bring attention to the way you move, breathe and balance yourself. Through the simple act of moving a drone with your hands, smooth and meditative movements are facilitated. The experience unfolds in four stages. First you pick a drone from a vine. Once it is in the air, it hovers in place so you can explore the relationship between your hands and the brightness of the drone’s glow. Once you are comfortable with this relationship, the drone then begins to fly in a slow, vertically oriented circle. If you keep the light bright, the circles grow larger and the drone gradually turns pink. Now reactive to your movements, you can move the drone around the room and explore your relationship to it.³

**Designing Drone Chi**

To design *Drone Chi*, I mashed together the methodologies of soma design with my training and professional experience as a product design engineer (de Vere et al., 2010). In my pictorial *Designing Drone Chi (paper D)*, I describe this as, “taking a slow and open-ended design research approach, we iteratively developed the project through somaesthetic, product design and engineering perspectives, drawing heavily on analogies and imagery for inspiration. This elevated the influence of the soma against narrow engineering parameters and usability requirements” (La Delfa et al., 2020a). By elevated I meant explicitly writing down and returning to, the somatic experiences I found interesting from my tai chi lessons. These experiences became part of a design brief that I wrote to myself, along with the other technical and usability requirements (see Figure 2.9). In doing so I was both grounding the design in my experiences of learning the movements of tai chi whilst also using imagery as a technique to generate new ways of mapping my body to the drone. soma design validated this approach by providing me with the tools to probe my own somatic experiences and deepen my understanding of them. For example, as tai chi movements became more familiar the notion of estrangement facilitated inquiry into how to make them strange again.

The process was a discursive one, but the design brief kept it from turning into an aimless meander. I alternately played with the physical form of the drone, the look and feel of the hand sensors, how the drone mapped to the body and how the experience could unfold for the participant. When I ran out of ideas in one area I moved to the next. As evidenced in the timeline which unfolded over a period of 9 months. I will skip past most of the details of this process for now, as they will resurface later in the chapter when we talk about Mechanical Sympathy (you can also turn to paper D for a full recount). There are two aspects of the design process that I will mention here as they are relevant to the overall story arc of this thesis. The first is how imagery played a generative role in sorting out

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³For video footage please visit https://github.com/cafeciaojoe/mechanical-sympathy alternatively you and find my channel ‘Joseph La Delfa’ on YouTube.
how to map the drone to the body. As I explain in Paper D, “Starting with the idea of “holding a ball,” the drone was programmed to remain in between the hands (see figure). This mapping was extremely responsive, whilst delivering a very light feeling as the drone faithfully darted around the room. However, it did not inspire slow movement qualities, which are a cornerstone in tai chi practice.” I cycled through a few different analogies, before I found the one that I thought fit the brief.

The second aspect worth mentioning is my fascination with jellyfish and octopuses. Since before my PhD started, I have been very much enamoured by the otherness of these creatures thanks to the accessible writings of Peter Godfrey-Smith (2016; 2020). His biologically grounded thought experiments explored the nature of consciousness for organisms inhabiting distant branches of the tree of life and later laid the groundwork for my appreciation and understanding of the Umwelt. This fascination spilled into the design work during the development of Drone Chi after I realised that drones, jellyfish and octopuses all share a radially symmetric morphology; I explored these similarities through various mock-ups (some of them you can see in Figure 2.11). Then, whilst playing around with the carbon extrusions that were protecting the propellers from wandering fingers, I accidentally made a few loops that looked like a lotus flower, an iconic image in Tai Chi. This discovery also solved a few technical problems I was having at the time - so I abandoned my fascination with these creatures for the time being.

Evaluating Drone Chi

The 32-participant user study had each participant fly the drone twice, with a basic introduction on functionality before the first session and the opportunity to ask any clarifying questions in between the sessions. Afterwards a semi-structured interview was evaluated using thematic analysis (Braun and Clarke, 2006), which was the prevailing method of evaluation at the Exertion Games Lab at the time. However, as we saw in the previous chapter, articulation of experience is just as important as attention to experience, otherwise how can we share with others and learn from their experiences? This is why I included a body map in the interview process and explicitly asked participants to explain everything on the map to me, such that it could be included in the thematic analysis. As a quick reminder, drawing a body map involves drawing over a silhouette of a body as a way to help articulate certain aspects of your felt experience (see Figure 1.5). The subsequent evaluation of the exit interviews yielded 4 themes and 5 implications which are summarised below. Refer to paper C for more details on the study design.

4 The tree of life is a sprawling taxonomy of living organisms arranged to reveal common ancestors (Wong and Rosindell, 2022). An interactive version is available online at www.onezoom.org
5 Looking back now, I see that there are many ways to achieve a rich articulation of an experience. Many of which can be borrowed directly from the soma design methods section. At the time, however, I was still learning the ropes of how to write a paper for the HCI community and thematic analysis was a widely accepted method of evaluation.
Study Results

1. Looping mental states - A generalised account of how the participants came to understand the drone. “The learning loop describes participants trying to familiarise themselves with the interaction, where participants alternated between states of curiosity and focus. Occasionally, an error, misunderstanding, or unexpected event could push the experience out of this loop, into a state of frustration. The learning loop was commonly associated with accounts from the first session, while during the second, participants seemed to be attracted to an expression loop characterised by meditative and inventive mental states. Here, on occasions, the experience could fall into a state of boredom” (La Delfa et al., 2020b).

![Diagram of learning and expression loops](image)

Figure 2.1: The experience of all 32 participants, swiftly generalised and neatly categorised into a ‘learning loop’ and an ‘expression loop’.

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6Use of the term mental states is interesting as I probably would not have used that term today. However, my use of the term in a paper about aesthetic appreciation is a good representation of the awkward grasp I had of the interdisciplinary scholarship in HCI at the time.
2. Environment - A spacious and non-judgmental environment (and we meant that in a physical and an affective sense) gave the participants the patience to learn and the confidence to explore their relationship with the drone. Essentially echoing the soma design concept of “making space”.

3. Agency vs Control - Participants certainly felt close to the drone in a way similar to that I described when the drones first reacted to my hands. However, the ways they articulated this relationship ranged from the drone being understood as an object to control, through to it being an agent to cooperate with. Examples include riding a skateboard, teaching a pet and riding a horse.

4. Physical Narratives - The physicality of the experience was an important element that drove the narratives that each of the participants created for themselves. In other words, their interpretations of the experience were derived from what they sensed in a 3D space and conversely that furthered their own narrative through movement in a 3D space.

**Study Implications**

The five implications we derived from the study and the long and winding design journey were:

1. *Design for both simplicity and mastery* - Aim for a body to drone mapping that is forgiving for beginners but allows a deeper understanding and appreciation with further practice.

2. *Allow for exploration one dimension at a time* - Introducing *Drone Chi* in the four stages was an implicit way to exemplify the meditative movements the experience was designed for.

3. *Support fragility to facilitate intimate interaction* - Presenting the drone as fragile through visual and tactile queues, heightens that feeling of being captivated but not under control that I described earlier in this chapter when I first flew a responsive drone.

4. *Drone noise can be used constructively* - The drone’s noise was relatively constant in tone and volume, as they were being flown in such a steady manner. Therefore participants knew when something was awry as the noise deviated from this constant state.

5. *Imply softness through form and movement* - Despite the hand pads and the drone feeling anything but soft, participants spoke a lot about soft movements. This cross-modal description should be exploited in future designs.
Reflecting on Drone Chi

I remember when I was writing this paper that I was so excited about reporting on the findings, but not quite so excited when writing the implications. They felt a bit flat in comparison, but I could not articulate why. One of the reviewers remarked that the work was “very much in the lane of soma design”. At the time I interpreted this as a complement. I was flattered that this work was recognised as a solid example of soma design. Reflecting on this comment whilst writing the thesis, I realise that it is also a critique. The implications, which are intended to “inform the design of movement-based close-range HDI (human-drone interaction)” (La Delfa et al., 2020b), will only produce more of the same kinds of interactions. Useful to me, if I were to go down the analytical path of deepening the implications, further categorising them through taxonomies or axes, but not exciting to me. What was exciting were the wonderfully varied interpretations and rich articulations about the drones given by the participants, who were clearly drawing from their own lived experience to do so.

To give you the most striking example, one participant referred to the drone as his “guardian angel”. When I probed for the origins of this interpretation I immediately received a cacophony of additional interpretations from various video games and films. Such as a combat partner, a pet and a magical energy shield. I was struck not only by the plurality of his responses but also the prominence of them. Tai Chi, the lotus flower, meditation, it all took a back seat. Despite the participant being a Hong Kong native and growing up around Tai Chi, the connection was only barely acknowledged.

These interpretations caused me to delve deeper into my own past involvements with machines where I found remarkable parallels, specifically between designing Drone Chi, racing go-karts and maintaining old cars. I decided to explicate and diarise these experiences, collecting them as series of vignettes. It promoted the question, why was I trying to impose my interpretation of the drone onto my participants when they are perfectly capable of interpreting the drone themselves, based on their own lived experience?

In the Designing Drone Chi pictorial (paper D) I was asking myself questions such as “How can I share this experience with someone else through the drone? What are the essential sensory elements to the experience? How can I introduce these to a user? How can I reliably engineer a system to deliver these interactions?” (La Delfa et al., 2020a). From this it is clear that I thought that the Drone Chi experience was something that I had to deliver. All I had to do was use soma design to bottle my experiences learning tai chi and flying drones, then present them to the participants through the process of product design engineering, in the form of some interactive artefact. Drone Chi would then transfer the meaning I made with the drones over to them. To a certain extent it succeeded and the design implications from the full paper show you how to replicate this limited success. This however ignores the rich well of lived experience each participant carried within them. This is why the implications felt so flat. Drone
Chi inadvertently invited the participants to draw from that well and use it as inspiration to create their own meanings with the drone, just as I had done when learning cloud hands during the design of *Tai Chi in the Clouds*, and again when mapping the drone to the body during the design process of *Drone Chi*.

Looking towards the next design, I wanted to embrace the differences between the users. Leverage them, by giving their lived experience primacy in the meaning-making process. I still planned to use a first-person approach, but I intended to somehow minimise the imposition a designer places on a user by implying a certain way of interacting. This brings me to the other reason this *Drone Chi* participant made such an impression on me. Amongst his frenetic comparisons to pop culture icons such as HALO, *Zelda: Breath of the Wild*, *Super Smash Brothers*, *Pokémon* and *MU Online*, one comparison came to be the catalyst amongst my own experiences with machines, *How to Train Your Dragon*.

### 2.3 How to Train Your Drone

*How to Train Your Drone* is designed to explore the reflective process of cultivating a nuanced, somaesthetic appreciation of a machine. Unlike *Tai Chi in the Clouds* and *Drone Chi*, *How to Train Your Drone* places the drone and the human on more equal and interdependent terms. Each participant must draw from their own lived experience to shape and make meaning with their own unique drone. This happens through the cumulative process of generating virtual points around the drone that are used to move around with it. When it comes to explaining exactly how this works, I would like to emphasise that a large part of the system is tacitly understood. So in addition to the detailed description of the system that is available in section 5 of paper E, I highly recommend watching a video explanation. *How to Train Your Drone* lived in a home shared by three study participants to investigate how the relationship with their drone unfolded over the course of a month.

### Defining Mechanical Sympathy

*How to Train Your Drone* was developed through the same combination of soma design and product design engineering as *Drone Chi*. However this time, I approached the design with the realisation that not only did my body and the drone constitute an ever changing assemblage, but so too did the participants and their drones. So I drew inspiration from my collection of somatic vignettes which were

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7 Much like the characters Hiccup (a boy) and Night Fury (a dragon) portrayed in the popular book and movie saga *How to Train Your Dragon* For context, the main driver of the protagonists’ story arc is that they must learn how to fly together. The dragon is injured and cannot fly without the aero-mechanical aides of the boy. The boy iteratively improves the aides whilst they also learn how to instinctively move with each other.

8 For video footage please visit [https://github.com/cafeciojoe/mechanical-sympathy](https://github.com/cafeciojoe/mechanical-sympathy) alternatively you and find my channel ‘Joseph La Delfa’ on YouTube.
in effect recollections of such assemblages with various machines, as opposed to my experiences learning Tai Chi. Additionally, when it came to writing the *How to Train Your Drone* journal article this collection proved to be too discursive to drop directly into the design process section. My co-author Rachael Garrett and I eventually succeeded, but only after crystallising the vignettes into the notion of *Mechanical Sympathy*.

Mechanical Sympathy is the process of cultivating somaesthetic appreciation of a machine; a process of sensing and acting that leads to a cumulative appreciation of *human-with-machine*. It does not, in the reductive sense, mean being emotionally sympathetic towards a machine, but rather an affective or bodily understanding between human and machine that shapes how they can act together. This process entails fostering an awareness of your capabilities, limitations, and changing body in relation to a machine and vice versa. It also allows you to craft your own experiences with a machine and explore how that machine, in turn, shapes your aesthetic preferences\(^9\). Through this process, you can reflect on what kinds of human-machine experiences hold value and meaning to you.

**Five Aspects**

In paper E I further articulated Mechanical Sympathy through five aspects which are summarised below.

**Capabilities and Limitations** By repetitively engaging with your machine you begin to see what you are capable of together, and what you are not. For example during the development of *Drone Chi*, by repeatedly ‘slinging’ the drone up and down or left and right, I began to see, hear, and feel the drone approach the limits of its agility. Similarly, when I was racing go-karts, I would creep up towards the adhesive limits of the tyres by taking the same corner a little faster each lap until the go-kart started to slide. Discovering these limits together allows you and the machine to deconstruct and reconfigure them or just appreciate being within them.

**Appreciation of Changes** Machines change over time, and so do we. Somaesthetic appreciation advocates for attentiveness to these small changes in our own bodies and Mechanical Sympathy advocates for an extension of this appreciation to the changes in the human-machine assemblage, irrespective of whether those changes come from design developments, maintenance, environmental factors, or regular use. For example, I used to own an old car, about 40 years old at the time, it always needed something replaced and so the car constituted a rotating motley crew of parts all in different stages of their working life. At one point, the

\(^9\)By aesthetic preferences I am talking about that active process of engaging with the world and forming an opinion on it that opened the theory and method Chapter. Only now we are also acknowledging the mutual shaping between the human and the machine.
car had brand new brakes and clutch, a middle-aged engine and gearbox, and a very old steering box – each one of these major mechanical systems had their own feel to them. Together, these parts constituted the dynamic character of the car – a character that was largely familiar but always had an element of strangeness to it.

**Appreciation of Difference** How do people come to have a favourite car or bicycle? Appreciation of difference allowed me to understand the differences between fundamentally different cars: diesel, petrol, front-wheel drive, rear-wheel drive, front-engined, rear-engined, low to the ground, high above the traffic. Each comparison reveals a more nuanced understanding of the experiential characteristics, inherent to the structure of the machine, but also an appreciation of what you like and why. During the development of Drone Chi for example I switched the drone propellers from above the drone to below the drone. This was to make the participants feel a little more comfortable bringing their fingers close to the drone. However, this changed the structure of the drone, its morphology. The propellers changed from a pulling configuration to a pushing configuration (see Figure 2.15). This in turn changed the movement patterns of the drone as it stabilised itself. It went from correcting its movements in a pendulum like manner when the body of the drone was hanging beneath the pulling propellers. To a balancing-a-broom-on-the-palm-of-your-hand kind of movement pattern when the body of the drone was sitting on top of the pushing propellers.

**Joint Agency** The culmination of my sensitivity to a machine’s capabilities, limitations, changes and differences resulted in a constantly changing feeling of joint agency. Making it difficult but rewarding to sort out cause and effect. It was only through iterating the design of the drone or tinkering with the go-kart that I could make sense of this interplay between human and machine. For example if I made changes to the code that governed the position of the drone relative to my hands, I would then spend some time flying the drone to appreciate these changes. The problem was that the motion capture system was also sensitive to a sunny day, affecting positional accuracy. Plus, the drones also changed over time, batteries aged, arms got bent and propellers became unbalanced. All this effectted the flight characteristics in all sorts of ways. By navigating these tensions in the design process, I was routinely prompted to ask, *do I change myself or do I change the machine?*

**Cultivation Toward Aesthetic Pursuits** By routinely attempting to answer this question that arose from a joint agency, I began to develop my own sense of what was desirable or meaningful in my relationship between myself and the machine. For example take the whole journey I made from *Tai Chi in the Clouds* to Drone Chi. The drones started out as a tool to aid tai chi practice, then they were repeatedly experienced and iterated over. In doing so, their potential
for playful and meditative improvisation was cultivated, yet so was my aptitude for improvisation. It’s important to note that mutual affect gives rise to these aesthetic ideals. In the following example I will show that when this is missing it can get in the way of the meaning-making process. After five years of ownership, I sold the old car, in that time I had cultivated and shaped both myself and the car towards an ideal aesthetic experience. In so doing, I had made changes wherever I had the skill and the money, and accepted the rest as it was. Then, five years later I had the chance to buy it again. The new owner had completely restored the car and added some significant modifications. Now, it was a completely different beast and objectively better to drive. However, I felt a strong dislike for it despite the fact that very similar modifications were in the pipeline had I kept the car. This example highlights the mutual constitution – and mutual cultivation – of meaningful experiences of human-with-machine; an ongoing process of reflective shaping of the human-machine relationship and appreciating the gradual changes that this process brings forth.

**Origins of the Term**

Before we get into the design process, I want to touch briefly on the origins of the term Mechanical Sympathy. The term originates in motor sport, where it is loosely used to describe a ‘sense’ of how to drive smoothly, consistently, and at speed. For Formula One driver Sir Jackie Stewart, Mechanical Sympathy was about being attuned to the limits of his car’s adhesion to the track, enabling him to extract its maximum possible corner speed (Stewart and Manso, 1972). For endurance racer Peter Brock, Mechanical Sympathy constituted a sensitivity to change over time that allowed him to anticipate the failure of various components and increase the longevity of his machine (Denton, 2003). Other drivers will have their own take on the term, but essentially it is seen as tacit knowledge that someone has that enables them to communicate with their engineers, not only what they are feeling but what they want to feel when testing and tuning their machines. This means that technical knowledge of the machine is not a critical requirement for Mechanical Sympathy, technical knowledge may help guide your attention or give you the vocabulary to talk to engineers but it does not make you a good driver (Stewart and Manso, 1972).

I am adopting this pop culture term with two important caveats. The first is that I see it as a process instead of a talent. Something that you do, not something that you have. Drivers are constantly asked to translate the rich, qualitative experiences felt when driving into quantitative changes that are actionable by a mechanic or engineer (Newey, 2017). It is through the cumulative frustrations, unknowns, pleasures, and joys (i.e. the process) that a driver makes sense of what their machine is doing, and, further, cultivates a profound aesthetic appreciation of how their machine should feel. I am looking to extend this process to those outside of motor sport for its ameliorative benefits to the soma.

Secondly, by moving away from this context we leave behind motor sport as
a kind of established practice, similar to the way in which Redström defines a design practice (Redström, 2017). We will see in the next section that the process of Mechanical Sympathy was practised in the absence of any widely agreed notion of style or technique; and without any concrete way of measuring success that you would find in motor sport. For myself, and the participants in the user study, this adds an additional layer of ambiguity to what we are feeling and what we want to feel when flying these drones.

Designing for Mechanical Sympathy

We again employed a fusion of the soma design and product design engineering techniques to design for Mechanical Sympathy. This time however, to produce a research product (Odom et al., 2016) which is a kind of prototype that appears more like a consumer product in a domestic setting than a prototype in a lab. When exploring ambiguity in design, research products are handy because they appear as a polished product that operates as intended. This is opposed to a more rough-looking prototype in a lab setting, where ambiguous behaviour may be disregarded as the result of a prototype unfinished (ibid.). Research products have been used previously to probe the blurred relationships between designer, user and object (Hauser et al., 2018; Wakkary et al., 2018). Something I aspired to emulate in this project.

I began by contemplating what aspects of the interaction should be shaped by the participants. What levers was I offering them to pull? Initially I had the lofty aim of offering them all the levers, with the prospect of inviting the participants to link any kind of bodily movement to any of the drone’s movements. I had the wide-eyed idea of implementing a machine learning algorithm that would identity patterns and start to link human and drone movements based on the strength of these patterns... or something like that. One week into a general machine learning introductory course, I quickly learnt how much of a mammoth undertaking it would be for my participants to face such an intimidatingly blank canvas. In the case of reinforcement learning, I was reluctant to train the model by choosing a reward policy to adhere to as it carried with it explicit implications about what I wanted the model to to learn. Tasking this to the participants with would likely have caused some sort of analysis paralysis, which would not have been very conducive to learning and designing through movement. Similarly, in the case of an unsupervised learning approach, asking the participants to gather enough data to derive recognisable relationships between human and drone movements seemed like an intractable problem that no amount of movement could have solved in a reasonable time. Then in the case of a supervised learning approach, I was reluctant to train the model on pre-made gesture data-sets as they had already assigned meaning to images, words, sounds and movements.  

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10I am sure there were ways around this even back in 2019, but I would argue that most were outside my skill-set. The pandemic also put a bit of a damper on collaboration. No doubt in 2023, in the midst of another AI summer, there are more tools available for the keen amateur.
So instead, I picked up where I left off from *Drone Chi*. Employing imagery-driven body storming to explore different ways I could relate to the drone and how these relations could be parametrically modelled. The difference was, however, that I planned to use an additional layer of technology (computer vision or, more specifically, pose estimation) to longitudinally tweak the way the drone responded to the body. For example, with a camera watching my movements at all times, I could track the average height between my knees and the ground, and use it to "weigh down the drone" by making the drone height a function of this average. Another example being to track my average centre of gravity and use it spin the drone clockwise or counter clockwise when it was skewed more to the left or right (see Figure 2.21). This would in turn affect the drone’s ability to stabilise in flight. In other words, the more off-centre my centre of gravity was, the less stable the drone felt to fly.

I assumed that if I was able to layer enough of these relationships on top of each other, I would end up with a unique set of ‘tweaks’ or ‘weightings’ that depended on how an individual moved with the drone. This was intended to emulate the kinds of changes I was making to the drone during the development of *Drone Chi*, which in turn facilitated reflection on how you move with the drone. Something still did not feel right about this, and eventually I realised that each coupling I made between human and drone encoded a way of moving that I thought was meaningful. As I said previously, the aim was to give the user’s lived experience primacy in the meaning-making process. I had hit a dead end trying to pull myself out of this circular problem and so I put aside the pose estimation and started working on fabricating a new shroud and charging station for the drones.

Previously I explained part of the *Drone Chi* process that was driven by a fascination with the *otherness* of creatures such as the octopus and the jellyfish. For the design of the drone shroud and charging stations, I returned to this fascination, this time more determined to stay close to the *mollusca* and the *cnidaria* branches of the tree of life. I settled on a design based loosely on the multistage life of a jellyfish. When charging on the dock, the drones emulate the *polyp* stage of the organism’s life cycle, where they are attached to some hard surface and grow like a plant, but not quite. When flying, they emulate the *ephyra* stage, where the jellyfish ventures off into the sea, like an animal, but not quite. I say loosely because one, there are more stages to this life cycle; and two, time was limited and fabrication methods were limited. This is where the design brief again saved me from a meander that I may have never returned from, by mandating the reconfiguration of *Drone Chi* parts instead of the design of completely new ones.

So at this stage, I had an ambiguous looking physical form, conveying an
ambiguous level of agency\textsuperscript{11}. Not quite plant, not quite animal. But no idea how the drone’s control inputs were going to map onto the human body. Additionally, I had decided (for simplicity’s sake) to charge all the drones in the lounge room of the participants’ home and not build every participant their own personal charger as initially planned. This meant I needed a way of telling the drones apart. While on a the hunt for some fancy stickers I came across a shop that sold teddy bear eyes. I was reluctant to add an eye as it would signify a front and back of the drone, breaking the radial symmetry. However, I was also struggling to integrate the magnetic charging port for the same reason. Furthermore, the \textit{Drone Chi} participants did say they enjoyed having a focal point in the form of the flower drone’s stamen. So I solved two problems at once by buying an assorted pack of teddy bear eyes.

While the eyes arrived in the mail, I started to fiddle with the propeller guards that looped around the drone. By changing the length and thickness of the looping guards I was able to simultaneously affect the look of the drone and its physical balance in flight. It felt like I was styling not only its hair, but also its limbs. I realised that this ‘haircut concept’ (see Figure 2.25 was a solution to the earlier issue of enabling the primacy of the participants lived experience. This idea allowed the participants to physically shape the drone based on an aesthetic preference of how it should look and feel. However, it did not take many changes until the guards stopped being guards and started to jam up the propellers, causing some spectacular failures. The pragmatic design brief struck again, and I abandoned the idea as it would have been too time consuming to achieve a reliable way to solve this.

After the adhesive teddy bear eyes arrived in the mail, I stuck four different colours onto four different drones. Things started to accelerate from here on in. The eyes immediately implied that each drone had a different personality, having four drones with a different eye colour prompted me to think of them as my babies. Being a sleep deprived new father at the time, this was not too hard to believe. A breakthrough in respect to the mapping problem came soon after, when I was watching my infant daughter rolling on the floor, grabbing her limbs, and tasting her feet. Whilst attending neonatal lessons, I learnt that babies, through sensing and acting, learn the boundaries of their body parts and how to use them. I saw the opportunity of a system that could \textit{grow} with the participant and cumulatively change with them, because in this way my preconceived notions of movement could recede into the background. Making space (in the somaesthetic sense) for more chance encounters, confusion, frustration, reflection and inquiry. Essentially just more learning through doing. Not only that but each drone could “grow up” differently, learning skills in a different order to that of the other

\textsuperscript{11}Agency in HCI is a complex term and is used in many different ways as exemplified by Bennett and colleagues (2023). In this context and at this stage of the design process I am referring to \textit{my perception} of the drone’s agentic capacity. In other words, leaning on Russel and Norvig’s definition of an agent to assess how much the drone can sense and act on the world. We will touch on this again in the next chapter.
drones. Just as babies learn to crawl, walk or talk at different stages to each other, based on the interactions with their parents and their environment. The ‘newborn’ concept took the multi-layered relationships between drone movement and human movement from the spinning concept, but introduced those layers randomly and one at a time.

The problem of who should design the coupling between the human movement and the drone movement was less pronounced in the ‘newborn’ concept but it still remained. I wanted my preconceived notions of movement to further recede. I wanted to be designing the rules behind the rules. This is where the second breakthrough came, if my ‘babies’ were going to sense and act differently to one another, then they needed not only different parents to interact with, but different bodies to sense and act with. The ‘haircut’ concept drone I mentioned earlier (see Figure 2.25) was one way to implement this physically, but recall this was too difficult to reliably implement in a one month study. I began to think of ways to implement it virtually. This is where the final ‘point cloud’ concept came from. A realisation that the participant should be able to grow and shape the (virtual) body of the drone, and in doing so, build their own layered relationship whilst also having differently behaving drones to make comparisons against. The difference in the ‘bubble size’, ‘time to train’, ‘launch height’ and ‘spin rate’, was all a projection of the different personalities I saw in the four eye colours\textsuperscript{12}.

Once the notion of the point cloud was implemented in its basic form, I turned to the more human-centred aspects of the interaction. After all, this was a month-long user study, not a year-long study. Additionally, the drone battery only lasted about 6 minutes. Therefore, designing at least some clear and consistent behaviour patterns for the participants to pick up on was still pertinent. Considering that I wanted to keep the verbal introduction to the drone’s operation to an absolute minimum, there was not much left to work with. The somaesthetic, technical and complexity bounds of the design brief had left only two communication channels left to use, the yaw of the drone (its ability to spin) and the buzzers on the hand sensors. Given that the buzzers were partially being drowned out by the drone’s propellers, the yaw was primarily used to communicate when the drone was responding to the hands.

This left the sometimes inaudible buzzer free to play a less functional role. I discovered that sending low frequency signals to piezoelectric buzzers made them sound more like something in between a dolphin and a Geiger counter. By playing around with different rhythms I found I could have them all beat to distinctly different cadences. Something reminiscent of my time with old cars as the cadence of an engine at idle begins to constitute its personality, especially if you listen to it long enough in peak hour traffic.

Finally, a fine tuning of the parameters that governed the behaviour of the drones was undertaken. I flew them around to find the highest and lowest toler-

\textsuperscript{12}A reminder that an in depth description of the How to Train Your Drone system can be found in section 5 of paper D
able values. Drawing from my experience observing the Drone Chi participants to approximate what they could achieve with the drone had they had a month to play with them. In other words, some educated guess work. I hard coded each drone to behave somewhere in between these extremes (see Table 2.1). They were then randomly assigned to the study participants.

<table>
<thead>
<tr>
<th>Eye</th>
<th>Train Time</th>
<th>Bubble Size</th>
<th>Spin Rate</th>
<th>Launch Height</th>
<th>Flown By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>10 sec</td>
<td>.20 m</td>
<td>60 deg/sec</td>
<td>1 m</td>
<td>Tom</td>
</tr>
<tr>
<td>Clear</td>
<td>12 sec</td>
<td>.24 m</td>
<td>80 deg/sec</td>
<td>1.2 m</td>
<td>Nora</td>
</tr>
<tr>
<td>Amber</td>
<td>9 sec</td>
<td>.18 m</td>
<td>50 deg/sec</td>
<td>.9 m</td>
<td>Justin</td>
</tr>
<tr>
<td>Green</td>
<td>8 sec</td>
<td>.16 m</td>
<td>40 deg/sec</td>
<td>.8 m</td>
<td>Joseph</td>
</tr>
</tbody>
</table>

Table 2.1: The parameters that establish the flight characteristics of each drone. Training time corresponds directly to how long the participant must hold their hands steady to create a new set of active points. Manoeuvrability is defined by the diameter of the ‘magnetic bubbles’ around the active point (I refer you to section 5 of paper D for a more in depth description of ‘magnetic bubbles’). The launch height influences how the participant approaches the drone. The spin rate influences how easy it is to tell if a spinning drone is slowing down.

Evaluating How to Train Your Drone

The user study took place in the shared home of participants Justin, Nora and Tom. A domestic setting as opposed to a lab setting was important because it allowed the participants to make space for the drone in both the physical and somaesthetic sense. In other words they were not only able to use the drones in a physical space that suited them (the lounge room), but also at a time that suited their schedules and their capacity to somatically engage with them. The three participants each had their own drone. Initially, I had planned to have six participants, but the pandemic had other plans and forced three participants out of the study. However, I wanted an even number so that the participants could pair up and compare their drones at the half way point, so I stepped in to even out the numbers, giving Tom something to compare his drone with.

At the beginning of the month, each participant was shown the basic functions of ‘creating a point’, moving the drone using that point and ‘breaking away’ from that point. A short, semi-structured interview was conducted before the study and after each session. Longer interviews were conducted at the half way point (after the participants had flown a drone that someone else had trained) and at the end of the study. Thematic analysis was again used to process the interviews, participant explanations of the body maps were fed into the interview data just like in Drone Chi. Participants were also asked to do a body scan prior to their

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13 A reminder that an in depth description of the How to Train Your Drone system can be found in section 5 of paper D.
2.3. **HOW TO TRAIN YOUR DRONE**

body maps to further enrich their articulation of their experience. The drone swap at the half-way point was intended to provide further opportunities for articulation through comparison.

In the following three sections, I will demonstrate the different ways Mechanical Sympathy manifested for Nora, Justin and Tom, and different ways they made meaning with their drone. Then I will abstract the similarities from how they became somatically appreciative of the capabilities, limitations, change, and agency of the human-with-drone assemblage; framing these similarities as *oscillations*.

**Justin-with-the-amber-drone**

Justin is a maverick with relentless positive energy. He works as a bio-mechanical engineer, spending his days researching how to implant bionic eyes into sheep. Beyond work, Justin leads a busy life filled with many interests, including record collecting, ice hockey, and working on the restoration of his small wooden sailboat. His drone has the smallest ‘magnetic bubble’. This means it is more difficult to manoeuvre; Justin’s hands can only be moved a short distance from the active points before the position is lost. However, the amber drone also has the shortest training time (see Table 2.1).

The first time Justin launched his drone, he immediately stretched his hands out in front of him and successfully trained a position that held the drone in between his hands at about waist height. However, he could not take a single step in any direction before the drone abruptly broke contact, returning to spinning in place as his hands moved away from the active points. He often moved so quickly that he even bumped into the drone itself. Justin and his drone were very clearly discordant. However, this did not surprise him as he reflected, “moving slowly is not something that I would do very often... most of the time, I mean to do things as fast as possible.” Justin lamented the “pickiness” of his drone, describing it as an “old man” in comparison to Nora’s “puppy” and finally likening it to a rock which “has its own inertia”.

By being challenged, however, Justin also came to understand the technical aspects of the system better than the other participants. His systematic approach to reconfiguring his and his drone’s capacities, drew his attention to other aspects of the system that went unnoticed by the other participants. Justin realised the on-board lights turned green when at least one of the wall mounted tracking beacons had a direct line of sight to the drone. He discovered the system was not as well calibrated along the perimeter of the tracked space and so avoided training new positions in these areas. Finally, while watching the other participants fly their drones, he demonstrated a fine-grained understanding of training times; cor-

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14 Again looking back, the similarities between the soma design process and the evaluation of soma designed artefacts are becoming clear. Both demand articulations of experience, and require a range of tactics to evoke this. Taken out of context, the drone swap at the half-way point could easily be mistaken for a body storming session. This further supports my worldview of a very blurred line between design and user.
rectly estimating (down to the second) how much time the other drones required to learn a new position relative to his own.

Through sensitising himself towards the capabilities and limitations of the drone, Justin came to move his body in a highly coordinated manner. He began to appreciate that, to be able to move with the drone, he needed to coordinate his whole body to support the lateral movement of his hands. To move left, for example, rather than moving from the shoulders or the hips, Justin would cast a pointed left foot out to the side while placing his weight on a firmly planted right foot. He would then slowly shift his weight onto his left foot, keeping his arms still, as his torso glided to the left (see Figure 2.30).

Towards the end of the study, Justin still struggled to move the drone laterally, but no longer stopped abruptly when the drone broke contact. Instead, he continued sweeping his hands past the drone diagonally like a brush stroke. He repeated this movement continuously, inching the drone in a lateral direction with each stroke (see Figure 2.31). When describing his body map, he reflected; “This is now how I visualise the drone – a mossy stone that is shaped by water flowing over it. The water being like the cascading movements that I make with my hands and that shape the rock. I also feel as if I am made of moss as I enter a really peaceful state of feeling like I am organically interacting with something” (see Figure 2.44).

The combination of rich, metaphorical descriptions and practical, technical concepts was central to Justin’s sense-making with the drone. Justin had initially attempted to exert his agency over the drone and experienced frustration with the drone’s resistance to moving fast. By the end of the study, however, he came to appreciate the “stubborn” nature of the drone, which he playfully interpreted, giving the drone the affectionate nickname “old stoney”

**Nora-with-the-clear-drone**

Nora is a creative person at heart with many different experiences from which to draw. She is astute but does not take life too seriously. Outside her job as a lead service designer, Nora loves learning new things, such as welding, casting and woodworking. She regularly attends circus school and has previously participated in a choir and practised kung-fu. Nora had minimal experience with drones prior to the study, other than once having seen her housemate fly a drone. Nora was given the clear drone. The clear drone is the easiest to move, having the largest ‘magnetic bubble’, but takes the longest time to train (see Table 2.1).

Nora’s drone first launched in front of her at chest height. She immediately placed her hands at head height and trained a position. She then took a casual

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15To satisfy the more observant readers out there, it is worth mentioning the fact that a stone being shaped by running water probably wouldn’t gather any moss. I am prepared to give Justin the benefit of the doubt here and say that perhaps he felt like the stone and the water at different times given that his body map depicts moss on both himself and the drone (see Figure 2.44). This oscillation of perspective is something we will explore later in Section 2.3.
2.3. **HOW TO TRAIN YOUR DRONE**

step sideways and the drone followed smoothly. She continued to move back and forth across the room, taking big strides with a wide smile. “I feel like a weird puppet master!” she exclaimed with excitement, her hands still held at head height. From the outset, Nora was very mobile, but kept the drone close to her body this influenced how the points accumulated around her drone (see Figure 2.46). Nora described her first sessions as intense, as she explained through body map, “I was not thinking about my body the entire time. So, I drew these like giant eyes and some brainwaves because I feel like I was very engaged in what I was doing and trying to learn” (see Figure 2.44). After her flight sessions, she also reflected on her elevated heart rate. Despite her excitement, there were still attempts to explore how the drone moved, “I was trying to figure out, the dimensions of movement up down sideways and in circles.”

Once Nora understood the basics of flying her drone, she quickly turned to playfully subverting these ways of flying and this became a consistent source of amusement and inspiration for her (see Figure 2.34). This included “fighting it” by shadowboxing with the drone, “booping it” by pushing down on the drone without making it crash or “tricking it” by removing her hands and bringing them back faster than the drone could react. One example involved Nora deliberately pulling the drone close to her face and using the air-wash from the propellers to un-fog her safety goggles. “Self-cleaning drone!” she proclaimed proudly to Justin, “Can your drone do this?” Through this subversion, Nora became sensitised to some of the more nuanced aspects of her drone’s capabilities and limitations. “I got to know the parameters, for example, can I move my hand around and will it still follow me or not? And to be able to anticipate that, and to also be fine with it if it didn’t follow me.”

Nora began to draw from her various creative practices to inspire her flight sessions with the drone. During one of her solo sessions, she experimented with different movements including some ballet positions before Justin, who was watching nearby, suggested excitedly, “Oh, we should do a ballet!” “Yeah, that’s what I am thinking!” replied Nora. During the following session, Nora and Justin placed ‘stage curtains’ on each side of the video camera. The curtains drew apart to reveal Nora standing with the drone held at chest height while tinny applause rang out from a nearby laptop speaker. As the melody of Tchaikovsky’s *Dance of the Sugar Plum Fairy* began to play, Nora lifted the drone high above her head and it broke free from her hands, spinning in place. Nora spun gracefully beneath the drone. When she reached up to retrieve the drone, she realised it was out of reach, and she leapt to retrieve it. Impressively, she did this in time with the music, bringing the drone down whilst smoothly dropping to her knees. Nora continued to break and reconnect with the drone rhythmically for the duration of the two-and-a-half-minute performance.

Nora’s performance also prompted her to reflect on what kind of experiences she was trying to achieve with the drone. Prior to the performance, Nora described her experiences as “this fun game where you have all these like secret mechanisms that you try and understand through play.” However, following the
performance, Nora reflected that the drone “was an extension of what I was doing rather than this separate thing” that she was trying to understand. She instead opted to “use what I already know [to] do a dance and see how the drone follows me or does not follow me.” Nora also did not feel so driven to understand the inner workings of the drone, stating that “there is [still] an element of ‘you don’t know what is going to happen to it’ all the time. But I think that counts as an opportunity because it forces you to improvise to what is happening.”

Nora-with-the-clear-drone’s Mechanical Sympathy manifests as subversive play. Like Justin, Nora initially began by sensitising herself to the capabilities and limitations of her drone and their joint capabilities. However, unlike Justin, Nora used subversion to probe the boundaries of their capabilities – trying to uncover different ways of interacting with or tricking the system. This ultimately produced a somatic sensitivity and responsivity towards herself and the drone, but a different flavour of appreciation towards their joint capabilities. Nora set about reconfiguring their joint capabilities in a manner differing from that of the other two participants. Instead of trying to maintain constant contact (adapting her body to the drone or training points to adapt the drone to her body), Nora again subverted the system by reconstituting these limitations as opportunities for creative expression. She allowed for their connection to be broken and let the drone spin alone as part of her performance whilst she danced around it. This example also shows that Nora was less interested in exerting her own agency over the drone, but rather embracing a joint agency that fuelled her creative process and presented opportunities for subversive fun.

Tom-with-the-blue-drone

Tom loves to mess around but can also be intensely curious. He has a razor-sharp focus when leaning or discussing something meaningful or of interest to him. He works as a machine learning engineer and enjoys going to the gym, practising yoga, and playing board games. Tom had some experience with drones prior to the study. He previously participated in the Drone Chi user study, and he also aided in several aspects of the technical implementation of How to Train Your Drone and as such, had a partial understanding of how the points were computed and stored. Tom was given the blue drone. The blue drone is average in all its parameters with launch height, training time, magnetic bubble diameter, and spin rate all falling midway between the corresponding parameter values of the other drones (see Table 2.1).

During Tom’s first session, the drone launched just below waist height. He moved his hands to either side of the drone and successfully trained a position. Then, he immediately began to work on a plan. As he explained: “I was attempting to lock the drone into positions that I was wanting to move through in a series of movements that I found fun and relaxing [while] maintaining a connection – a rewarding experience in some way whether that’s pleasurable or challenging. And then the constraints of thinking about the next set point, and what that
would mean, and how that is linked into the overall thing. There might be some positions that might feel really good, but they are not related to the other set points that you want to do. As in, it does not transition into those other set points in a way that you like.”

Towards the end of the study Tom’s sequence went something like this: starting with the drone at eye level and about arms length away, he would then pull the drone down and inwards towards his navel before pushing it down and up again from head height and then opening his arms outwards to full span while keeping the drone still in front of his chest before finally closing his arms inwards to return himself and the drone to their starting position (see Figure 2.38). For him, this was a constantly evolving and iterative project. He describes his sequence as “a predefined list to an extent, but a flexible one. Where I thought it would be useful, I made extra set points – I would train new set points to do something that I wanted to do.” However, as he created more points, Tom realised the space was becoming so crowded that his points risked becoming indistinct from each other. He reflected, “I was trying to minimise the number of points I made because otherwise I think it would remove this interesting constraint from the whole thing which is like trying to lock into these patterns and these paths. If you just had points absolutely everywhere, that would be sort of boring to me, like free-form poetry. You have the whole world available to you, so, it is very hard to make a decision about which thing to use, as opposed to when you are constrained by the form and can be very creative in that form.”

During the partnered session, Tom tried to fly with my drone. My approach to training points was far less structured. I had created a dense ‘wall of points’ between myself and my green drone, into which I would place and move my hands (see Figure 2.48). My drone had the smallest ‘magnetic bubble’ around each active point which allowed me to train many points close together without them overlapping and becoming indistinct. As a result, the drone would frequently ‘snap’ to different positions as my hands moved through close points in quick succession. Tom immediately noticed this when he said that my drone felt “snappier” but was unsure as to the cause. “It just seemed to be more responsive to updates to my hand position... but, uh, it might just be my slow brain now relative to the speed of the drones being like, wow.” After some further practice with my drone, Tom began to appreciate the difference. “It sort of feels like moving between them is pretty easy. And when you move between them, the drone sort of suddenly it gives the illusion of snappiness. Whereas [my drone’s] set points, were quite far apart, so you have the process of sort of like slowly moving out of one, and then you’re in this transitional zone where it’s not doing anything, and then you enter another one.”

Tom-with-the-blue-drone’s Mechanical Sympathy is characterised by purposefulness and premeditation. Unlike both Justin and Nora, Tom had a specific goal he wanted to achieve with the system (a choreographed sequence of movements) and employed a methodical approach to exploring the different possibilities available to him – within the scope of achieving his goal. Like the other two par-
participants, Tom somatically sensitised himself to both his and his drone’s joint capabilities and limitations, meticulously exploring the different movement possibilities available to him while holding a position. However, unlike the other two participants, Tom had a different view of the limitations of the system. Where Justin wanted to overcome such limitations and Nora wanted to entirely reconstitute limitations as creative possibilities, Tom actively desired these system limitations to add challenge and reward to his experience: having too many possibilities available to him removed the challenge of being creative within boundaries. Finally, Tom-with-the-blue-drone’s Mechanical Sympathy was cultivated toward achievement and reward, creating an engaging experience that Tom found both pleasurable and challenging.

Cultivating Mechanical Sympathy

In each of these stories, we see unique outcomes of the Mechanical Sympathy process. Here, I frame three common mechanisms that drive this process of somaesthetic appreciation as oscillations. The three oscillations appear under separate headings below, however, they have some overlap, much like the methods and concepts that underpin the soma design process. Characteristic of all three of these oscillations is the question, *what am I feeling/doing* which requires both a pre-reflexive and reflective approach. Finally, it is worth noting that the examples from this section are drawn only from Justin, Nora and Tom, however, I found that their experiences resonated strongly with how I made sense of, and meaning with, the machines from my own lived experience.

Oscillating between movement experiments and experimental movements

It is possible to characterise the intent of the participants’ movements as *movement experiments* and *experimental movements*. Each participant performed movement experiments when trying to understand how a specific aspect of the *How to Train Your Drone* system functioned, in other words, trying to make sense of how their actions were affecting the system. Experimental movements were employed when attempting to discover something new, such as moving in creative ways to discover how the system would respond to them. This process – oscillating between experimental movement (trying a new movement) and movement experiment (understanding that movement), in turn leading to a new experimental movement – is vital to both sense-making and meaning-making with the system. This is best illustrated by Tom during the process of choreographing and constructing his movement sequence. In this example, Tom had created an entire semi-circle of points trailing from each side of the drone. He moved his hands through this arc of points to the outermost ones. Then, he performed a movement experiment by playing with the edges of the ‘magnetic bubbles’ – incrementally moving his hands left and right, probing
where the connection would break. Once the connection broke, he would pause and train a new set of points there (see Figure 2.39) by growing the arc.

These movement experiments allowed Tom to uncover the edges of his point cloud and incrementally expand the points that allowed him to hold the drone. With his arms now at the outermost boundary, Tom would engage in experimental movements to probe the different possibilities for the next part of his movement sequence. With his hands constrained to the ‘magnetic bubbles’, Tom creatively experimented with the different ways he could move his body while his hands maintained their relative position. For example, he lent to one side like a teapot (resulting in the drone breaking contact); took a long step forward with one foot to drop into a lunge (resulting in the drone moving diagonally); and twisted his torso from the hips (resulting in the drone moving in an arc). He refereed to this process as doing “body puzzles”. This process of sensing and acting with the system, allowed Tom to make sense of the different capabilities and limitations of his drone while appreciating incremental changes to the system and uncovering the aesthetic possibilities of each change (see Figure 2.40).

Oscillating between the familiar and unfamiliar

Cultivating Mechanical Sympathy can also be characterised as oscillating between the familiar and unfamiliar. In the case of How to Train Your Drone, this manifested as notes of unfamiliarity against the background of a familiar drone, or familiar notes against the background of an unfamiliar drone. This is best illustrated by Nora, who demonstrates her familiarity with how to catch her drone. “I know I have trained a lot in this kind of position, which is quite reliable and my hands are flat and straight and aligned with my body so I know that I have trained that enough.”

However, Nora also frequently encountered her drone moving in unexpected ways. This behaviour would sometimes surprise her as she moved from one trained point to another, but in a way that she had not done before. This drew her attention to an unfamiliar note against the background of familiarity of her drone, often prompting movement experiments to make sense of what had occurred and experimental movements to further develop this new discovery. For example, during one of her flight sessions, Nora took a side-step to move around the drone, but the drone unexpectedly jumped upwards by half a meter. Nora had inadvertently moved into a set of points that she had previously trained and forgotten (see Figure 2.41). After making sense of what had occurred, this prompted Nora to explore how she could flow from one point to the next, rather than explicitly releasing a point before moving to another.

Conversely, when Nora tried to fly with Justin’s drone, she began using her habitual ways of moving before encountering a stark unfamiliarity in how Justin’s drone responded. Nora’s habitual way of interacting with her drone was fluid and carefree. However, Justin’s Amber drone was far less manoeuvrable, and would not respond to any of her attempts to move it. “You’re at my speed now”,


Justin commented as Nora struggled to get the drone to move. Encountering this unfamiliarity, Nora reassessed her ways of moving, adopting a similar weight shifting techniques to move the drone laterally (see Figure 2.42). She even had to pay attention to her breathing, as a deep breath could cause her hands to drift out of the ‘magnetic bubbles’. She reflected that “with [my drone], I was not aware of my breathing the whole time.” Eventually, Nora locked her hands like her wrists were taped together. This stabilised her hands and made it easier to manoeuvre Justin’s drone. Nora carried her increased repertoire of movements back to flying with her own drone, using this position to instead vigorously bounce her drone up and down in the manner that eventually flowed into her ballet performance. This demonstrates how the alternating between the familiar and the unfamiliar led to expanding Nora’s movement repertoire; in turn, she developed a deeper appreciation for what her drone could do and what she desired to do with her drone.

Oscillating between perspectives

Another way in which we can characterise this process of appreciation is looking at how the participants oscillated between perspectives. In the case of How to Train Your Drone, this manifests as alternating between the interdependent perspectives of human and drone. Justin illustrates this via two distinct attempts to make sense of how he could move with his drone. The first occurred when Justin tried with difficulty to move the drone laterally (i.e. left, right, or diagonally). Moving laterally required him to coordinate more parts of his body, requiring rotation of the shoulders, extension of the elbows, and articulation of the wrists – all of which could unfold at different speeds therefore easily losing his relative position to the drone (see Figure 2.43). He found moving up and down with the drone easier than moving laterally. This is because he rotated at the shoulders with only a slight extension of the elbows to move his hands smoothly along a vertical path; his shoulders set the distance between both hands making it easier to hold this relative position. Following this discovery, Justin tried holding his arms in place and rotating only at the hips, which resulted in the drone moving side to side (albeit in an arc around his body rather than a straight line). He reflected on this relationship in his interviews, explaining that in order to move laterally he needed to be consistently mindful of the “separation between my hands, number one, and also the separation between myself and the drone.”

The other distinct attempt came in response to the limitations the drone placed on Justin’s ability to move. He created an elaborate set of points that he hoped would make it possible to ‘lever’ the drone and fling it across the room like as if it was being fired out of some virtual catapult. He explains, “so I wanted to figure out whether or not I could get the drone to rotate with respect to a central point. For example if I had my hands very far away and the drone was out in front of me. I was wondering If I could get the drone to spin around me. If that was the case then just making really small movements should spin the drone even
faster. Because it would result in the centroid, i.e. the axis point, being close to my hands.” Whilst explaining his plan, Justin demonstrated a perspective that was less centred on the fine motor control of his own body, and more focused on the drone’s body and its hypothetical mechanical linkages that enabled this kind of movement.

In both situations, making sense of these movements required Justin to oscillate his attention between his individual body parts, his whole moving body, and the movements of the drone – cycling between different perspectives to make sense of how his individual body parts related to the whole of his body, and how his body in turn related to the drone.

Towards the Value of Making Meaning

These examples show how oscillating between movements, perspectives, and familiarities characterises the cultivation of Mechanical Sympathy; that is becoming somatically appreciative of the capabilities, limitations, change, and agency of human-with-drone. Ultimately leading Justin, Nora and Tom through their own journeys of meaning-making with the drone. Note that these oscillations were occurring in both a pre-reflexive sense and a reflective sense. soma design is certainly messy work and writing about it was not straightforward either. As I mentioned in section 2.3, the examples Rachael and I used to define Mechanical Sympathy and the process of cultivating it were almost all interchangeable, making a definition slippery and elusive. On paper it has some structure to it, but in the wild it was a tangled mess. I think this speaks to how unique the process is to the individual.

Broadly speaking, however, Justin, Nora, Tom and myself all got to know ourselves better. We did this by somatically exploring and designing with the machine, expressing ourselves through the machine and paying attention to the machine. Through making meaning with these machines we also came to understand them in a very practical way and were each able to demonstrate high levels of control and manoeuvrability with them, although this wasn’t measured in any objective way. Up until now I have kept the notion of meaning-making closely aligned with somaesthetic appreciation. In the next chapter I will decouple them slightly to discuss the value of making meaning and its incorporation into each of our interactions with ambiguous machines in greater detail.
Figure 2.2: Dramatised re-enactment of when the PhD really started.
2.3. HOW TO TRAIN YOUR DRONE

Figure 2.3: Top: In these four frames the drone moves in a half circle, the participant follows the drone back and forth. Bottom: Facilitating a demonstration. Note that the ‘cloud-like’ drone at the bottom of the frame is not very fluffy. I discovered that fluffy things and propellers don’t mix well.
CHAPTER 2. DESIGN PROCESS AND RESULTS

Figure 2.4: Attending an early morning public tai chi class in Melbourne, some of the moves were pretty advanced and so were lost on me. Afterwards however, the class had breakfast together, I enjoyed talking to them about what tai chi meant to them.

Figure 2.5: This figure has been taken from the original publication (La Delfa et al., 2018), where I tried to highlight the potential of incorporating imagery into interactive tai chi experiences, which in my opinion were too evaluative and literal.
2.3. **HOW TO TRAIN YOUR DRONE**

Figure 2.6: That first flight feeling, you can see it all over my face!

Figure 2.7: Master Han in the lab with my the first responsive prototype. A motion capture camera lurks in the background.

Figure 2.7: Master Han in the lab with my the first responsive prototype. A motion capture camera lurks in the background.
Figure 2.8: Top: The *Drone Chi* drone. Bottom: Demonstrating *Drone Chi* at the CHI conference in 2019. Bottom Left: Picking a drone from the charging station. Bottom Middle: The drone moves in an expanding circle. Bottom Right: The participant moves the drone about the space.
2.3. HOW TO TRAIN YOUR DRONE

Figure 2.9: The PDS was referred to continuously during the design process. This practice was taught to me during my design training and so I also took comfort in referring back to it.

Product Design Specification (excerpt)

- Moving with the drone must emulate the coordination, pace and imagery of Tai Chi.
- A visual aesthetic treatment that engenders a sense of lightness and grace during flight.
- Hide electrical hardware and move visual aesthetic toward the organic and the natural.
- Use radially symmetrical examples from nature to inspire the visual treatment and allow movement around the drone.
- Investigate the roles of leading and following the drone.

Technical and Usability Requirements

- Controllers must be ‘one size fits all’ quick to put on and withstand repeated use during demonstrations.
- Battery life > 5min
- Net weight < 34g
- Maintain factory centre of gravity position
- Marker size > 8mm
- No. of visible markers ≥ 4 (asymmetrical formation)
Figure 2.10: Top: Different mechanical analogies were experimented with during the design process. Bottom: The “offset midpoint” mapping used in Drone Chi.

Figure 2.11: The discursive Drone Chi design process rendered somewhat chronologically, with distinct stages categorised as soma design, product design engineering or both.
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Figure 2.12: Left: Taking corners for fast times. When aiming for personal best lap times, I drove in very focused and almost choreographed way. I sit upright and my eyes dart from braking points to corner entries as I try to clip each corner apex with a front tyre. Changes to the go-kart or the route taken around the track are made incrementally with each change like a purposeful experiment. Right: Taking corners for fun times. When sliding around, I can relax into my seat. I have to ‘toss’ the go-kart into corners and not know exactly where it will emerge. Changes to the go-kart or the route taken around the track are made impulsively with each change like an experimental discovery.

Figure 2.13: Over many hours of repeated movements developing Drone Chi, it was possible to appreciate the capabilities afforded by a healthy drone battery. Left: A healthy battery felt like a strong elastic band with little stretch. By quickly supplying power to the motors driving the propellers, a healthy battery allowed the drone to follow hand movements more quickly. Right: A battery in poor health felt like a weak elastic band that was slow to contract. By failing to supply power as quickly, an old battery causes the drone to execute long arcs or deep drops when trying to change direction.
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Figure 2.14: Left: My old car (white) next to one manufactured one year later (silver). When the owner of the silver car took me for a test drive, he drove it as habitually as I would have driven my own. However, when I drove the silver car, I was astonished at how unfamiliar it felt. The clutch felt loose and the brakes were vague, but the steering was tight and responsive. Right: The Drone Chi system used for the user study and demonstrations consisted of twelve identically built and programmed drones. However, each drone, despite flying using the same hardware and software, flew in a manner that differed significantly from each of the other drones. Just like the cars, they had begun to display characteristics based on the “lives that they had lived” at the hands of various conference goers and study participants.

Figure 2.15: What happens when you evolve with the machine. Left: The standard ‘Crazyflie’ drone in its propeller ‘pull’ configuration. In the factory state, the drone is a blank canvas. There were lots of things I could do, almost anything was possible, but neither the drone or I knew how. Right: The same drone in the less conventional push configuration. These drones not only fly differently but are also the product of a mutually-shaping design process. In other words, the journey from one drone form to another cultivated and constrained how the drone could sense and act towards me and vice versa.
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Figure 2.16: What happens when the machine evolves without you. Left: After five years of ownership I loved the way my old car looked and drove. It sported the original narrow wheels which it had rolled off the factory floor with and the original interior maintained a distinct smell of vintage vinyl. Despite some engine smoke and a crunchy second gear, it always offered a tidy and spirited drive on a twisty back road. Right: The new owner had completely restored the car and added some significant performance modifications – it had received a new and improved engine and gearbox, wider wheels were squeezed under pumped up wheel arches and the interior had been re-upholstered, which meant the vintage smell was lost. The acceleration felt too explosive, the brakes unnecessarily sensitive, and the handling too aggressive. The car felt angry and skittish – like it had to race every other car on the road to prove it was the fastest.
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Figure 2.17: Top: The drones were deployed in the living room of an old home, shared by study participants Justin (left), Nora (centre) and Tom (right). Bottom Left: Tom makes himself a coffee before flying. Middle Right: Justin fits sensors to his hands. Bottom Right: Nora and Justin fill out a body map.
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Figure 2.18: One of the drones used in the user study.

Figure 2.19: The charging dock.
Figure 2.20: The hand sensors used to ‘train’ the drone.

Figure 2.21: The spinning concept tied the balance of the human body to the balance of the drone body.
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Figure 2.22: A mood board that aims to highlight the textural and morphological parallels between a drone and a deep sea creature. Specifically their radial symmetry, transparent flesh and exposed hardware. Credit: BBC Natural History Unit, NewBeeDrone, Kartell, Ross Lovegrove, Harman Kardon

Figure 2.23: Left: An early mock up used modified parts from Drone Chi. Right: An early rendering of the new design.
Figure 2.24: Exploring different materials for mounting the hand sensors. Settling on an almost slimy feeling plastic called ethylene-vinyl acetate (commonly referred to as EVA) due to it eliciting the notion of the other through childhood memories of touching jellyfish at the beach.

Figure 2.25: The ‘haircut’ concept, participants styling the drone to affect both the look of the drone and its feel in flight.
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Figure 2.26: Design inspiration taking book and human form.

Figure 2.27: The newborn concept. When a participant exceeds a threshold whilst flying the blue drone for example, (i.e. the cumulative time with hands above head exceeds x seconds) then the blue drone will have ‘learnt’ how to spin. Subsequent thresholds unlock translation, then forward/backward and finally up/down capabilities.
Figure 2.28: The amber drone. Learn Rate: HIGH. Manoeuvrability: LOW. Launch Height: LOW. Spin Rate: LOW.

Figure 2.29: Justin in action.
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Figure 2.30: Justin demonstrating how he typically moved the drone left and right; using his toes to smoothly shift his weight from one leg to another. The drone’s position changed very little in relation to his body.

Figure 2.31: Justin takes three attempts to move the drone laterally. He does not stop when the drone abruptly stops moving, but rather continues past the drone to instead bring his hands to a gradual stop before trying to move the drone again. He locks his hands to increase stability.
Figure 2.32: The clear drone. Learn Rate: LOW. Manoeuvrability: HIGH. Launch Height: HIGH. Spin Rate: HIGH.

Figure 2.33: Nora in action.
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Figure 2.34: Top: Nora shadowboxes the drone by raising her fists in quick succession. Middle: Nora pushes the drone down by physically touching the top sensor panel. Bottom: Nora tricks the drone by quickly removing her hands and replacing them.

Figure 2.35: During the mock ballet performance, Nora leaps up to retrieve the drone and improvises a dance movement upon landing.
Figure 2.36: The blue drone. Learn Rate: MEDIUM. Manoeuvrability: MEDIUM. Launch Height: MEDIUM. Spin Rate: MEDIUM.

Figure 2.37: Tom in action.
Figure 2.38: Tom performs his movement sequence incorporating a variant of the ‘warrior pose’ taken from his yoga practice. He ends in the same position as he starts.
Figure 2.39: Top: The points that form the semicircle Tom created around the drone are visible amongst the other points trained over the course of the month. Bottom: Tom creating the semicircle of points around the drone.
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Figure 2.40: Top: Tom tips his body over while holding the drone. Middle: Tom lunges while holding the drone. Bottom: Tom twists his body from the torso while holding the drone.

Figure 2.41: Top: Nora is surprised to discover that she can move from one point to another without having the action feel so premeditated. Bottom: Leading her to realise she can make the drone jump around by moving her hands through random points.
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Figure 2.42: When Nora uses Justin’s drone she moves it left and right using a similar weight shifting technique to Justin but instead taking smaller steps.

Figure 2.43: Top: Justin trying to move the drone laterally using only his arms, his right hand almost bumping into the drone as it abruptly stops. Middle: Justin moving the drone up and down moving from the shoulders. Bottom: Justin moving the drone in an arc, moving from the hips.
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Figure 2.45: A visualisation of the points Justin built up with his amber drone, Justin’s drone is characterised by a dense collection of points either side of it. The points trained by each participant accumulate around their drone and continuously alter the possibilities available to them. I highly recommend looking at the supplementary videos of the point clouds spinning in place. Not only does it give you a better appreciation of the form but shows how meaningless these points are as a static 2D image. This highlights the seminal work of James Maas and Gunnar Johansson mentioned in section 1.4. For video footage please visit https://github.com/cafeciaojoe/mechanical-sympathy alternatively you and find my channel ‘Joseph La Delfa’ on YouTube.
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Figure 2.46: A visualisation of the points Nora built up with her clear drone. Nora’s point cloud is characterised by its even distribution and large spaces between points. The points trained by each participant accumulate around their drone and continuously alter the possibilities available to them.
Figure 2.47: A visualisation of the points Tom built up with his blue drone. Tom’s point cloud is characterised by the two upper most points, which he was able to seek out instinctively. As well as the arc that stretches out either side of the drone. The points trained by each participant accumulate around their drone and continuously alter the possibilities available to them.
Figure 2.48: A visualisation of the points I built up with my green drone. My point cloud is characterised by a collection of points aligned in one plane. The points trained by each participant accumulate around their drone and continuously alter the possibilities available to them.
Chapter 3

Discussion and Contribution

Thesis Outpost  We now come to the final chapter, the part where we scale the mountain range that lies between the lost forests of HCI, the great lakes of new robotics, and the enchanted woods of human-robot interaction (HRI); in so doing, we will reach a height that allows us to see where we have come from and where we might go. There I will leave the contribution of this thesis for future designers to forge a mountain pass between the three landscapes.

In this chapter, I will attempt to bring Mechanical Sympathy into sharper focus, firstly by grounding it vertically (Höök and Löwgren, 2012) to the concepts and methods of soma design. Secondly, by grounding it horizontally (ibid.), to other common concepts in HCI and HRI. Then I will seek to expand the soma design program such that the somaesthetic ideals of amelioration can be striven for not only by designing digital materials but by evolving ambiguous machines. This will be done by relating Mechanical Sympathy and the Umwelt to some early design principles from evolutionary robotics.

3.1 Grounding Mechanical Sympathy

Research Through Design and the First-Person Perspective

Soma design is a Research Through Design process in which the knowledge contribution is arrived at by doing design (Durrant and Price, 2015), the open ended, nitty-gritty, failure-rich and meandering process of design. For me, Odom and colleagues’s research product Olly (2019) was a model example of how to conduct Research Through Design. Olly is a somewhat ambiguous looking electronic appliance that bears a significant resemblance to a record player 3.1. It presents you with the opportunity to play a song from your listening history at a random time of the day. The work presents as a delightful and reflective way to access and relate to the masses of data being generated about your listening habits.

The team took intermediate concepts such as unawareness, intersections, and ensembles (Odom and Wakkary, 2015; Wakkary et al., 2016), then through the
practice of slow design (Hallnäss and Redström, 2001) fabricated a product that instantiated these values. This gave me a concrete example of a designer striving to ‘make the right thing’ (Zimmerman et al., 2007). I will let the authors explain further. “The infrequent yet ongoing computational action of slow technologies can make it difficult to establish a sensibility for when the temporal pacing is ‘right’. Others have reported difficulties in aesthetically manifesting subtly changing computational actions in a resolved physical form.” Furthermore, the kind of temporal unfolding and meaning-making experienced by those who used Olly for an extended period piqued my interest. I realised that this was what I eventually wanted to see in How to Train Your Drone. I tried to emulate this approach to Research Through Design in my own work, taking the abstracted concepts and methods of Mechanical Sympathy and have them manifest as research products.

Soma design is also a first-person design process, meaning that the designer’s biases, preferences, past experiences, skills, gripes and grudges are exposed for all to see. As a lover of cars and go-karts, it should come as no surprise that my first contribution is called Mechanical Sympathy, a term often used by race car drivers and childhood heroes Sir Jackie Stuart (Stewart and Manso, 1972) and Peter Brock (Denton, 2003). It should also come as no surprise that Mechanical Sympathy is framed as a kind of somaesthetic appreciation, something to be cultivated.

It is my hope that other designers will take Mechanical Sympathy and blend it with whatever other concepts they are inspired by to drive their practice. I would be equally delighted if it inspires others to explore and explicitly use their first-person experiences as a generative design resource.

The Concepts and Methods of Soma Design

With this epistemological position in mind I would like to ground the different notions of oscillation in the methods of soma design. Thereby explicitly demonstrating that the mechanisms driving somaesthetic appreciation and Mechanical Sympathy are very much alike. Their differences, however, will highlight the need for new perspectives and methods, expanding the practice of soma design to a reflective conversation with an agent as well as a material.

Starting with oscillating between the familiar and the unfamiliar - where an unfamiliar aspect of the system presents itself to you against a backdrop of familiarity and vice versa. Examples include Nora having to re-assess how she moves with Justin’s drone, despite the rules of the interaction being the same, the characteristics or the dynamic gestalt (Löwgren and Stolterman, 2007) of Löwgren and Stolterman liken the dynamic gestalt of an interactive system to our overall impressions of other people. “The dynamic gestalt of a digital artefact can be understood to some extent by the notion of overall character. We form ideas of people’s (and artefacts’) overall character rather quickly, ideas that are not deductively traceable to the sum of all individual actions and utterances of the person in question. Our idea of the character of a person is, in that sense, a holistic property” (Löwgren and Stolterman, 2007).
the interaction were very different (due to the size of the ‘magnetic bubbles’), or how the character of my old car changed due to the constantly degrading and variable condition of the mechanical systems. This bears an obvious link to the concept of estrangement (Wilde et al., 2017) because it encourages exploration and experimentation in order to reach an understanding, which is quite central to the soma design process and somaesthetic appreciation more broadly (Höök et al., 2021).

This leads us to oscillating between movement experiment (understanding that movement) and experimental movement (trying a new movement). Examples can be found in how Tom created his semicircle of group points around the drone, then tried to work with that structure in different ways (he referred to this as a body puzzle), or how I would creep up to the limits of the go-kart’s or the drone’s agility through repetitive movements until something unexpected happened which led to further inquiry or reflection. This is closely related to the change and interest method mentioned in the theory and method chapter, in the sense that both of these are action-driven inquiries into how one part of the body feels different to the other, or how one part of the body is connected to another. Except ‘the body’ here could mean the human body, the drone body or both.

This leads us finally to the notion of oscillation between perspectives. Here the perspective is routinely shifting between the first-person perspective, to some imagined first-person perspective of the drone or a third person perspective of the human-drone assemblage. Examples include Justin’s construction of the drone catapult, or my use of imagery when trying to appreciate how changes to a drone or a car’s morphology affect its movement characteristics. Engaging in interdependent perspectives has been used in soma design practice in the past (ibid.). Here, Höök and colleagues focus in the first, second and third person perspectives of the designer in relation to various materials that they experiment with and reflect on.

I hope I have demonstrated that the processes that drive the cultivation of Mechanical Sympathy share similarities with the soma design methods from which they grew. There is a key difference however. There are now additional agents requiring attention and understanding in the mix. Whilst the felt experience of your body is still the medium through which these additional agents are understood, soma design as a program lacks a way to recognise and design with this entanglement of human-with-machine. Höök and colleagues have begun addressing this by recognising the dichotomies that arise from the body such as inside and outside; individual and social; body and technology (Höök et al., 2021), arguing that embracing these dichotomies and adopting a holistic approach to the body in the design process can be a very generative one. I see Mechanical Sympathy as further work along these lines - a response to the ambiguities that arise from these dichotomies. Affording both the designer and the user a concrete way of making meaning with ambiguous machines.

For the duration of the design process, the work has maintained a very HCI-oriented worldview. As the contributions of the thesis began to manifest them-
selves, I realised that they were beginning to push soma design towards new territory, namely HRI. Therefore in this section, I relate Mechanical Sympathy to some established notions in both HCI and HRI. These comparisons are with Research Through Design, anthropomorphism and zoomorphism, autonomy and bio-mimicry. Their main purpose is to serve as jumping off points for discussion on how this work relates to the broader research community.

**Anthropomorphism and Zoomorphism**

Anthropomorphism and Zoomorphism, our innate ability to treat inanimate objects as social actors is a well studied phenomena in both HCI (Rogers et al., 2023) and HRI (Reeves and Nass, 1996). Storytellers have leveraged this process ever since Karel Čapek’s famous play, *Rossum’s Universal Robots* from 1920 (Čapek, 2014). So too have robot designers, to the point where representing humans and animals became the normative mode of facilitating communication between a human and robot (Sandry, 2015).

Elanor Sandry studies the way we communicate with “machine-like” robots, that is, a robot that neither looks like a human or an animal (ibid.). In a paper entitled *Re-evaluating the Form and Communication of Social Robots* she argues that we have conflated our ability to treat machines as people and animals with the need to design robots that look like people and animals (ibid.). She also states that we don’t always need to do this. Rather, we can use the ambiguities that arise from not doing so as an opportunity to build affective communication between humans and machine like robots. “Successful communication is not only based on what communicators have in common, but also seeks to increase the sense of commonality between them as interactions progress” (ibid.). She cites the lofty expectations we place on humanoid robots, and the problems that arise when they are not met by using examples such as the social limitations of ASIMO and the discomfort caused by robots in the uncanny valley (ibid.). She then argues that understanding the differences between humans and machines is a process that takes time and physical engagement.

The *Blo-Nut*, an interactive and inflatable doughnut-shaped robot, is a great example of this (Bewley and Boer, 2018) (see Figure 3.2). Like a drone, its body is radially symmetric and thus radically different to our own. You have to touch it, feel it and play with it to make sense of it, then through programming different rhythms of inflation you make meaning with it.

Elsewhere in HRI, similar approaches to meaning-making are taken to those used in the design of and interaction with non-anthropomorphic robots, but with more of a focus on movement than form. Naoko Abe argues for an approach that embraces the way a robot moves, as opposed to wrangling it into some

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2The topics I related the work to were selected not only because they were closest, but because they were most helpful in clarifying and supporting my contributions. There are of course many more topics that I could have related this work to; animism, post-humanism, ethics of care and post-phenomenology were amongst those considered.
human or animal-like form - a "robot-specific motion" which "can be characterised as motion that is designed and generated by robot features drawn through its mobility, materiality, and electro-mechanical ability" (Hoffman and Ju, 2014). Similarly, Hoffman and Ju refer to similar point light studies to those I carried out (see Figure 1.7) to highlight that we as humans, “are inclined to, and extremely capable of, extracting information from a minimal set of visual features” and that this capacity is crucial for understanding a robot’s intentions during joint activities (Hoffman and Ju, 2014).

There are obviously plenty of examples of anthropomorphism and zoomorphism in both the Drone Chi and How to Train Your Drone results, where the participants were immediately recognising commonalities between their past lived experience and their in-the-moment felt experience. However, these commonalities had their limits and when these limits were reached the commonalities were extended or combined in creative ways, based on the immediate felt experience. This is where I see the process of Mechanical Sympathy being relevant, as a form of somaesthetic appreciation it sensitises you to aspects of the drones movements and sounds, affording both user and designer a richer way to sense the drone and thus a more nuanced way to react to it. In other words there is more bandwidth for communication between human and machine. Additionally, it allows us to temporally unpack people's sense-making processes relating to machines, so that we can better articulate how we communicate with them.

**Autonomy**

Ever since my very first prototype, people who have tried moving with my drones often comment on not being sure if they were flying on their own or not. I liked this ambiguity as it often facilitated movement-based enquiries towards clarification or less frequently, a resignation in frustration or an embracing of the unknown. Clarification often came in a way that was unique and meaningful to the individual, as demonstrated by the rich variance of interpretations of the Drone Chi user study (La Delfa et al., 2020b). In all of my work however, the drones had very limited autonomy, and so the consequences of an unclear locus of control\(^3\) were small. What about bigger robots with more autonomy and the potential to inflict fatal harm? Take for example autonomous cars, does Mechanical Sympathy have anything to offer these scenarios?

Wendy Ju, author of *The Design of Implicit Interactions* (2015) argues that it is all about choosing the right analogue. Ju critiques a popular “H-metaphor”

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\(^3\)Locus of control is a term that originated in early days of HCI scholarship, when productive screen based interactions dominated research agendas. Shneiderman and colleagues state that, “experienced operators strongly desire the sense that they are in charge of the interface and that the interface responds to their actions. Surprising interface actions, tedious sequences of data entries, inability to obtain or difficulty in obtaining necessary information, and inability to produce the action desired all build anxiety and dissatisfaction” (Shneiderman and Plaisant, 2010).
for an autonomous car (the H standing for horse) where a rider would ride with loose reins in most situations, tightening them for greater control and feedback in critical situations. “I would argue that the H-metaphor is not a good one for autonomous cars. The prospect of drivers being mostly uninvolved in driving but then being expected to take over direct control just at the moment of greatest danger and uncertainty seems like a recipe for disaster” (ibid.). Ju instead advocates for another H-metaphor, “My husband is an autonomous driver. I trust him to drive by himself every day; I never worry once about his capabilities. However, when I sit next to him in the passenger seat, I also participate in driving. I help make decisions about where to go, and suggest alternative routes to take. I warn about potential issues and point out latent hazards that I think my husband might not see” (ibid.).

In response to the ever changing landscape of interactive technology, Ju encourages designers to “explore” and “break the rules” to find new analogues, closing out her book with positive encouragement, “In this book I have emphasized how interactions follow social patterns, but it is also important to know that social patterns are being renegotiated and reinvented every day. Societies develop rituals and patterns to suit our ever-changing contexts, and as designers, we should lead the way in interrogating what is possible on the way to discovering what is desirable” (ibid.). I think it is worth exploring an extension of this invitation to the users themselves to some degree, which is where I see the process of Mechanical Sympathy as being useful. Through the iterative development of a mutually affective relationship between human and machine, the pair choose their own analogue, sometimes even inventing their own analogue together.

The husband metaphor is after all based on Ju’s own lived experience, just like the Drone Chi participants. Can we expect an autonomous agent to “know” all the possible analogues that any human could apply to their relationship? This not only requires an embodied understanding of that experience (Dörrenbächer et al., 2022, p.22), but potentially obstructs the creation of novel analogues, born from a shared lived experience between human and machine. Mechanical Sympathy is relevant here in much the same way as it was in the previous section in that a sensitised soma, shaped by engaging deeply with the machine, will offer the human-machine pair the opportunity to choose their own analogue, or at least creatively remix the implied one.

The need for Mechanical Sympathy becomes apparent when autonomous vehicles start to bleed into other categories of machines, like Yamaha’s MOTOROiD. This is an electric motorbike that can ride on its own, thanks to a unique self balancing mechanism that also fundamentally changes its ride characteristics compared to a conventional motorcycle (Hara et al., 2019, 2020, 2021) blurring the lines between motorbike, robot and steed. However, taking a choose-your-own-analogue approach risks creating a fractured understanding of how to be in and around autonomous vehicles across a population, which just seems like another “recipe for disaster” (Ju, 2015). This highlights a tension between reflective, meaningful and ameliorative relationships with ambiguous machines and func-
tional, universal and safe interactions with autonomous machines.

**Biomimicry**

Mood boards full of flowers, mushrooms, jellyfish and octopuses (Figure 2.22), combined with all the talk about the Umwelt and evolutionary robotics means this thesis presents like an exercise in biomimicry. This is true to some degree, however, I would like to bring a little more nuance to this term. The widely understood intention of biomimicry is to “transfer solutions” that have evolved from nature to problems that engineers are trying to solve with technology (Vincent et al., 2006). Burdock seeds transferred to Velcro, winged seeds transferred to the aeroplane and shark’s skin transferred to swimming suits are some of the more iconic examples of this (ibid.).

I would like to distance my work somewhat from these intentions for two reasons. Firstly, because the radially symmetrical form that the drones, flowers, mushrooms and jellyfish all share was actually explored with an aesthetic intention. In other words, these explorations helped me imagine what it would feel like to move with these organisms, experience their otherness. Similar to Eriksson and colleagues’ work entitled *Dancing with Drones*, in which a choreographer moved herself in order to “imitate and feel the affordances and expressivity of the drones’ ‘otherness’ through her own bodily experience; communicate to the engineer of the team how she wants to alter the drones’ behaviours to be more expressive; enact and interactively alter her choreography” (Eriksson et al., 2019). I see these processes as an important part of Mechanical Sympathy, and an extension of the somaesthetic ideals.

Secondly, this interpretation of biomimicry fails to see these “solutions” that nature has “designed” as evolving elements, mutually entangled with a balanced ecosystem. The organisms that embody these “solutions” are completely indifferent to the impartial evolutionary forces that seek to temper or enhance their effectiveness with every generation. These forces are of course in the service of maintaining an ecological balance. In other words, I see the practice of removing solutions from the context from which they have evolved as problematic and, therefore, not the intention of this work.

However, I cannot distance this work completely from biomimicry by definition and so I draw out these two extremes in order to position my work within them. In the next section we will see how the processes of biology as opposed to its “solutions” are used to generatively expand the soma design program.

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To further emphasise this contrast I draw your attention to Nabeshima and colleagues’s *Arque - Artificial Biomimicry-Inspired Tail for Extending Innate Body Functions* (2019). This work is almost identical to Dag Svanæs’ *Human Tail Project* but with a solution-oriented intention, as opposed to Dag’s work which positions your felt experience centre stage. They are so removed from each other’s academic spheres that they don’t even cite one another.
3.2 Expanding the Soma Design Program

Soma design argues that cultivating somaesthetic appreciation can lead to more fulfilling relationships with technology (Höök et al., 2016; Höök, 2018). In the case of How to Train Your Drone, we see that the process of cultivating Mechanical Sympathy allowed each participant to move from an ‘infant’ stage of sensing and acting towards a relationship with their machine flourishing with meaningfulness. In this section we will work backwards through Mechanical Sympathy, from meaningfulness towards sensation and action in order to highlight the depth of bodily understanding that comes from starting at the “infant” stage. We will primarily use examples from the How to Train Your Drone study participants so that we are not keeping track of too many journeys at once. (However, recall that the journey I took from Tai Chi in the Clouds through Drone Chi, to the design of How to Train Your Drone, takes on a similar trajectory.) I will then gradually reintroduce the worldview presented in the theory and method chapter to expand the soma design program.

From Making Meaning to Sensing and Acting

During the process of cultivating Mechanical Sympathy, each participant reflected on and articulated what they found meaningful and fulfilling in their experiences. Tom pondered the experiences that he might be missing because of his methodical and narrow approach to exploring the system. Nora spoke about the social interactions that arose around the drone, including how she found joy in performing with Justin and how interacting with others helped change her attitude towards her body. Nora also described how the playful learning experience offered her a kind of exploration that she had not engaged in since she was a child. Finally, Justin reflected on how the system allowed him to combine poetry and metaphor with technical and practical descriptions – in which he found value as a means of expressing himself. Justin also explained how the system made different experiences available to him – experiences of slowness and calm – by forcing him away from his habitual fast-paced ways of being and doing.

Ståhl and colleagues have shown how long-term engagement with rigorously crafted somaesthetically designed objects can offer similar transformative experiences (Ståhl et al., 2022). Mechanical Sympathy supports these transformative reflections by providing the ‘scaffolding’ to move from reflection on meaningfulness and value towards meliorative improvement, or in other words, supports the participants in actively practising and cultivating these new uncovered values. In this sense, Mechanical Sympathy denotes, not only a process, but also an attitude or willingness towards engagement. According to Schön, this willingness is critical to meaningful engagement (and by extension, to the cultivation of value):
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“I can tell you that there is something you need to know, and with my help you may be able to learn it. But I cannot tell you what it is in a way you can now understand. I can only arrange for you to have the right sorts of experiences for yourself. You must be willing, therefore, to have these experiences” (Schön, 1983).

In other words this is not a property wholly intrinsic to the designed object. You cannot inject somaesthetics into whatever you design and expect people’s somas to sensitise with no will or effort - being open to change and critical reflection is also a must. What’s more is that it is often difficult, and, therefore, designing technology to support this transformation is what a lot of the methods and concepts in the theory and method chapter (see section 1.1) are intended to support.

In *How to Train Your Drone*, the active and dormant points constantly present the participants with a simple choice; Do I catch an old point or train a new one? Through repeatedly being faced with this question, a new question began to emerge; What do I want to be feeling/doing?. Justin sought the capacity to engage in humorous tomfoolery with his drone; Nora desired to create joyful and creative performances; and Tom wanted a feeling of reward either through pleasure or challenge. By implicitly asking each participant to construct their own experiences in the face of ambiguity (Sengers and Gaver, 2006), the participants were supported in the critical and meliorative practice of cultivating Mechanical Sympathy. Here, these meaning-making processes reveal a process of somaesthetic self-stylisation – prompting the participants to make decisions concerning how to shape themselves and how to shape the system to suit themselves.

Through making space (Höök et al., 2016) for participants to cultivate Mechanical Sympathy, there is a shift in the relationship between the designer and the user. Here, as designers, we asked more from the user in the interaction - by handing them an interaction laden with ambiguity and a distinct lack of obvious purpose. *How to Train Your Drone* provokes the user to find the intrinsic value of the machine, a value largely unique to the individual. This has long been lauded as a good thing in the field of HCI because it matches the realities of the everyday experience (Sengers and Gaver, 2006) and the situated nature of our meaning-making processes (Suchman, 1987). It also blurs the traditionally perceived boundary between the designer and the user, where the designer hands something finished over to the user to use, complete with an instruction manual. This shift renders the relationship closer to the notion of “contemplating the
CHAPTER 3. DISCUSSION AND CONTRIBUTION

truth” alongside the designer mentioned in the theory and method chapter (see section 1.2).

The lived experience of an individual also plays a pivotal role in this meaning-making process (McCarthy and Wright, 2004; Petersen et al., 2004). The somatic meaning-making explorations – with their own bodies, with their drones, and their relationships with their drones – were often expressed by the participants using rich, anthropomorphic, zoomorphic, metaphorical, or analogous descriptions. Tom said his bodily creativity within the limitations imposed by the drone was analogous to writing poetry; Nora anthropomorphised the drone as a means of allowing their joint agency to shape her creative process; and Justin conjured poetic, metaphorical interpretations of the relationships between his felt experiences and the technical parameters of the system. These articulations shed light on how participants drew from their lived experience, interests, values, and desires.

Beneath these linguistic interpretations lies a bedrock of pre-reflexive sensing and action. The participants made sense, through epistemic action (Kirsh and Maglio, 1994), in analogous fashion to how my infant daughter explored the world in her early days. I refer back to the quote from psychologist Barbara Tversky in Section 1.4 to explain these parallels. These processes were fundamental for the participants and myself in making sense of how the machine functioned and the different reactions our movements elicited from it; the question of what am I feeling/doing? that drove the oscillations would not be possible without it.

When Nora accidentally stepped into a previously trained point for example, she united an action to a sensation in the human-with-machine assembly, opening up new possibilities for her to explore (see Figure 2.41). Similar possibilities were revealed to Justin when he discovered how to perform translational movement, or to Tom when he began to solve his body puzzles or to myself when I had that first flight feeling (see Figure 2.6) and the drones were finally responding to the movements of my hands. I believe that affectively engaging with the drone at this embryonic level, where meaning has yet to be created, somatically equipped us to cultivate Mechanical Sympathy - a process of sensing and acting that leads to a cumulative appreciation of human-with-machine.

Shaping the Machine’s Umwelt

I also see this kind of engagement as an example of our constantly changing kinetic bodily logo’s, which we explored in the theory and method chapter (see section 1.4) shaped by a swirling mix of genetic, societal, behavioural, morphological and environmental factors. Factors that we must constantly adapt to, yet which at the same time reveal new interaction opportunities. However, it is also clear that the drones are also adapting and being shaped by the very same factors, which is in turn revealing new interaction opportunities to them. We could now use Sheets-Johnstone’s concept of kinetic bodily logos to talk about the drones’ capacity to respond and adapt, but recall in the theory and method chapter I decided to
import Jakob von Uexküll’s Umwelt (see section 1.4). They are indeed closely related. Both of them are grounded in sensory biology and natural history and both of them view sensing and acting as fundamental building blocks to meaning-making. Sheets-Johnstone even refers to the Umwelt in her essay *Consciousness a Natural History* (Sheets-Johnstone, 1998):

“Animate forms are built in ways that are sensitive to movement. They can be sensitive to dynamic modifications in the surrounding world and to dynamic modifications of their own body. A moment’s serious reflection on the matter discloses a major reason why movement sensitivity is both basic and paramount: no matter what the particular world (Umwelt) in which an animal lives, it is not an unchanging world.”

Sheets-Johnstone (1998)

Given all that, we will now pivot to the Umwelt. My reasons are borderline semantic but important nonetheless. By moving forward with the Umwelt we carry with us the dynamic, situated and generative character of kinetic bodily logos, but now we explicitly acknowledge that radically different organisms, in radically different environments will experience life in radically different ways. Ways that are unknowable to us. In doing so we leave behind the debates about consciousness and the explanatory gap, leaving us free to marvel and appreciate the incomprehensible differences between us and the other. I think this presents rich opportunities for somaesthetic appreciation to both the designer and the user alike.

Now let’s turn our attention to the drones. In Figures 2.45, 2.46, 2.47, and 2.48 we see Tom, Justin, Nora’s and my own drones, each surrounded by little cubes. Each cube represents a point that we created around our drone. If you squint at them, you can see that they begin to take on a form of their own. In Figure 3.5 our drones are playfully rendered out as deep sea creatures. Now the size of the ‘magnetic bubbles’ around each point are also visualised and the differences in form are even more clear. The drones are rendered as deep sea creatures to demonstrate the point that each of them has its own areas of ‘sensitivity’ relative to itself. It is important to note that the negative space is as important as the positive space, and that the size of the ‘magnetic bubbles’\(^7\) dictates the density of points as they accumulate. The process of shaping of this overall form is what makes these drones meaningful to Tom, Justin and Nora.

Each time a pair of new points are created, it can be thought of as an alteration of the drone’s capacity to sense the human. As such, I consider the drone’s (virtual) morphology and by extension its Umwelt as being dramatically shaped by the participants’ accumulative interactions with it. The human-with-machine assemblage is the architect of the drone’s sensory layout. Here I stretch the Umwelt to include the robotic agents from *How to Train Your Drone* not because

\(^7\) A reminder that an in depth description of the *How to Train Your Drone* system can be found in section 5 of paper D
I think they are conscious or intelligent in some way but because in doing so we decentralise the human as the only way in which to experience the world and instead foster a curiosity for the experience of the other.

**Affective Communication Between Umwelten**

This acknowledgement of unknowable worlds is an important one, and is the reason why Mechanical Sympathy is not called mechanical empathy. In other words Mechanical Sympathy is about mutual affect, not mutual effect. To tease out these differences I am going to start quoting the dictionary, which is bold of me since I was often scolded at school for mincing my words. The top two Merriam-Webster definitions of empathy are “the action of understanding, being aware of, being sensitive to, and vicariously experiencing the feelings, thoughts, and experience of another” and “the imaginative projection of a subjective state into an object so that the object appears to be infused with it” (Merriam-Webster, 2023a). Now, upon first glance this seems quite somatic, we have the words, “being aware of” and “sensitive to” but these words are directed at another agent, not inwards. So within a given human-with-machine assemblage, we do not expect the drone to have the necessary lived experience to appreciate what Justin is talking about when he describes it as “a mossy stone that is shaped by water flowing over it” with all of the statement’s sensory and cultural connotations. Just as we do not expect Justin to be have the lived experience to appreciate what it is like to have to fly with an unbalanced propeller or an improperly tuned control algorithm. These understandings are mutually inaccessible.

On the other hand, the top two Merriam-Webster definitions of sympathy are “an affinity, association, or relationship between persons or things wherein whatever affects one similarly affects the other” and “mutual or parallel susceptibility or a condition brought about by it” (Merriam-Webster, 2023b). So within a given mechanically sympathetic human-with-machine assemblage, if something is happening to the machine, nominal or not, the human is going to know about it and vice versa. They are mutually affecting one another. We do not need to know how exactly this will effect each agent, what is important is then the affective link between the two; enabling them to intimately communicate to each other without the implication that they need to completely understand each others experience of reality.

**Infinite Umwelten - All valuable in their own right**

Jakob von Uexküll used his biological training to reconstruct the rich environments of other species such as the sea urchin and the jellyfish. This may seem, based on what I just wrote that he was trying to empathise with these animals, perhaps even humanise them. What he was trying to communicate however, was that there are an “an infinite variety of perceptual worlds” that are “all equally perfect and linked together as if in a gigantic musical score” (Agamben, 2004).
Similarly, science writer Ed Yong, whom I also quoted in the theory and method chapter, discusses the meaning-making process as being intrinsically tied to how we sense and act. I here I a quote from him: “The senses transform the coursing chaos of the world into perceptions and experiences—things we can react to and upon. They allow biology to tame physics. They turn stimuli into information. They pull relevance from randomness, and weave meaning from miscellany” (Yong, 2022). He continues, “The senses constrain an animal’s life restricting it to what it can detect and do” (ibid.).

Yong also recognizes the value of appreciating the hidden realms of animal experience in their own right by writing, “Some scientists study the senses of other animals to better understand ourselves, using exceptional creatures such as electric fish, bats, and owls as ‘model organisms’ for exploring how our own sensory systems work. Others reverse engineer animal senses to create new technologies… . . . I’m not interested in either”. He continues, “Animals are not just stand-ins for humans or fodder for brain storming sessions, they have worth in themselves” (ibid.). Like von Uexküll, Yong espouses a curiosity to uncover some of the “infinite variety of perceptual worlds” out there and his reasons for doing so also have a humanistic bent. “Nothing can sense everything, and nothing needs to.” Indeed, that is why Umwelten exist at all. It is also why the act of contemplating the Umwelt of another creature is so deeply human and so utterly profound. Our senses filter what we need. We must choose to learn about the rest” (ibid.).

His attitude or willingness to engage with the world is similar to the one we described earlier using a quote from Schön, and is one of the three reasons I am importing the Umwelt into the soma design program. The second reason is to add weight to the argument that we will never know any other way of being in the world other than our own, and as such should instead explore designing and interacting with robots that enable us to have the kinds of mutually affective relationships with them that we have discussed in this thesis rather than expecting the robot to sense and act on the world from a human perspective (Hu and Wang, 2020) or projecting our bodily experience of the world through theirs (Dörrenbächer et al., 2022, p.140). Thirdly, the notion of an “infinite variety of perceptual worlds” is, to me, humbling and inspirational, regardless of whether it spawned on the bottom of the sea or was engineered on a lab bench. Each and every agent’s Umwelt presents you with an opportunity to appreciate how its Umwelt differs from ours, appreciate a different aspect about our own human condition, and, finally, make meaning from these differences.

These potential assemblages are what gets me most excited about the future of somaesthetic robot design and I owe this enthusiasm to a large extent to the writings of Godfrey-Smith, Yong and von Uexküll. Every time I take an excursion

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8I especially like the beginning of this quote as it speaks for the value of limitations. How they bring meaning to reality. Just like the points around the drones, technically we could have points everywhere at an arbitrary density. But as Tom said, it would be like “free form poetry” and “would start to lose its meaning.”
into an unknowable world it spawns a stream of ideas I want to explore. I once again get the feeling of wanting to make things with abandon in the face of ambiguity, just as I had at the beginning of this PhD. I feel like I could start all over again, how lucky am I to be able to say this and mean it!

**Evolutionary Robotics and Research Through Design**

Recall the initial examples of morphological computation in the theory and method chapter (see section 1.4). The *Eyebot* demonstrated how an insect-like arrangement of its light sensors can make it “computationally” less expensive to avoid its prey than a human-like arrangement. The *Sprawl* robot exploited its material properties and morphology to leave ASIMO in the dust over uneven terrain. Both of these examples not only allude to their own sensory way of being in the world, as discussed in the previous section, but have also reached their morphological state through some combination of iterative and evolutionary design processes. I see deep similarities between the evolutionary robotics approach and Research Through Design both in motivation and practice.

As mentioned in the theory and method chapter (section 1.4), Pfeifer and Bongard state that a broad aim of evolutionary robotics is to “learn about biology, but also about intelligence in general. An exciting prospect is that this enables us not only to study natural forms of intelligence, but to create new forms of intelligence that do not yet exist; ‘intelligence as it could be’” (Pfeifer and Bongard, 2006). They argue that “Intelligence, in this sense, is not so much a property of an agent, or of the brain, or of evolution, but rather resides in the eye of the beholder, so to speak, who observes the agent” (ibid.). Compare this to Research Through Design, which according to Redström questions, “what can design reveal about the world, as it could be?” (emphasis my own) (Redström, 2017). Just as the roboticist would continue on their research path, informed by some notion of intelligence, so too does the researcher practising Research Through Design, informed by some notion of a worldview. Redström describes the worldview as a “a set of theories held true as a foundation for further research”. Before we get into these similarities, I will offer a little clarification on what I mean by ‘the roboticist’ in the coming sections. I use the term strictly in an evolutionary robotics (GEC, 2023) and an artificial life (ali, 2023) context, not in a human robot interaction context. Therefore the roboticists that I write about are not primarily concerned with how the human interacts with their designs.

**The Synthetic Methodology**

The roboticist in practice, looking to explore a robot design at a more holistic level, would include the shape of the robot, its materials and the integrated software in their search for an optimal design. Given the sheer complexity of this undertaking, the solution space can grow unfathomably large. Which is why Pfeifer and colleagues state that “evolution can also be viewed as a designer,
3.2. EXPANDING THE SOMA DESIGN PROGRAM

albeit a “blind one”, but an extremely powerful one nevertheless” (Pfeifer et al., 2005), evolution still requires some boundaries to work within otherwise “the length of the genome which is required for encoding these shapes will grow very large and there is no hope that anything will ever converge on a good solution” (ibid.). This is why there are many different approaches to agent design. “As a consequence, agent design is - typically - performed in an ad hoc and intuitive way” (ibid.) and that “often the path towards a final design is guided by a set of heuristic principles” (some of which we will visit later) (Corucci et al., 2015). Furthermore, morphologies are typically optimised with a specialist roboticist working in tandem with an evolutionary algorithm, simulations and real world tests to navigate the solution space (Bredeche et al., 2019). This approach is what Pfeifer and Bongard refer to as the *synthetic methodology*, which, as you may recall from the theory and method chapter (section 1.4), carries the motto “understanding by building” (Pfeifer et al., 2005).

Now compare this to Research Through Design in practice, where it is normal to find open ended approaches and research questions that are too slippery to be defined or are constantly changing. If you consider the solution space to be analogous to the possible futures a design researcher considers when designing, then the number of possible futures is also unfathomably large. This calls for the researcher to practice design within some program, apply their craft knowledge, be inspired by past lived experience and or draw from the concepts and methods of established disciplines. Soma design (used here as a specific example of Research Through Design) is not really rules based either, but rather a collection of intermediate knowledge in the form of strong concepts (Höök and Löwgren, 2012), experiential qualities (Löwgren, 2009) and design methods (Wilde et al., 2017) that help to generate new design work (Höök, 2018, p.122). Therefore, there is a fair amount of flexibility afforded to the designer so that they can navigate the solution space and converge on an ultimate particular (ibid.).

Finally, to add one more similarity, the two disciplines are in healthy, academic and cross-disciplinary tension with their more scientific neighbours. “Physicists and control engineers have a preference for differential equations, but they are better suited for analysis than for design”, Pfeifer and colleagues continue. “For the time being, it appears that progress over the last few years in the field has been slow, and we may be well-advised to search for an “intermediate” solution, between no theory at all (or purely [philosophical] ones), and a rigorous mathematical one,” they conclude before introducing morphological computation as one of their intermediate solutions. I will repeat my favourite quote in HCI again, as it reflects the epistemological tightrope that these two practices walk, “A concept can be used to rationalise why one design is better than another. Or it can be used to design something else” (Pierce et al., 2015).
**Evolving with an Umwelt - A case for a soma in the loop**

Soma design, being a kind of Research Through Design, is well positioned to incorporate the practices of evolutionary robotics into its program. In the theory and method chapter I introduced the evolutionary approach to design through the 2D boxcar (see section 1.4), *Sprawl* and *Eyebot* examples. Now let me introduce an example that is closer to *How to Train Your Drone*. The *Block Pusher* is a virtual agent that is comprised of spheres or “cells” (see Figure 3.6). White cells can sense and actuate, grey cells can only sense and black cells can neither sense or act. The multi cellular agent attempts to push a block as far as it can in a single time step. Between steps it grows in shape, size and complexity. This growth is regulated by a “biologically inspired” genome that is being modified by an evolutionary algorithm, which in turn evaluates the agents “fitness” based on how it performed in the task environment\(^9\).

The 2D box cars are evolving in a relatively narrow solution space compared to the Block Pusher. The designer of the simulation, had already determined that a vehicle with powered wheels and a rigid body will be the way that these agents will traverse the bumpy road. The evolutionary algorithm is limited to various size combinations of rigid chassis members and powered wheels. On the other hand, the Block Pusher is more open ended because it uses an accumulation of spheres with different characteristics - here the algorithm is able to evolve a much broader set of ways of pushing the block.

Pfeifer and Bongard see this as not only a way of broadening the solution space, but also as a way of abstracting the designer’s bias. Stating that “If we want to explore different types of morphologies, we want to introduce as little designer bias as possible. This can be done using ideas from biology, such as working with large numbers of building blocks.” This resonates with my intentions of the ‘point cloud’ in *How to Train Your Drone* (which I consider analogous to building blocks here), as a way to minimise my influence and allow the participant’s soma to drive the process of Mechanical Sympathy.\(^{10}\)

Figure 3.7 is an example of a solution that could push the block, a worm like agent with various appendages protruding form one end of its body. Cells

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\(^9\)A task environment is the definition of a task within some virtual or non-virtual environment. In other words it is an objective definition of the tasks that need to be performed, how to evaluate them, and the exact conditions that the tasks will be performed in (Pfeifer and Bongard, 2006, p.101). Whilst designing a robot, a roboticist will often cross the “sim to real” gap (Bredeche et al., 2019) in order to iterate their designs in both a simulated and real task environment, each bringing unique advantages to the design process.

\(^{10}\)It would be foolish to think that my influence could be completely removed from the interaction and therefore I tried to demonstrate an awareness of this influence during the design of *How to Train Your Drone*. However, there will always be blind-spots. For example, whilst the participants were free to create points anywhere around the drone, the rules that governed recapturing those points were programmed by me. I made them quite binary in the sense that you were either holding points or you weren’t, this inadvertently brought with it the idea that holding points was a ‘success’ and dropping them was a ‘failure’ (which resonated most strongly with Justin and Tom).
sense and act in a certain rhythm in order to move the agent or push the block - similar to the motors driving the Sprawl robot in the theory and method chapter (see section 1.4). These rhythms are always changing, reacting to new growth or environmental changes like friction or block weight, but eventually settle on something that ‘fits’ with the body. Therefore, the shape of the Block Pusher’s body stands as an example of both morphological computation and the Umwelt. A body, shaped for the task, an ‘experience’ of reality, unknowable to us bipedal humans. However, there is a lot to be felt and aesthetically appreciated from the movement of this agent and its development - rhythm, agility, strength. If we could only move with them somehow to experience how they grow and change over the course of (in this case) 500 development cycles.

The accumulated virtual points around each of the participants’ drone in How to Train Your Drone is a less dynamic example of what I am getting at here. Just like the Block Pusher we have a body, changing and growing, in response to the stimulus from its task environment. Only that in the case of How to Train Your Drone it was the human providing the stimulus and the (virtual) body is changing and growing in response.

Here in lies the difference between projects like the Block Pusher and How to Train Your Drone, despite both projects requiring the designer to tread that fine line between a science and an art form, the Block Pusher looked to the objective process of evaluating and optimising a task environment (Pfeifer et al., 2005), while How to Train Your Drone looked to the subjective process of ameliorating the soma. Both of these are iterative processes with very different epistemological stances. Referring back to Höök’s horse riding experiences, where she wished to transfer qualities such as rhythm, reciprocity and tacit knowledge to interaction design, note that she wrote “it is not the ability to fulfil a task, but the experience of the corporeality of doing so that matters here” (Höök, 2010).

If evolutionary robotics places a roboticist in the loop to ensure an agent is optimised for a task environment, what if an interaction design places a designer in the loop to explore and ameliorate their own soma? By incorporating the methods and concepts of evolutionary robotics into the Soma design program, a design space emerges driven by the aesthetic appreciation of designing and evolving ambiguous machines. Shaping the robot whilst being shaped by it — its constantly evolving morphology and behaviour a source of reflection, estrangement, change, interest and playful delight.

Making Meaning Between Academic Fields

Now that I have explained the motivation for incorporating an evolutionary robotics approach into soma design, I would like to draw a few parallels between it and some of the so called New Robotics design procedure principles (Pfeifer et al., 2005). The principles are typically used in the broader academic contexts of evolutionary robotics (GEC, 2023) (in service of novel robot designs) and artificial life (ali, 2023) (in service of discoveries in biology through the robotic
emulation of biological systems (Vargas et al., 2014)). There are 5 of these design procedure principles. All of the principles are intended to facilitate inquiry into the notion of intelligence. They are generative in the sense that they are meant to spawn more questions than answers. I think that makes them well suited for incorporation into the soma design program. In doing so, we turn the direction of inquiry from intelligence to meaning-making through appreciation.

The 5 design procedure principles are:

1. The synthetic methodology (covered in Section 3.2)
2. The frame of reference principle
3. The time perspectives principle
4. The diversity compliance principle
5. The principle of emergence

These parallels each have their limitations that should be acknowledged. The new robotics principles are grounded in the fields of biology and computer science, fields that I have only a basic grasp of. Additionally, the connections that I do draw are based on the relatively superficial example of morphological computation from How to Train Your Drone that I wrote about earlier. As such, these parallels are admittedly speculative, but hopefully generative.

As I wrote in the theory and method chapter the new robotics principles were written back in 2003. Since then the field has advanced tremendously. Bongard’s team alone has moved from electro-mechanical robots (Bongard et al., 2006) to soft robots (Kriegman et al., 2019) to, most recently, robots grown from organic tissue (Blackiston et al., 2021), which he views as further “demolishing dichotomous thinking with synthetic proto-organisms” (Bongard, 2022). It is my hope that these advancements serve to inspire further integration of evolutionary robotics and soma design.

The Frame of Reference Principle

This principle acknowledges three distinct perspectives - those of the agent, the observer and the designer. The agent’s perspective is informed by the stimuli from its environment and its reactions to them. The designer or team of designers’ whose perspective is informed by being involved in the design and evolution of the agent. The observer’s perspective, who has little knowledge of how the agents were designed or evolved and will perhaps draw very different conclusions than that of the designer (Pfeifer et al., 2005; Pfeifer and Bongard, 2006). This principle reminds roboticists that perspective matters when considering questions of intelligence. Similarly, exploring the relationships between these perspectives is a way of structuring somaesthetic inquiry. In other words, a way of appreciating your own perspective through an inquiry into the perspective of the other.
We have touched on perspective taking before in this thesis, both in a physical/literal sense (e.g. the bystander, observer or operator’s perspectives) and in a figurative/lived experience sense (e.g. the designer, user, engineer or artist’s perspectives). The sessions where the participants tried each other’s drones or when Justin attempted to construct a drone catapult, stand as good examples of cultivating Mechanical Sympathy through perspective taking.

The Time Perspectives Principle

This principle frames the development of an agent across three different time-based perspectives. The here and now, considers the sensing and acting capacities of the agent in the moment. The ontogenetic view, which considers an agent’s capacity to learn over its lifespan. The phylogenetic perspective, which considers the morphology of the agent’s particular generation, where it came from and how it could shape the next generation. These three perspectives constitute a continuously unfolding and multidimensional way of considering why an agent is doing what it is doing, with each perspective contributing a different and complementary explanation. This thesis has only just touched on the here and now perspectives and the ontogenetic perspectives of drones, cars and go-karts (refer to appreciation of change and appreciation of difference in section 2.3). Nevertheless, this was done at a very superficial level as there was no concrete affect between the three different perspectives. Considering machine behaviour and morphologies over generations opens up a longer time scale through which you can appreciate and make meaning with a machine.

The Diversity Compliance Principle

This principle puts the actions of exploitation and exploration at odds with each other. Through exploitation, an agent can build on the existing capabilities of its body and how it is controlled. Through exploration it can find new capabilities by growing its body to a new form or performing seemingly random exploratory actions to discover a better strategy. For example early generations of the Block Pusher started as single worm-like form that both pushed the block and moved itself. Many generations later, it began to grow new limbs that had a similar structure to its body but specialised only in pushing the block, not locomotion. It leveraged the capability of growing the worm like structure to grow new appendages that work more like arms (Pfeifer et al., 2005; Pfeifer and Bongard, 2006). In this thesis I presented the human-machine assemblage with a similar kind of exploit or explore dilemma, which was to use existing points or create new ones. In doing so, the participants and I developed our relationship to the drone through movement experiments (akin to exploitation) and experimental movements (akin to exploration). Recall that Nora was able to make the drone “pop up” by moving her hands through the points in a certain way, thus expanding her improvisation repertoire. This is just one example of an explore/exploit
dilemma, there are many other ways that could facilitate this kind of richness in the meaning-making process.

The Principle of Emergence

This principle considers any behaviour that is not programmed explicitly into an agent. For example, the genes that drive the growth of the Block Pusher’s body contain no information on how to coordinate amongst themselves, yet the worm-like motion emerges. Another example is that the shape of the ‘2D boxcars’ tends to be triangular such they never land flat on their back, giving themselves a chance to right themselves again. What is most valuable to those who carry out research into intelligence are the processes of explaining and designing emergent behaviour in order to be able to look at the behaviour from all the different aforementioned perspectives and come up with an explanation, or, a more challenging prospect, be able to work with the basic rules as they unfold and design for a certain outcome (Bongard, 2022).

From a soma design perspective, this kind of reflection and articulation is also important and drives the inquiry into the human-machine relationship, as we have seen many times in this thesis. In doing so we also make meaning with the machine in ways that have not been done before - analogues or metaphors born from a mix of our own lived experience and the felt experience with this unique form of machine, one that is hard to place into existing categories. Julian’s shuffling star move was appreciated by all as an impressive move. Who would have thought that would be something of value at the start of this study? It was the catalyst that fused his interpretations of “old man” and “mossy stone being shaped by water” into a novel and rich analogue “old stoney”.

Balancing Amelioration and Optimisation

In this thesis I have put forward two ways to support meaning-making with ambiguous machines. The first being the process of cultivating Mechanical Sympathy. Through this process, you are able to sensitise yourself to a machine, and jointly develop a way of interacting. This also improves your ability to articulate and make sense of what you are feeling/doing with the machine. The second being a proposed expansion of the soma design program to incorporate design principles from evolutionary robotics. This expansion, gives some structure to the soma design process when the thing being designed is less of a socio-digital material (Höök, 2018) and more of an ambiguous agent.

In this final section, I will draw upon work within the field of HRI, weaving together designerly, performative, aesthetic and feminist perspectives to support the
3.2. EXPANDING THE SOMA DESIGN PROGRAM

need for Mechanical Sympathy and an expansion of the soma design program.\textsuperscript{11} Then, using Matthew B. Crawford’s romantic notions of the craftsperson and the mechanic (Crawford, 2010) as a starting point, I will attempt to sketch out a future where meaning-making with ambiguous machines plays a bigger role in our everyday experience.

In the previous section, I made the distinction between the amelioration of the soma and the optimisation of a task environment to highlight the change in intention these design procedure principles now represent within the soma design program. In the field of HRI, some researchers lament a lack of balance between these intentions. In a paper calling for the appreciation of aesthetics in soft robotics, Jonas Jørgensen states that “any consideration of the significance that aesthetics might have for soft robotic design practices and interactions between humans and soft robots have generally been elided in favour of a focus on functionality and safety” (Jørgensen, 2023). Similarly, in a paper that makes the case for a feminist approach to HRI, Winkle and colleagues argue that there is a “a lack of consideration regarding users’ bodily experiences, in place of focus on opinions about the robot or more objective measures pertaining primarily to task efficiency” (Winkle et al., 2023). Finally, Gemeinboeck and Saunders argue against the apparent need for “predefined meaning of an individual robotic agent” through performatively designing with cube shaped robots (Gemeinboeck and Saunders, 2023).

Furthermore, each of these researchers highlight something different that goes missing as a result of such an imbalance. Jørgensen describes his experiences interacting with soft robots, “contemplating the expression it facilitated was triggering, as the movements were imbued with both consistency and sense yet retained an indistinction and open-endedness” something he claims that the dominant epistemology is not able to capture (Jørgensen, 2023). Winkle and colleagues suggest that “a sensitivity to power [structures] and to individuals’ goals and values” should be more prominent and the politics of who gets to design for who should be more deeply considered (Winkle et al., 2023). Gemeinboeck and Saunders demonstrate that meaning-making with the non-human, unleashes the human capacity to move and imagine (Gemeinboeck and Saunders, 2023).

By synthesising these views we see the need to consider design as a continuous process, happening across the designer-user divide. In other words, rejecting the idea that the designer hands something ‘finished’ over to the user. Winkle and colleagues propose that participatory approaches to design is one way to address this need. “Participatory design and ethnographic studies highlight the importance of trying to account for the broader social context a robot will be embedded in” (Winkle et al., 2023). I argue that there needs to be more fine-grained and ongoing approaches to complement this. Approaches that are able

\textsuperscript{11}By highlighting these approaches, I do not mean to imply that my work is critical of HRI, I acknowledge that this work is not properly grounded in the field. My work is instead approaching the fields of HRI and evolutionary robotics from its designerly HCI beginnings to discuss how the three of them might coalesce.
to support the individual soma and the specifics of their context. Gemeinboeck and Saunders describe their work as participatory, but with this higher level of granularity, they write, “as we strive to collapse the distance between subjects and objects, we also seek to render the boundary between performers and audiences more porous” (Gemeinboeck and Saunders, 2023). They do so by performing in gallery spaces, where the lack of a stage encourages the audience to perform with them. Asking them to interact with their ambiguous, “blank slate” cube robots and make their own meaning with them (ibid.).

This thesis “Cultivating Mechanical Sympathy, Making Meaning with Ambiguous Machines” stands as another example with perhaps an even higher granularity. This is insofar as each person had their own drone, car or go-kart, in their own lives and sets about creating with it or maintaining it, in a situated context. However, if we are serious about the soma design program growing into a fully fledged practice and impacting the day-to-day lives of those beyond the reach of a field study, then we need to have a discussion about the real world. Here I bring in the romantic notions of the craftsperson and the mechanic, from Matthew B. Crawford’s Shop Craft as Soulcraft, an inquiry into the value of work as a springboard into this, the final leg of this chapter.

“To be master of ones own stuff, is to be mastered by it” Crawford writes of the mutually shaping relationship between a craftsperson and the material in their hands or between the mechanic and the machine they are fixing (Crawford, 2010). Here he highlights two different dimensions of this shaping that I see in the cultivation of Mechanical Sympathy. The first dimension is the intrinsic value of the process, Crawford writes about his pursuits as an electrician and a motorcycle mechanic, “I felt responsible to my better self. Or rather, to the thing itself — craftsmanship has been said to consist simply in the desire to do something well, for its own sake. If the primary satisfaction is intrinsic and private in this way, there is nonetheless a sort of self disclosing that takes place” (ibid.). This resonates strongly with Mechanical Sympathy in an ameliorative and generative sense.

The second dimension is the humbling experience of repairing a machine, which Crawford refers to as a stochastic art. “Because the stochastic arts diagnose and fix things that are variable, complex, and not of our own making, and therefore not fully knowable, they require a certain disposition toward the thing you are trying to fix. . . . . . . Getting it right demands that you be attentive in the way of a conversation rather than assertive in the way of a demonstration. I believe the mechanical arts have a special significance for our time because they cultivate not creativity, but the less glamorous virtue of attentiveness. Things need fixing and tending no less than creating” (ibid.). This resonates strongly with Mechanical Sympathy in a reflective and critical sense.

Crawford, advocates strongly for the situated mechanic and craftsperson. Romanticising about the communities built around the speed shop, a place where you go to buy parts to make your car go faster, where you can also swap stories and favours with other petrol-heads. Or the kind of undeniable responsibility
3.2. EXPANDING THE SOMA DESIGN PROGRAM

that is owed by a craftsperson to their work, as it is physically situated for example, in a person's home, who may live in the same area. The quality of the work reverberates throughout. It is only through situated practice, that you begin to realise the impact of your work. “There is a progressive revelation of why one ought to aim at just this, as well as how one can achieve it. As you learn your trade this particular end takes its place in a larger picture that is emerging, a picture of what it means to be a good plumber or a good mechanic” (ibid.). This is much like the kind of realisation you have cultivating Mechanical Sympathy, where your aesthetic preferences begin to reveal themselves.

Unsurprisingly, Crawford laments the way that, globalisation, automation and oppressive labour laws have limited the opportunities (jobs) for engaging with the world in this way. Stating that the “grime-under-the-fingernails”, bodily involvement with the machines we use entails a kind of agency\textsuperscript{12} “the idea of agency I have tried to illustrate in this book is... ...activity directed toward some end that is affirmed as good by the actor, but this affirmation is not something arbitrary and private. Rather, it flows from an apprehension of real features of the world, yet the decline of such involvement, through technological progress, is precisely the development that makes for an increase in autonomy. Is there a paradox here?” (ibid.)

Crawford’s views here demonstrate a tension between amelioration and optimisation, or rather a job worth doing and a job well done. However I think this tension is only there when viewed through his sepia tone glasses. Taking them off we see something much richer, and in full technicolor. All I see is the dominance of one epistemology rather than an exchange between them. Jørgensen characterises this exchange by stating that, “Artistic work with robotics technology has potential to yield novel and sometimes surprising and unexpected solutions that, from an engineering perspective, are not supposed to work, yet somehow do. In my own research, soft robot morphologies and technical solutions developed for art purposes have thus been transferred to both evolutionary robotics and neuromorphic computing as well as HRI experiments” (Jørgensen, 2023). Jørgensen is not suggesting that artistic practices play hand maiden to the applied sciences, rather they should be recognised for their unique ability to “pay attention to the singular, not just the general, and accept to remain with ambiguities and conditions of not-knowing for an extended period, hence they are uniquely poised to uncover and invent the new” (ibid.).

We return now to the design procedure principles I proposed be incorporated into a soma design program, with this notion of an epistemological exchange in mind. These principles contain evaluative and optimisation purposes in one research domain (evolutionary robotics) and now hold ameliorative purposes in another (soma design). I see the possibility of this kind of exchange at the level of granularity I was talking about earlier, especially if you consider that while

\textsuperscript{12}The kind of agency Crawford is talking about is very similar to the notion of joint agency that I put forward in Mechanical Sympathy.
making meaning with the machines in this thesis, both the participants and I became quite proficient at using them.

Furthermore, in the context of evolutionary robotics, these principles are intended to eventually produce “embodied and situated, autonomous, and self-sufficient agents” (Pfeifer and Bongard, 2006). The promise of this field is great, and continues to make great strides towards this end. With every GECCO or ALIFE conference, more and more powerful tools are generated that enable designers to navigate the infinite solution space of material, morphology and control (GEC, 2023; ali, 2023), bringing us closer and closer to an every day existence alongside these machines. However, as Pfeifer and Bongard mentioned, evolution is a powerful designer, albeit a blind one none the less (Pfeifer et al., 2005). In other words, having a soma in the loop is an opportunity to make meaning in this expansive space, to engage with these machines as they evolve, feel how they move across modalities, people, contexts, time frames and generations. To become mechanically sympathetic to their Umwelt, by shaping its development, or, to again quote Ed Yong, “constrain the senses” in order to “pull relevance from randomness, and weave meaning from miscellany” (Yong, 2022). In a paper about the role of design in HRI, Lupetti and colleagues speak to this process, “In order to create artifacts (or prototypes), one needs to absorb knowledge from different directions and confront, integrate, and contextualize this knowledge” (Lupetti et al., 2021). What I am proposing here is that all soma’s should be involved in this process to some degree, not just the designers’ soma. We all need to engage. With ourselves, with our machines and within the context in which we exist. I refer again to the relationship between the designer and the user as one of contemplating the truth together (Bardzell and Bardzell, 2016).

The degree of autonomy and ambiguity that these agents present to designers, users and observers is a multidimensional problem affecting many stakeholders. Clearly we cannot have ambiguity in life threatening situations, nor should we be denied the opportunity of working with machines that we cannot relate to or grow with. However, at the same time, not every moment in life should be somaesthetic or, “an event” as Dewey calls it (2005), this would be exhausting and meaningless. I believe the common ground that I outlined earlier when relating synthetic methodology to Research Through Design will be instrumental in navigating these tensions. In other words the messy, iterative and reflective process of attempting to “make the right thing” (Zimmerman et al., 2007) will be as important as ever before. Perhaps in doing so, the soma design program will reach its natural limits before it reaches the scope and scale of a practice (as Redström explains it in Section 1.3), spawning instead some new program, with all new axioms that strive for an exchange between amelioration and optimisation from the outset. The best thing is that they will always be in tension, or at least they should be. Design is never finished.
3.2. EXPANDING THE SOMA DESIGN PROGRAM

Figure 3.1: The design process and field work behind Olly was a true inspiration. The artefact was well made, engaged with in the long term and presented as an ambiguous appliance with a familiar feel. Credit: Odom et al. (2018).

Figure 3.2: An example of the different rhythms and modalities that the Blo-Nut is capable of; and the various interpretations they afford. Credit: Bewley and Boer (2018).
Figure 3.3: Left: A rider calls over his Yamaha MOTOROiD at the Tokyo Motor Show in 2017. Credit: Japan Times. Right: The bike can autonomously twist itself along its ‘AMCES’ axis (see red line), which allows it to stay upright unassisted or actively change the balance of the bike whilst riding. Credit: Hara et al. (2019).

Figure 3.4: Åsa Unander-Scharin in rehearsal for her operatic performance entitled ReCallas/Medea, in collaboration with Carl Unander-Scharin. Credit: Åsa Unander-Scharin.
Figure 3.5: The amber (Justin), blue (Tom), clear (Nora) and green (Me) drones rendered as living creatures.
Figure 3.6: Josh Bongard’s Block Pushers. Left: An evolved agent in its physically realistic virtual environment. Right: Growth phase starting from a single cell, showing various intermediate stages (last agent after 500 time steps). Credit: Pfeifer and Gomez (2005).
Figure 3.7: Emergence of locomotion. Top Left: the actual Block Pusher. Bottom Left: The pattern of motion is reminiscent of how an inchworm moves: waves travel along the animal’s body in order to move it forward. Right: The inchworm like locomotion of the Block Pusher. A sensor, S, in one cell is connected to a motor, M, in a neighbouring cell. Whenever S touches the ground, it will actuate the motor M, which subsequently will lift up the cell containing S. This reflex propagates through the entire creature and causes the locomotion behaviour. This figure and description has been reproduced (with permission) from Bongard and Pfeifer’s book, *How the Body Shapes the Way We Think* (2006).
Epilogue

“Man had always assumed that he was more intelligent than dolphins because he had achieved so much—the wheel, New York, wars and so on—whilst all the dolphins had ever done was muck about in the water having a good time. But conversely, the dolphins had always believed that they were far more intelligent than man—for precisely the same reasons.” Douglas Adams (1979)

If we compare this quote from Douglas Adams to the one from Victor Papanek I used in the prologue, we get a sense of where I have started and where I have ended up. At the beginning, I was a frustrated designer who was angry at the shortcomings of commercial design and was looking for a way to distil this anger into some sort of message about how design should be. As a practising designer Victor Papanek was in the thick of it, his solutions were practical and grounded in reality. Douglas Adams, in his space comedy, *The Hitchhiker’s Guide to the Galaxy* has instead a very out-of-this-world perspective on us humans. This allowed him to invent the most ridiculous alternative realities I have ever read. A Research Through Design PhD grants you a similar licence to speculate.

And so this quote seems to imply that my speculations have brought me to a place where I can poke fun at how serious we are all the time, spending great amounts of time and energy to wring out an extra drop of productivity or efficiency. This is in part true. We have lots to gain from mucking about in water, rolling around on the floor and dancing about with drones. However, I can’t ignore the fact that somaesthetic appreciation also takes time and energy to practice, and many people simply cannot afford to do it. So that leaves me with a kind of mixed attitude, comprised of Victor’s scathing critiques and Douglas’ cunning wit. This led to the position I have tried to hold towards the end of the thesis, half way between the lofty ideals of soma design and the concrete problems facing robot and interaction designers.

Industrial design was taught to me as a democratising force. Through clever manufacturing, we can all have nicely designed things and experiences. I see soma design as a similar force. Except it is democratising the *space and time* to cultivate the soma through nicely designed things and experiences. The blurred distinction between design and user in soma design was a thread I just had to pull,
and I think I pulled it pretty hard. In doing so I fell into some pretty recursive and confusing reflections on my design practice.

After the *Drone Chi* project it was clear that meditative movement was not the only thing going on in the participants’ experience. I became interested in how individuals somaesthetically appreciated the unique aspects of their relationship with the drone. However, if my own practice was soma design and product design engineering then does that mean I need to try and somaesthetically appreciate how to somaesthetically appreciate? How do you even do this? Looking inwards and recalling how I came to appreciate my drones, cars and go-karts was the way I chose to do this. Implementing these reflections sent me down another recursive whirlpool. What was essential about the way I appreciated these machines? How can I pass this on? But this line of questioning was too close to *Drone Chi*, where I tried to push meditative movements onto my participants. Bringing me back to square one. On and on these thoughts went, no matter which way I cut it, I felt like I was passing a portal into itself. Breaking this cycle during the design of *How to Train Your Drone* meant relinquishing control, and an explicit acknowledgement that your designs are not finished, but rather, alive.

Like the hard rubbish in the prologue, the machines that (hopefully) come out of the expanded soma design program will require an ongoing engagement, as they are designed to continuously evolve and learn from the people and environments that surround them. They are born next to useless, the meaning is made in the space in between the world and the agents. What then, is design in this potential future? What is design if everyone needs to do their own design? What is user testing if the user needs to do their own testing? How can you even market a robot so ambiguous? Who even has the time to engage with something like this? We would have to quit our very serious productivity jobs to make meaning with these machines. Perhaps the government grants you one at birth as a cyber-physical right to a virtuous life, only then would the dolphins think a little higher of us. In the end the question that this thesis leaves me with is, *what is the relation between aesthetic appreciation and a highly optimised task environment?*

Speaking from experience I can say that design practice such as soma design certainly spills over into your private life. I am often thinking about why my experience feels the way it feels and if I want it to change or not. It is both enriching and exhausting - a blessing and a curse. At least it was one I had (almost) full control over. I had the choice to pull back from the work in order to have the time and the headspace to enjoy date nights with my wife or story time with my daughter. During the times when I did not, then at least I was able to (mostly) enjoy a deep dive into the design work and the literature. I count myself very lucky to have had that choice.

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13Even after the fact, I lost count of the number of times I renamed the Section designing *for* Mechanical Sympathy to designing *with* Mechanical Sympathy and back again.
References


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