Thesis for The Degree of Licentiate of Philosophy

From the Ground Up

Designerly Knowledge in Human-Drone Interaction

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Department of Computer Science and Engineering
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"I am not doing science – I am flirting with science.
Do not quote me on this."

- William Gaver

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Abstract

There are flying robots out there – you may have seen and heard them, droning over your head. Drones have expanded our human capacities, lifting our sight to the skies, but not without generating intricate experiences. How are these machines being designed and researched? What design methods, approaches, and philosophies are relevant to the study of the development (or decline) of drones in society? In this thesis, I argue that we must re-frame how drones are studied, from the ground up, through a design stance. I invite you to take a journey with me, with changing lenses from the work of others to my own intimate relationship with this technology. My work relies on exploring the fringes of design research: understudied groups such as children, alternative design approaches such as soma design, and peripheral methods such as autoethnography.

This thesis includes four articles discussing perspectives on designerly knowledge, composing a frame surrounding the notion that we may be missing out on some of the aspects of the wicked nature of human-drone interaction (HDI) design. The methods are poised on phenomenology and narratives, and supported by the assumption that any subject of study is a sociotechnical assemblage. Starting through a first-person perspective, I offer a contribution to the gap in research through a longitudinal autoethnographic study conducted with my children. The second paper comes in the form of a pictorial expressing a first-person experience during a design research workshop, and what that meant for my relationship with drones as a research material. The third paper leaps into a Research through Design project, challenging the solutionist drone and offering instead the first steps in a concept-driven design of the unlikely pairing of drones and breathing. The fourth paper returns to the pictorial form, suggesting a method for visual conversations between researchers through the tangible qualities of sketches and illustrations.

Central to this thesis, is the argument for designerly approaches in HDI and championing the need for alternative forms of publication and research. To that end, I include two publications in the form of pictorials: a publication format relying on visual knowledge and with growing interest in the HCI community.

Keywords

human-drone interaction, design epistemology, first-person methods, sociotechnical systems

List of Publications

Appended publications

This thesis is based on the following publications:

[I] **M. Gamboa**, *Living with Drones, Robots, and Young Children: Informing Research through Design with Autoethnography*
NordiCHI'22, October 8–12, 2022.
https://doi.org/10.1145/3546155.3546658

[II] **M. Gamboa**, *Conversations with Myself: Sketching Workshop Experiences in Design Epistemology*
C&C'22: Creativity and Cognition, June 2022.
https://doi.org/10.1145/3527927.3531450

[III] **M. Gamboa**, M. Aydın Baytaş, S. Hendriks, S. Ljungblad, *Wisp: Drones as Companions for Breathing*
TEI'23, February 2023.
https://doi.org/10.1145/3569009.3572740

[IV] **M. Gamboa**, S. Ljungblad, *Conversational Composites: Conversational Composites: A Method for Tangible Illustration Layering*
TEI'23, February 2023.
https://doi.org/10.1145/3569009.3572793

Research Contribution

In this section, I describe my contributions to the appended papers.

Paper I is an autoethnography and naturally a single-authored paper, although written with the invaluable contribution of my family. The idea of autoethnography as a method was already suggested in our funding, and became particularly helpful in the context of the COVID-19 pandemic. I followed the suggestion with the full support of my supervisor, who reviewed the paper multiple times. I wrote and envisioned the whole paper from there on, including conceptualisation, combination of methodological framing, documentation, data analysis, and writing.

Paper II is yet another autoethnography, and also single-authored. This paper is a pictorial, and hence most of the work is based on visual expressions. I conceptualised, illustrated, and wrote the pictorial.

I led the work in **Paper III**, together with a team of researchers. I conducted the initial interviews with experts, transcribed, and analysed them. I conceptualised the project and its theoretical framing, and produced the first sketches and ideas for the prototype. Together with the second author, we implemented the ideas into a prototype. I documented the whole design process. I conducted the evaluation of the prototype, including the post-experience interviews. Along with the third author, we analysed the results of the evaluation. I developed the combination of frameworks and final contributions. I wrote the majority of the paper with contributions and supervision from the fourth author.

Paper IV, another pictorial, was led and conceptualised by me. It is the result of an exercise conducted together with the second author. I imagined the method and implemented it with the second author, who contributed with her reflections and illustrations. To conduct the method, we gathered data through a short online survey developed with the second author. Along with the third author, I formulated the conclusions and instructions for appropriation of the method. I designed all the method illustrations.

Other publications

[a] **M. Gamboa**, *My Body, My Baby, and Everything Else: An Autoethnographic Illustrated Portfolio of Intra-Actions in Pregnancy and Childbirth*
TEI '23: Proceedings of the Seventeenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '23), February 26-March 1, 2023.
https://doi.org/10.1145/3569009.3572797

[b] B. Baldursson, D. Peterson, **M. Gamboa**, *Nebula: Artistic Somaesthetic Appreciation with Biosignals in Virtual Reality*
NordiCHI '22: Adjunct Proceedings of the 2022 Nordic Human-Computer Interaction Conference, October 2022.
https://doi.org/10.1145/3547522.3547710

[c] **M. Gamboa**, S. Ljungblad, *Designerly Ways of Knowing in HCI Education: A Case Study of a Peer Community-Based Studio*
Frontiers in Computer Science, May 2022.
https://doi.org/10.3389/fcomp.2022.793968

[d] M. Sturdee, M. Lewis, **M. Gamboa**, T. Hoang, J. Miers, I. Smorgun, P. Jain, A. Strohmayer, S. Alaoui, C. Wodtke, *The State of the (CHI) Art*
CHI EA '22: Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems, April 2022.
https://doi.org/10.1145/3491101.3503722

[e] P. Alves-Oliveira, M. L. Lupetti, M. Luria, D. Löffler, **M. Gamboa**, L. Albaugh, W.Kamino, A. K. Ostrowski, D. Puljiz, P. Reynolds-Cuéllar, M. Scheunemann, M. Suguitan, D. Lockton, *Collection of Metaphors for Human-Robot Interaction*
Designing Interactive Systems Conference 2021 (DIS '21).
https://doi.org/10.1145/3461778.3462060

[f] **M. Gamboa**, M. Obaid, S. Ljungblad, *Ritual Drones: Designing and Studying Critical Flying Companions*
Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction, March 2021. https://doi.org/10.1145/3434074.3446363

[g] S. Ljungblad, Y. Man, M. Aydın Baytaş, **M. Gamboa**, M. Obaid, M. Fjeld, *What matters in professional drone pilots' practice? An interview study to understand the complexity of their work and inform human-drone interaction research*
Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. https://doi.org/10.1145/3411764.3445737

[h] S. Hendriks, S. Mare, **M. Gamboa**, M. Aydın Baytaş, *Azalea: Co-experience in Remote Dialog through Diminished Reality and Somaesthetic Interaction Design*
Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. https://doi.org/10.1145/3411764.3445052

Acknowledgment

I always write the acknowledgements right before a paper is to be published. This time, I am struggling to see how I can even fit all the names of the people that have contributed to my work! It makes me immensely happy to think that the list is so long, and grateful that I have such a wide and generous safety net. I wanted to mention most of them.

Everything I do and all my achievements would be impossible without Magnus' steady support – even though he has never really read any of my work. He keeps me sane, and is the most incredible father to our three children. To Tesla, Lyra, and Alvar, the stars in my sky and most precious co-authors. All of them have been both motivation and participants in our joined autoethnographic studies. I hope you will look back into your childhood and find that our research together helped you see the world through a critical and yet caring lens. To Judite, my mother, who will probably also never read any of my work (it does not quite matter because, according to her, everything I do is amazing. Wish she would review all my papers).

My supervisor and friend Sara Ljungblad, who is the most kind and supportive supervisor, reminding me often to take a break. I could not have imagined someone better to have by my side in this PhD journey. My co-supervisor Mohammad Obaid, who is excellent at giving feedback, and my examiner Morten Fjeld who has been a fantastic examiner despite my unusual way of doing research. All three have been able to guide my work by facilitating the path through each threshold. Everyone involved in following up my process have been incredibly kind and supportive, including Agneta Nilsson and Wolfgang Ahrendt.

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I have probably forgotten someone. I apologise. Truly – this list was almost impossible to do.

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[1]https://wasp-hs.org/projects/the-rise-of-social-drones-a-constructive-design-research-agenda/

Contents

Part I

The Compilation

Chapter 1

Introduction

Explaining the theme of my research – the design of social drones – has been an experience throughout the time it took to write this thesis. The reactions divided themselves into a mixture of assumptions about my work and perceptions of drones. Most of course, involved the words "cool" and "exciting", but many evolved towards stories of their encounters with drones in real life.

Those working within Human-Computer Interaction (HCI), or Human-Robot Interaction (HRI), will know that it is not unusual for articles within the field to start with a statement such as: "As robots become increasingly prevalent in everyday life..." However, many robots seem to remain elusive and expertly avoid being seen in society, particularly humanoid ones. What we know is that our skies are rapidly being populated by flying robots, both for hobby and professional use [1]–[3]. Tourists and police alike are adopting the technology at a rapid pace, with the legislation framing their use barely catching up. The Swedish news channel SVT reported in August 2022 that the entity that approves commercial use of drone pictures expected to take 49 working days to approve an image. The number of applications in the last five years has increased from around 700 to over 23 000, with the entity expecting 30 000 just this year. This approval is necessary due to a legal framework to avoid the spread of sensitive military information [4]. The increase in waiting times has resulted in a lot of frustrated pilots, many of them taking on the social networks to complain about the absurdity of the situation. According to some, at times the same picture could be taken with a camera on a stick, but in that case, it would not have to go through approval.

At the start of this research, I had not had any significant contact with drones. To be fair – as many others [5], [6] – my associations were primarily military. That, and the one time many years ago my brother gifted a small toy drone to my husband. The drone worked a couple of hours, as he managed to immediately fly it against the garage ceiling and wreck it beyond (at least novice) repair. In retrospect, this experience proved to be a portentous moment to this thesis.

My research is framed by the WASP-HS grant named *"The Rise of Social Drones: A Constructive Design Research Agenda"*, funded through an initiative for humanistic and social scientific research in AI and autonomous systems. The project is grounded on making connections between the spreading of consumer drones in society and the growing research field of HDI through design research in a critical manner. It included the need to take a stance on drone technology and drones as a design material, and this licentiate thesis is a reflection of that personal process. As I started investigating drones, I realised my questions required

much more than good knowledge of the state-of-the-art drone research. They demanded a renewed look into what it means to be an interaction designer[1], how the discipline of design is (or should be) relevant to Human-Drone Interaction (HDI)[2], and a more developed situated and first-hand understanding of drones.

This meant I needed to define my own approach – and in the process – my goal became to re-frame HDI through (at least some) designerly perspectives. Framing and re-framing is a recognised approach to wicked problems [7], [8]. Dorst suggests methods for re-framing (open, complex, dynamic, and networked) problems: *"These design practices are well positioned to help us develop the problem situation, consider a broader context, build a deeper understanding of the underlying factors behind the problem, and most importantly to then create a new approach (or frame) to the problem situation"* [9, Ch.4]. As noted, *"frame creation entails a shift in perception, seeing the problem situation differently than before. This is problematic because the problem-solving capacity in our society is implicitly organized by type of solution, rather than by type of problem."* [9, Ch.7]. In my work, I seek to find ways of steering *"conversations away from specific outcomes to an exploration of deeper situational values."* [9, Ch.3]

Hence, I formulate the goal for my work as:

G: Re-framing human-drone interaction research through a designerly lens.

The work in this thesis is guided by the following research questions:

RQ1: How might ethnographic methods and narratives ground design knowledge in human-drone interaction?

RQ2: How might visual and concept-driven approaches inform human-drone interaction design?

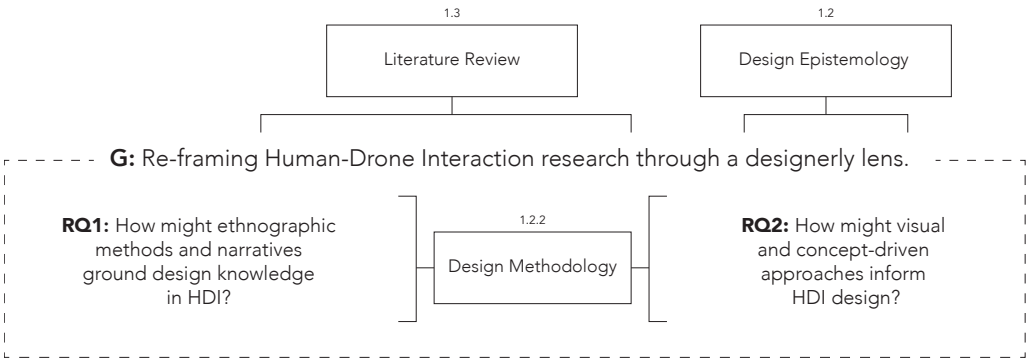


Figure 1.1: Diagram representing the goal of the research and the research questions in this thesis. The concepts given are developed in the sections represented in the diagram.

[1]The double meaning behind the title of this thesis is not incidental – drones fly from the ground up – but I also seek to frame the knowledge in human-drone interaction from a grounded and situated perspective informed by designerly approaches.

[2]HDI is here seen simultaneously as a subset of HCI and a subset of HRI.

This thesis includes therefore four pieces of research, exemplifying ways to surface and re-frame some of the aspects of the wicked nature of interaction design when developing drones which may otherwise be missed. For example, I make extensive use of ambiguity and open-endedness through tools such as narratives and sketching. The methods are poised on phenomenology, and supported by the assumption that any subject of study is a sociotechnical system/assemblage. The processes currently reported in Human-Drone Interaction (HDI) research points towards a general lack of design knowledge in the field, along with the underdevelopment of critical stances, and the absence of ethnographic studies and situated engagements with drones.

Starting through a first-person perspective, I offer a contribution to the gap in research through a longitudinal autoethnographic study conducted with my children. Results indicate design opportunities for drones, but also a challenge to the dichotomy of 'user-bystander' in HDI. The second paper comes in the form of a pictorial narrating in text and visuals a first-person experience during a design research workshop, and what that meant for my relationship with drones as a research material. The third paper leaps into a concept-driven Research through Design project, challenging the solutionist drone and offering instead the first steps in a critical design of the unlikely pairing of drones and breathing. Results are centred on the role of critical design programmes for the framing of drones as companions. The fourth paper returns to the pictorial form, suggesting a method for visual conversations between researchers through the tangible qualities of sketches and illustrations. An application of the method is exemplified by a drawing exchange between two researchers interpreting hobby drone pilot statements gathered through an online questionnaire. This method is developed as a way to incorporate the diffractive and ambiguous nature of visual knowledge in design research.

1.1 Positionality

In line with a feminist approach to research as situated [10]–[12], I disclose my positionality as a framing for understanding the work behind this thesis. My positionality is, in fact, a strong component of the re-framing suggested above. In truth, the work presented here was invaluable as a reflexive activity in order to articulate positionality. As noted by Holmes [13], the current statement is unavoidably volatile, and will change both with time and context.

I was raised in Portugal, in a white family of academically educated public service employees. I attended private schools until enrolling in public university at the age of eighteen. My family always voted in left-wing parties, although nobody was particularly active in the political discourse. I am a member of the Swedish left-wing party and an advocate for socialism. I suffer – since a very young age – from a condition called misophonia, making me very sensitive to certain noises. My background is in arts, with a master's degree in architecture from Lisbon University. At the end of the master's degree, I moved to Sweden to marry a Swedish man, and have since lived in a hetero relationship, and became the mother to three children. I am a cis-gender woman, and my pronouns are she/her.

During my education as an architect I (unknowingly) became a phenomenologist. The degree was poised on philosophies of the primacy of experience and embodiment authored by philosophers, anthropologists, and architects alike [e.g. 14]–[19]. The

tacit and subjective nature of architecture, as well as the necessity for a visual language were undisputed notions. Simultaneously, much of my education was grounded in authors such as Edward Hall [20] and Christopher Alexander [21], who aimed to find ways to create a common language for architects and urban planners.

Due to my academic and personal background, I usually present my stance as follows:

- No separation researcher-research – knowledge is situated.
- Being human is being subjective – I favour the immeasurable.
- No such thing as mind-body dualism – all experiences are embodied.
- All things are entangled – research should be messy.
- Everything is ethics.

1.2 Design as a Discipline and Designerly Knowledge in HCI

Although we thread towards a transdisciplinary approach to Human-Computer Interaction [22], understanding the epistemological tensions present in the field is fundamental to recognise the necessity of continued work in developing design methods and approaches. Design has not always been perceived as a discipline of its own – and its place within HCI is still not a given. Because my background is in design – I present first my own epistemological assumptions grounded in design knowledge[3].

What is remarkable about design, is that it connects theory and practice through artefacts and processes, bridging scientific and creative limits in order to address ill-structured and open-ended problems [23]. As early as 1979, Archer [24] argued for 'Design' as the third area of education, poised between sciences and humanities; defined as "Design with a capital D" which means, according to Cross *"the collected experience of the material culture, and the collected body of experience, skill and understanding embodied in the arts of planning, inventing, making and doing"* [25, p.221]. Cross frames 'designerly ways of knowing' by positioning design as a discipline of its own paired with a particular epistemology, noting that *"we are certainly faced with the problem of being more articulate about what it means to be 'designerly' rather than to be 'scientific' or 'artistic"'*. There are many discourses surrounding ways of knowing in design – for example when contrasting designerly ways of knowing and design thinking [26]. However, *"from an academic perspective, this plurality in discourses within designerly ways of thinking is not a sign of weakness but rather a sign of maturity."* [26, p.132]

It is reasonable to claim that the socio-technical design issues being tackled in HCI can be described as 'wicked problems' [7]. Indeed, Buchanan [8] uses this notion and argues that design tries to get rid of the "wickedness" through placements – *"the tools by which a designer intuitively or deliberately shapes a design situation"* [8]. A placement comes in distinction to a category, it is not fixed: it is a guiding position with negotiable boundaries and yet representing a *"systematic approach to the invention of possibilities"*. As he notes, *"design is a remarkably supple discipline, amenable to radically different interpretations in philosophy as well as in practice. (...) It is a history of the changing views of subject matter held by designers and the concrete objects conceived, planned, and produced as expressions of those views"* [8, p.9]. What is remarkable about Buchanan's description of conceptual placement is that it is grounded on the assumption that each designer has a a set of placements which they have developed and tested through experience, and that can be described as intuitive or serendipitous. Therefore, the skills of a designer lie in *"natural or cultivated and artful ability to return to those placements and apply them to a new situation"* [8, p.13].

The overlap of humanities and arts, led through a scientific mindset is echoed by Fallman [27]. Figure 1.2 shows a model of what interaction design research can look like, as a triangle stretching towards three different edges described as 'design practice', 'design studies', and 'design exploration'. Fallman's argument is that while the methods can be similar, research in positioned within these triangles

[3]This decision to structure the thesis as such was curiously questioned more than once by those around me. For them, HCI is the umbrella term and design a subset of it. However, I see design first as an approach and lenses to see HCI. Hence, I saw it more fruitful to present it first.

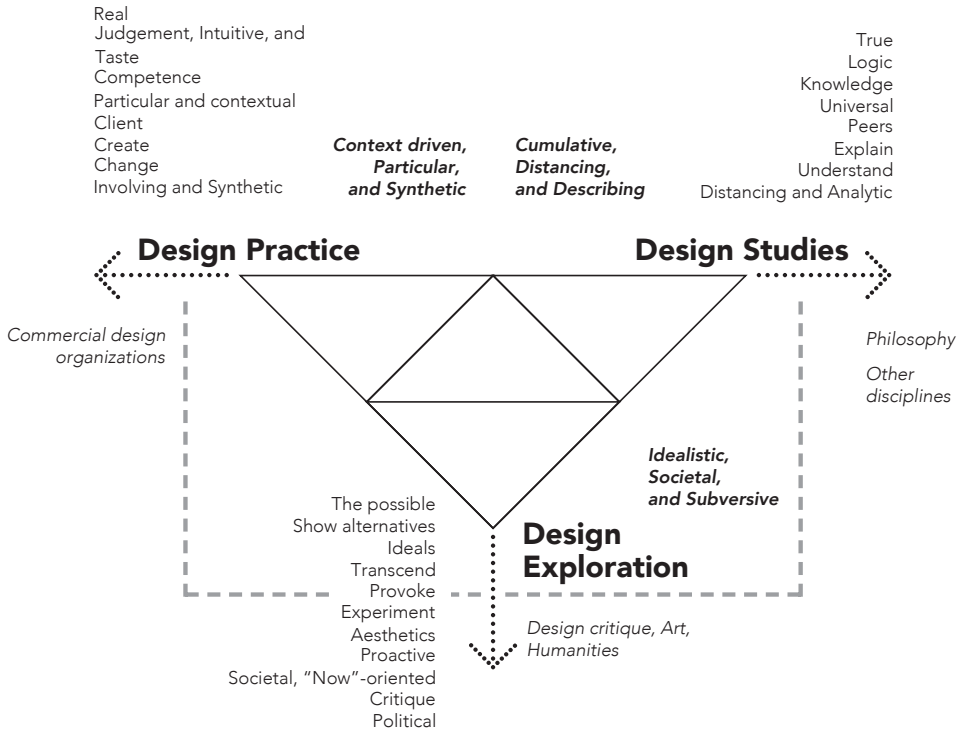


Figure 1.2: A "more complete model of interaction design research" as presented by Fallman [27]. Re-drawn from the original paper.

differs in tradition and perspective. My work navigates precisely these triangles, presenting different perspectives, and grounded in different traditions.

In my work, however, I seek ways to stay with the wickedness. In what could be described as 'staying with the trouble' [28]. The position as a designer is framed by my background as an architect, where the embedded artistic and poetic way of thinking, making, and feeling are an accepted and applauded way of working. In *'Thinking Architecture'*, Zumthor writes:

> "There was a time when I experienced architecture without thinking about it. Sometimes I can almost feel a particular door handle in my hand, a piece of metal shaped like the back of a spoon. I used to take hold of it when I went into my aunt's garden. That door handle still seems to me like a special sign of entry into a world of different moods and smells. I remember the sound of the gravel under my feet, the soft gleam of the waxed oak staircase, I can hear the heavy front door closing behind me as I walk along the dark corridor and enter the kitchen, the only really brightly lit room in the house." [29, p.9]

These notions travel through the architect and formalise themselves often into new designs, practically traversing time. This too happens in other design fields, more or less explicitly. There was a time when I experienced drones without thinking about it.

1.2.1 Design Epistemology

Design is indeed a discipline on its own, and like any discipline, it has its own set of theories and practices. One way to tackle the difficulties that arise from the combination of theory and practice in design is to approach the discipline in a holistic manner, taking into account both the theoretical and practical aspects of the field. This means considering both the conceptual and the technical aspects of design, and striving to find a balance between them in. However, these negotiations bring issues in what is considered knowledge within the discipline – a discipline's epistemology.

The concept of 'reflective practice', introduced by Schön [30], focuses on the reflective aspects of practice-based work as a way of learning. For him, the experiences gained by being a practitioner are insufficient to result in knowledge – it is only through reflection upon and with the experience that design knowledge can surface. Schön identified two types of reflective practice: *reflection-on-action*, which involves reflecting on past experiences and actions to evaluate what could have been done differently, and *reflection-in-action*, which involves reflecting on actions during the process of designing, and using knowledge of best practices to guide decision-making. The latter relies on improvisation but also the ability to constantly adopt a critical posture. Reflective practice is important for developing skills in design, as it allows practitioners to evaluate their experiences and make informed decisions. Schön's ideas on design epistemology, including tensions between *technical knowledge* and *artistry*, are still influential today. Connecting back to my work, many of his notions were defined through observations of architectural practice – I suffered personally from his critique of higher education. He believed that institutions of higher learning often do not adequately prepare practitioners to handle improvisation, and suggested that a focus on educating reflective practitioners would be more beneficial than letting technical rationalism and positivism drive the wheel. Schön's message exhibits "distrust and dislike of positivism" [30], emphasising rather the importance of experience in the creation of knowledge. Reflective experience of design practice is but one way of attempting to bridge tacit and explicit knowledge.

Stolterman [31], [32] has been influential in making explicit that design practice challenges the experimental nature of complexity and rigour. As such, design does not deal with what is true (universal or generalisable knowledge such as statistics coming from controlled experimental studies/trials) but with what is real (particular or concrete knowledge, such as a perspective, context, and temporal notions)[33]. See Figure 1.3 for a visual explanation of this relationship. These difficulties in negotiating rigour become tangible in reconciling the nature of design practice with interaction design research, and transferring scientific methodologies and approaches to design practice may not be suitable. Stolterman argues that *"it is possible to predict the potential success of new approaches, methods, and tools based on how designerly they are"* [31], giving the example of the notion of *affordance*, as a tool to be used as inspiration in design practice rather than prescribing action.

As with any other research field, there are mainstream frameworks within HCI which generate what can be considered accepted knowledge [34]. This is what Kuhn would call normal science [35]. Many of these designerly tools or methods tend to fall outside of the mainstream approach, but have the potential to become widely appreciated. Non-prescriptive high level approaches such as user-centered

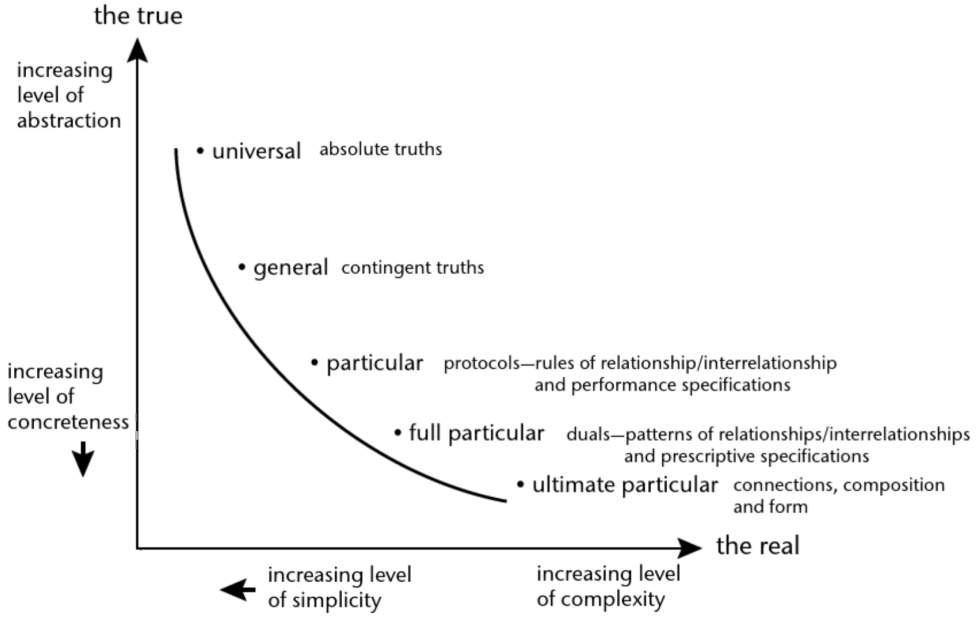


Figure 1.3: Graph illustrating the difference between Design and Science. Design does not deal with what is True (universal or generalisable such as statistics) but with what is Real (particular or concrete such as a perspective). The intention of design is not to replicate or reproduce knowledge but to shape reality (etc). Illustration from the book *'The Design Way'* by Nelson and Stolterman [33].

design are a great example of that. It is important to remind ourselves that research conducted well within a paradigm tens to lead to assumptions with more or less visible impact in what types of knowledge is accepted within a field. This may result in homogeneous types of argumentation supporting certain embedded beliefs [36], [37].

Designerly approaches have instead the great ability to break assumptions and prioritise critical thinking over simplification, for example through re-framing. While many activities that benefit a designerly stance may at first be considered fringe [35], they are essential to articulate situated knowledge [10] through unique lenses.

In this thesis, I choose to build on a variety of methods that have been seen as outside the mainstream in HCI, and started their journey from fringe activities [34], towards a wider acceptance. There are well known pieces of research, such as authored by Frayling, describing different approaches and contributions of design research [38]. The role of design theory and critical design has been presented as an important contributor to HCI [39], challenging a certain coherency and widening the possible goals of research within the field. However, we do know that the presence of competing paradigms of inquiry is beneficial and generative, where *"each paradigm orients to a particular kind of research program, and admits different objects and activities into its mode of enquiry"* [40, p.3543].

Redström's book *Making Design Theory* is dedicated to revealing the possibility of design practice to also be about making theory: *"exploring the idea that as design research engages in making many different kinds of things, theory might well be one of those things it is – or could be – making. And so the question is, what design theory could be made in research through design?"* [41, p.1]. However,

the theory making of design is not like that of other disciplines. There are two points from this book I would like to bring forward as they are essential to my work. First, it is the distinction between a *definition* and a *proposition* when considering design theory is often 'transitional':

> "Consider completely letting go of the idea that what we offer are different definitions of what design is, and instead just refer to them as different propositions. Would that help? It would certainly cast the idea of 'unified theory' in a different light, as an ambition to achieve 'unified propositions' sounds far less exciting. At the same time, however, it certainly feels as if something more is at stake here. Consider a more concrete definition made through design: having created this object for you to sit on, I can, of course, *present* it by saying, I'd like to *propose* that this is a chair,' but this is not quite the same as to say, This *is* a chair." [41, p.138]

The second is connected to the idea of artefact as a carrier of knowledge:

> "When our objective is to uncover and articulate the general, the exception becomes a problem, a disturbance or nuisance. In statistical analysis, for instance, extreme outliers are more likely to be considered extraneous experimental errors than actual data. Indeed, when studying what is, what is created during the process of observation is often considered a problem – and thus the notion of 'artifact' is used, along with other notions such as noise, to denote errors stemming from the experimental setup. When we turn to the artificial, to the artifact not as error but as intention, the issue of exception is also reversed." [41, p.140]

This thesis is therefore composed of a collection of artefacts, be them in the form of design ethnographies [42] or prototypes [43] – intentionally looking to be the disturbance or nuisance rather than the point of convergence. The work presented here is often at odds with the positivist expectations of scientific research, engaging instead with the particular.

1.2.1.1 Phenomenology

Within the understanding of (interaction) design as its own epistemological island inside HCI, there is an unavoidable connection made to phenomenology, particularly through the notion of embodiment [44], [45]. There is no place here to dig deeper into the philosophy, but it is nonetheless essential to know that the work in these pages is tightly connected to Merleau-Ponty's phenomenology of the *lived body* [46]. Interaction design is deeply engaged with understanding experience [47]. In this case, even the embodied experience of design processes is a valuable input for design theory. Merleau-Ponty is influential in HCI, with many researchers referring to the importance of a unified view of the body (refusing the Descartes' dualist ontology of mind and body). Within HCI, Svanæs discusses the concept of embodiment connecting it to recognising the importance of the designer's first-person experiences of design artefacts, both through analysis but also throughout the process of design. As noted *"if we take Merleau-Ponty's perspective seriously, we need to stop talking about the user's body. Users do not have bodies; users are*

living intelligent bodies. The concept of the user as an intelligent living body is hard to grasp." [48, p.8:25]

As Svanæs points out when discussing interpretative social sciences relying on phenomenology, *"valuable theoretical contributions can result from reflections that do not originate from a 'scientific' basis of hard data. In the present context, the value of the theoretical contributions must be judged by their applicability to real problems, and by the extent to which they have explanatory power and provide inspirations for design. Others will have to make that judgement."* [48, p.8:27]

The results presented in this thesis are open to interpretation of others, but include abundant dedication in expressing reflections and presenting the issues in a manner that can be inspiring to others.

1.2.1.2 Waves in HCI

Human-computer interaction (HCI) is often debated in terms of whether or not it falls within the discipline of design. There have been many discussions about the epistemology of design knowledge and its relationship to HCI [31], [34], [48], [49]. Some argue that HCI is a part of design, while others resist to the types of design knowledge and their unclear contribution to HCI. These debates often center around the role of HCI in shaping the user experience and the ways in which it intersects with other design disciplines. Ultimately, the relationship between HCI and design is a complex and nuanced one that continues to be a topic of discussion and debate.

The field of HCI has gone through at least three waves or paradigm shifts with marked effects in the applied methods. In short, the first wave is tightly connected to engineering and human factors, particularly dedicated to avoiding human error. The ultimate goal is to *"optimize the fit between humans and machines; the questions to be answered focus on identifying problems in coupling and developing pragmatic solutions to them. Occupying the center of the first paradigm are concrete problems that arise in interaction and cause disruption (...)"* [50, p.3].

The second wave represents rational approach to human-computer interaction, grounded on an understanding of the human mind and cognition as a computer, and how these two coupled processors handle information. Research prioritised causality and finding central tendency [50]. Essentially, from the first wave to the second, the focus shifted from issues of control and error prevention to issues of communication and efficiency [51]. Popular evaluation methods such as cognitive walkthrough surfaced to fit this wave.

The third wave is composed of many perspectives informing the study of interaction as phenomenologically situated. *"The goal for interaction is to support situated action and meaning-making in specific contexts, and the questions that arise revolve around how to complement formalized, computational representations and actions with the rich, complex, and messy situations at hand around them. Because of its emphasis on multiple meanings made in context, we term the third paradigm situated perspectives."* [50, p.8]. The third wave recognises the prominence of relationships and meaning-making between humans and machines in context. This wave brings an emphasis on experience as the primary object of study, bringing to surface the issues of subjective experience. Many methods within ethnography and participatory design serve well to study within this tradition.

We move now towards what can be called the 4th wave, or entanglement

HCI [52]. This wave shifts the focus towards a political, ethical, accountable view of research. There is also an interest on including more-than-human design (MTHD) methodologies, driven by a world in environmental crisis, and including actors such as things, animals, or robots [53]. As a personal critique to this wave, the heavily philosophical grounding may alienate many of those who do the practical work. Coulton and Lindley [54] offer an excellent example of how IoT demonstrates the need to consider more-than-human perspectives. They use the metaphor of a constellation to frame a speculative design illustrating one example of the complexities of IoT and how their metaphor could be applied: *"this metaphor represents the idea that, as with the cosmological constellations in the night sky and their constituent stars, IoT things are simultaneously 'stars' in their own right, as well as being part of groups, or constellations. Depending on what perspective an observer takes, how these constellations appear varies wildly."* [54, p.473] But as they state: *"Articulating how a metaphor impacts on design work, as with articulating what it is to 'do design', is more of an art than a science. Hence, though we cannot didactically tell the reader how the constellation metaphor 'should' be applied in terms of a step-by-step method, the following commentary is intended to put flesh on the skeleton described thus far and give one example of how it could be util."* [54, p.474]

Resonating with the message of more of an art than a science, this thesis lies on the verge between these two last waves, navigating back and forth. I will not delve into what the 4th entails, but acknowledge the direction of the work in HCI. The work I present seeks to find translations from the complexity of design philosophy through combinations of methods. The methods used in this thesis paint a picture that sometimes is in detail, and at times an overview. More importantly, my work is grounded on lifting situated knowledge [10], [11] to the limelight, often through unexpected means of knowledge creation. I am not attempting to be objective or unbiased, but rather transparent about which situations led to the research currently present. Below, I give examples of how the methods applied transition between these waves.

1.2.1.3 Systems Theory and Sociotechnical Systems

Historically, the notion of *Systems Theory* has been important to support a holistic, and yet delimited approach to research. One of its most important contribution is precisely the definition of system boundaries – and the premise that design processes should take in account both the technical and social factors of computer-based systems. The human factors and ergonomics community has been particularly active in developing research supported by Systems Theory frameworks, when in connection to applied cases in workplaces or other complex organisations or contexts. There are a number of theories within Systems Theory that have been generative for HCI, one example being Activity Theory [e.g. 55]–[59]. Both could be considered as perspectives on 'soft systems' [60] (See Figure 1.4). The difference here is that *"hard systems thinking assumes that the world is a set of systems (i.e. is systemic) and that these can be systematically engineered to achieve objectives. In the soft tradition, the world is assumed to be problematic, but it is also assumed that the process of inquiry into the problematic situations that make up the world can be organized as a system. In other words, assumed systemicity is shifted: from taking the world to be systemic to taking the process of inquiry to be systemic"* [60, p.S49]

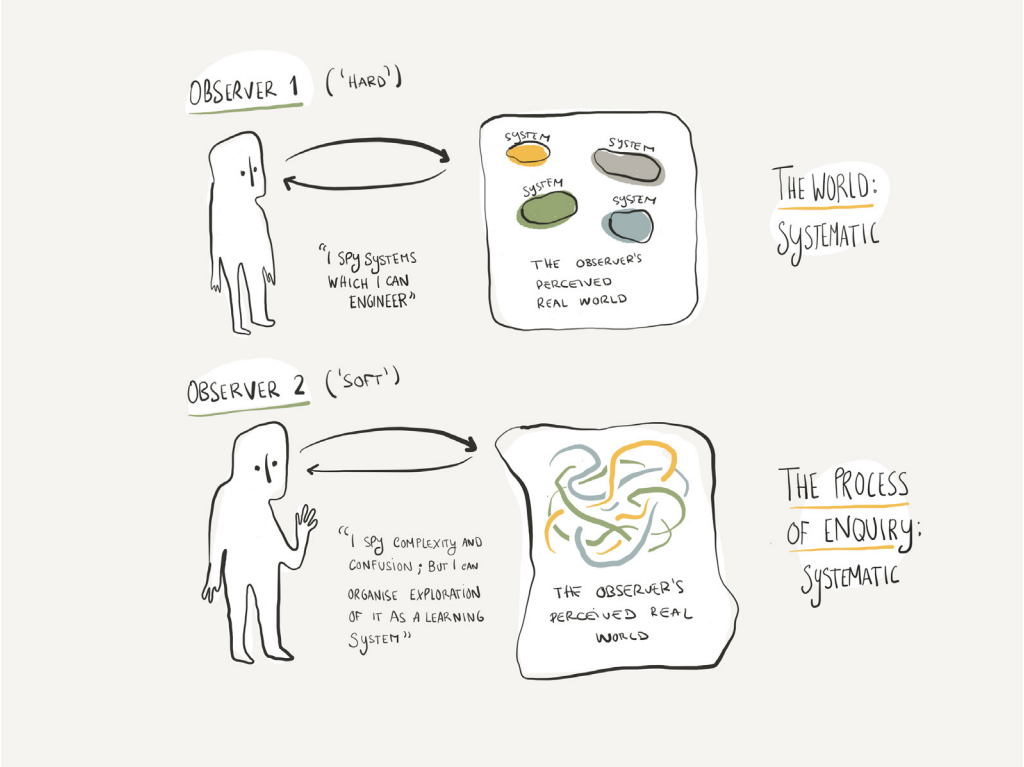


Figure 1.4: Illustration of the hard and soft system stances. Figure redrawn from Checkland's paper [60].

This idea may seem almost rudimentary for designers – but I find the theory surrounding system's theory and in particular 'soft systems' to be helpful when establishing groundwork for research in multidisciplinary teams. In a perhaps too harsh manner, Norman and Stappers, when discussing complex sociotechical systems, comments that *"engineers have been heard to say 'if it weren't for people, our systems would work just fine,' usually uttered after some accident has been blamed on 'human error.' On the contrary, when it comes to complex systems, if it weren't for people, the system wouldn't have worked at all."* [61, p.86] As exemplified by Kirwan [62], the application of StS and 'soft systems' seems to have more uptake when studying large systems such organisations and industries [62], but 'soft systems' can be found anywhere and on any scale.

The field of HCI is centred on the design of computational things – not just the technology – but the sociotechnical systems. Therefore, it is necessarily poised on the verge between many disciplines, which makes for a difficult description of what the research is actually concerned with. Baxter and Sommerville believe that *"... it is not enough to simply analyse a situation from a socio-technical perspective and then explain this analysis to engineers. We also must suggest how socio-technical analyses can be used constructively when developing and evolving systems. (...) We must avoid terminology that is alien to engineers, develop an approach that they can use, and generate value that is proportionate to the time invested."* [63, p.4] While this perspective seems to assume that an engineer is unable to do some of the translation work themselves, or that they are too busy to care, it is still a valid endeavour to make sure to not alienate other disciplines through vocabulary. The use of perspectives presented under sociotechnical systems may be a good strategy

to make clearer some of the 'softness' of systems, as well as negotiating levels of abstraction balancing for example the role of the context and of an individual.

The emphasis of sociotechnical system research has been on complex organisational systems. But smaller arrangements of technology, humans, and other agents, can be as complex. Silverstone denominates "domestic socio-technical systems" when studying the combination of once static (and now mobile) everyday technology such as televisions, telephones, computers [64]. As noted, '*'families are social units, systemic, more or less clearly bounded through networks of kin, more or less coherent or secure in the patterns of relationships through which they are defined, but the basis from which individual identities are forged and sustained."* Hence, *"the domestic socio-technical system consists of a bundle of skills, tastes and competences, expressed in styles and practices that construct and mark the cleavages of gender and age-based relations within and beyond the household"* [64, p.138]. These arrangements have implications both for the possibilities of design but also for research within HCI. For example, Slovák, Theofanopoulou, Cecchet *et al.* incorporate the multiple stakeholders in families in order to inform the design of a robot for children [65]. Their work is an example of how designing for and with children involves more than just the children themselves or the robot on its own. *"The principles of socio-technical design then apply on multiple levels: how the (technology-enabled) intervention becomes embedded into the current practices of an individual or the family unit; which mechanisms are assumed to lead to shift of these practices; and on which timescales and through which 'levers' this happens in the family context."* [65, p.160:6]

As a related notion – the concept of sociotechnical assemblages is widely used [10], [11], [66], [67]. In particular, Latour's 'matters of concern' describe the understanding of scientific and technological assemblages as something beyond objects but rather fluid arrangements of political and social interests [68]. The frameworks usually described under the label of sociotechnical systems represent the potential inability to incorporate the changing nature of assemblages (even if time is one of the aspects of the framework), but strive often to catch some of the parts of a system that may otherwise be neglected. As I see it – it is less helpful in design epistemology to strive for the use of a single unifying framework, and prefer the capacity to tolerate a multiplicity of approaches that may aid in re-framing knowledge in a pluralistic manner while still making bridges between multiple disciplines.

1.2.2 Design Methodology

What methods should be used to tackle what is possible to know (epistemology) within design is a large portion of a both a designer's and researcher's job[4].

[4]Years ago, when I attended my first course in Interaction Design Methodology, we were instructed to devise a toolbox of methods. The aim of the exercise was to consider what is important to know about methods to be able to correctly sort them and pick the most appropriate one for the situation at hand. My first go at the exercise was a tangible slot machine: at the time I was convinced the best attempts at sorting methods were already done, and that we should rather just give ourselves the playful mission of incorporating random methods into the design process. As part of the final exam in the course, we were asked to redesign said toolbox. I eventually wrote that I had understood that the most important way of sorting methods is by recruiting diverse people into design teams: we bring through the interdisciplinary combination of individuals the possibility for people themselves to be the toolbox. This brings great advantages, as we become experts in the methods we practice. I am of the opinion that often we hide the

There are many expectations as to what the output of research ought to be, and as discussed above, within HCI, there are mainstream ways of tackling these expectations. The methods described in this subsection gained a place here in many ways, often to fill a methodological research gap in Human-Drone Interaction as discussed in Section 1.3, but at times by mere chance of being the methods that I was interested in at the time.

When the work included in this thesis started we were still suffering from effects of the COVID-19 pandemic. Ethnographic studies were particularly difficult to conduct, for example. I place the description of some of the methods here as an introduction to what types of approaches were considered in my work, leaving out however descriptions of common methods such as interviews. This section is non-exhaustive and leaves outside many other relevant methods tried during the process, focusing instead on the most fundamental methodological discussions that surface through my work.

1.2.2.1 Ethnography

Ethnography, in its many forms, is a method widely used in third wave HCI. The issue of validity of empirical studies evaluating systems has been debated for decades [e.g. 69], [70]. Empirical research conducted in context of use is widely seen as more valuable from an ecological validity perspective, for example through the use of ethnography, particularly when aiming at triangulation through mixed methods [71], [72].

The issue of the compatibility between ethnographic research and design work is central to the practice-driven and pragmatic attitude usually preferred within the field of HCI [73]–[77]. Dourish questions in particular the use of ethnography in his influential paper called *Implications for Design* [77]. The issue here is that ethnographic research, when published in HCI venues, tends to close with an Implications for Design section, being otherwise at the risk of negative reviews. Dourish problematises the idea that such implications became the primary evaluative criterion for ethnographic research – proposing instead that *"what matters is not simply what those implications are; what matters is why, and how they were arrived at, and what kinds of intellectual (and moral and political) commitments they embody, and what kinds of models they reflect"* [77, p.7]. He dedicates considerate discussion to the issue of understanding ethnography as a tool to close the gap between society and technology. But *"seeking to close the gap through the application of ethnographic methods is a contradiction in terms; the gap is where all the interesting stuff happens, a natural consequence of human experience. Design is critical, but designs must always be put to work in particular contexts, adopted and adapted by people in the course of practice"* [77, p.6]. His critique is not that ethnography does not have implications for design, but rather that those implications can be difficult to trace, diffuse, or inappropriate to summarise into a list. The impact of ethnography is in providing new viewpoints in the imagination of relationships between people and technology, drawing on *"on the fundamental repudiation of a traditional separation between designer and user, between technology and practice. To the extent that these implications are not formulated as 'implications for design,' it is because the categories of design, user, and designer, are themselves in question"* [77, p.8].

true reasons as to why a method is chosen in the discourse of a research gap.

More than 10 years later, Khovanskaya, Sengers, Mazmanian *et al.* looked back into this discussion in an attempt to rework the gap between design and ethnography, recognising that design goes beyond the making of innovative things but rather is also a form of inquiry into the world [75]. They use speculative design as a way to 'get design wrong' and 'making tacit ideas and assumptions concrete'. This mixture of design with ethnography as knitted practices resulted in making misunderstandings – here perceived as productive rather than destructive to the research practice.

Along with all these critiques and tensions in the use of ethnography, the spectrum of available ethnographic methods is expanding, necessarily bringing new issues of how they can be made compatible with design practice, but also how they can be ethically applied. All ethnographic methods – participatory, observational, or covert – bring ethical issues in the relationships between researchers and participants [78]. When conducting ethnographic work, there both general concerns in the form of consent and procedural ethics (e.g. [79]); as well as situated issues such as unexpected effects (e.g. over-researching [80]), the need for unplanned action (e.g. micro-ethics [81]), and unexpected intrusions (e.g. sensitive data in the digital age [82]).

Two examples of growing ethnographic methods with their own set of difficulties both in compatibility with design and negotiating ethical issues are cyberethnography and autoethnography. The internet has created a new space for ethnography through social media, online fora, and news articles. It seems that this dear child has many names: cyberethnography [e.g. 83], netnography [e.g. 84], online ethnography [e.g. 85], virtual ethnography [e.g. 86], and probably many others. However, using data from online media is not without ethical issues to be considered [87]–[90].

Another form of ethnography comes in an approach where personal experience and first-person understandings of the researcher are at the centre [91]. Ellis, Adams and Bochner [91] describe how autoethnography challenges the notion of separability between researcher and research product by through the merging of an autobiographical method with the ethnographic one. This method is increasingly popular in HCI, which is unsurprising given the pull to make political agendas more visible in research [52].

The use of the method has had its presence in the field for many years. For example, Ljungblad [92] was part of her own study alongside her participants in using a life-logging passive camera. Höök [93] offered an account of her own practice of horseback riding and how it developed into ideas for soma design. Lucero [94] challenged himself to live without a mobile phone, and through ethnography reports on a set of themes to be considered when designing mobile interactions. Similarly, Homewood, Karlsson and Vallgårda [95], present two autoethnographies on self tracking and propose removal of technologies as a method for fourth wave HCI.

A similar approach (but connected to research through design) is autobiographical design, where probes are used by the designers themselves [96]. Desjardins and Wakkary present a twenty-three month long project of converting a van into a camper van together with her partner [97], and Lockton, Zea-Wolfson, Chou *et al.* [98] develop the notion of autoethnographic 'kits' through the work of undergraduates related to their sleep routines. Yang and Neustaedter [99] report on the use of a telepresence robot to support a long distance relationship during three months.

Autobiographical design serves well as a method to surface insight in intimate contexts. Helms [100] uses the method to surface concerns on more-than-human agents and materials in breastfeeding. Framed by speculative ethic, she also presents notions on the emotional cost of this research with her own bodily fluids [101].Devendorf, Andersen and Kelliher produce, as a community, a set of *design memoires* manifesting in wearable artefacts stories of their personal struggles with motherhood.where stories from their personal struggles with motherhood. These memoires *"can lean against emergent solutionist narratives about technology in early motherhood that I find inadequate for addressing the totality of a complex felt experience."* [102, p.2].

Desjardins and Ball [103] dedicate themselves to finding best practices for autobiographical design in HCI through the analysis of their own work. Their findings discuss: genuine needs, design participation, intimacy, reflexivity, and authorial voice. They offer recommendations for other designers interested in using this method[5]. They reflect extensively on the role of the families as changing roles between participants, users, designers, and many others. Naturally, the boundaries between work and private life become diluted, but *"part of the value of doing autobiographical design is to embrace these dual roles (researcher and everyday person) and to observe new types of reflections emerging from a convergence of thinking"* [103, p.760]. This type of work brings the need for making decisions for example on the use of voice (first person singular, plural, or third person), and what the consequences of that choice are to the written articles [103]. Finally, Desjardins and Ball suggest a set of recommendations for future autobiographical research: sincerity in the 'original stories' that led into the projects but also to intentionally design time into the process to allow for reflection and hindsight; transparency on who are the collaborating and authoritative actors of the research; and inventiveness in the approach to the method [103].

It is important to remember that autoethnography carries a weight. Only researchers in positions of certain power and privilege are allowed the possibility to tell their stories. However, the process is not without a cost to the researchers themselves, both in their personal lives but potentially also in difficulties publishing [104].

1.2.2.2 Visual Methods

While scientific publications have primarily focused on the written format [105], many academic papers include diagrams and other types of illustrations to make clear points on structural relationships and hierarchies. One interesting example of a primarily visual document that came hand-in-hand with scientific and design research is a patent. Hence, the value of visual methods (drawing, illustration, photography, videography, etc) should not be alien to science.

The use of visual methods supports other methodologies and aids in re-framing them, and aiding them beyond traditional and normative boundaries [106]. For example, in the phenomenological framing mentioned above (Section 1.2.1.1, the use of pictures to express embodied experience is justified, at times surfacing the constant re-emergence of the cartesian dualism [107]. Gillies, Harden, Johnson *et al.* found through the use of painting in their otherwise linguistic and text based research that: *"In contrast [to written accounts], the paintings had a looser*

[5]That would be me!

narrative structure, as they were generated in a medium that allowed for the expression of feelings in response to the trigger, rather than a more formulated description of events with the aim of telling a story" [107, p.209]. Visual data is argued to be more ambiguous than verbal:

> "Further, the lack of agreement about the translation of visual symbols, and the fact that we are used to being able to display these symbols in a slippery ambiguous way in order to control the amount of information we reveal, means that analysis becomes as much a matter of translation as interpretation. These features arguably make visual data more difficult to under- stand and interpret than verbal data. How- ever, while these problems and difficulties may be highlighted in relation to visual data, they can also remain problematic in the analysis of verbal data." [108, p.188]

While this can be a bigger issue for many other fields (such as psychology [108]), it is not necessarily an issue for design. Design knowledge favours ambiguity as a resource [109]. More importantly, the use of visual methods is inclusive to marginalised groups, making visible issues of intellectual ownership and ethics [105]. The necessity of considering visual media in research is made more urgent with the popularity of virtual spaces [105] – and hence a good match for the ethnographic methods mentioned in Section 1.2.2.1.

Design knowledge is often communicated through the combination of visual media and text [110]. Blevis has contributed extensively to HCI in clarifying the roles that visual thinking may take, for example as a material of interaction design, as a contrast and synthesis of analogue and digital world, as a form of information, as mechanisms of identity, or as documentary observation and photo-ethnography [110]. Returning to ethnography and its logical connection to visual thinking: *"the most important concern of still-image making, in a professional sense, is to make sense of the world and reveal what is extraordinary and meaningful about everyday scenes"* [110].

As noted, images play a definitive role for designers as *"as a key component of professional presence and portfolio construction"* [110]. For example, annotated portfolios [49] are a popular way of documenting the design processes in a manner that makes design particulars useful and understandable to others[6]. In the context of design practice, rigour is exhibited through systematic and careful documentation of the process. Often, such documentation comes in visual form through for example sketches, photographs, diagrams, illustrations, and videos – often paired with an annotation or explanation of their relevance.

All of these visual forms bring their specific set of characteristics. Sketching, for example, is commonly recognised as a technique intrinsic to design practice [111]. There is more to sketching and drawing than the final product, it is often the conversational process that conveys value: *"Drawing is both an active and subjective engagement, valued by artistic researchers, not only for what may finally be encrypted in the drawing, but more significantly for the access provided through drawing to thinking that is close to the unconscious"* [112]. This dialogical nature of sketching is a common notion [113]. As Goldschmidt notes: *"The self-generated sketch talks back, and its backtalk reflects some of the sketcher's innermost, tacit,*

[6]I offer a more extensive discussion on intermediate-level knowledge and making design particulars contributions to knowledge in Sections 2.3 and 3.2

otherwise untapped knowledge, biases, concerns, and preferences" [114, p.87]. This makes sketching an excellent tool for, for example, first-person methods.

Ings describes these effects beautifully as a justification to the notion of enstasis – a meditation-like state when drawing:

> "In design research I would suggest enstasis might refer to an induced interior state of self hood where one dwells in the creative potential of what is not yet formed. This process may involve the deployment of drawing in a slow, reflective process that allows the designer to become immersed in the world of the emerging image and story. In this approach, thinking becomes contemplative; the designer converses with drawing and the drawing talks back to him. This talking is generally more nebulous than literal. One talks in tone and weight, emphasis and potential. Ideas are coloured and lit and their parameters are nuanced. Thinking is not prescribed by the territorial limitations of words. Images operate with a more flexible grammar and one is able to connect possibilities in comparatively abstract and intangible ways." [115, p.2.4]

The field of HCI is aware of role sketching plays. Buxton and Buxton's seminal book in *'Sketching User Experiences'* is widely used both in research and in the education of interaction designers [116]. Sketching is also an integral part of ideation techniques [117]. To be able to quickly represent ideas is essential to become proficient in common methods used within HCI such as storyboards and paper prototypes. As an example of research hinging on sketching, Koulidou, Wallace, Sturdee *et al.* present dialogical sketching as a participatory design method, arguing that it supports and enriches the use of probes by facilitating discussions and maintaining sustained engagement [118].

But as noted by Sturdee, Lewis, Strohmayer *et al.*,

> "The current lack of perceived value, support and training for creative practice within HCI remains the biggest limitation of the approach. Sketching and drawing is often seen as a "soft" skill, of lower value than technical practices and outputs such as coding and writing, or a 'hobby' – but we show here the added value they can bring to the research table." [119, p.11]

They argue that sketching practice have a role supporting more-than-human approaches in HCI, adding value to ethical and futuring enquiries [119], definitely positioning sketching as an essential technique for 4th wave HCI [52].

The ACM CHI Conference on Human Factors in Computing Systems, which is the premier international conference in HCI, has had multiple workshops and courses dedicated to sketching [e.g. 120]–[134]. Within ACM there are many forms of publication that rely heavily on visual methods, even though full papers and text are still perceived as more important than any other contribution. But most remarkably, pictorials have become increasingly popular – as a sign of the growing acceptance of designerly visual knowledge in the field. Pictorials started in 2014 at the ACM Designing Interactive Systems (DIS)[7] and continued to successfully spread across other HCI venues such as the ACM International Conference on

[7] https://dis.acm.org/2022/

Tangible Embedded and Embodied Interfaces[8] (TEI), and the ACM Conference on Creativity and Cognition[9] (C&C). There are a number of pictorials visually discussing the pluralistic, unresolved and yet incredibly generative tensions between theory, text, artefact creation, visual documentation, and design knowledge in HCI [e.g. 119], [135]–[139]. Sturdee and Lindley present a curated pictorial exhibiting the arts practice of a range of HCI researchers, reflecting on the relationship between creativity and computing, and exemplifying how artistic narratives in HCI contribute to a desirable plurality, encouraging other researchers to make hidden artistic practices visible [140]. These examples agree on the necessarily incomplete, open-ended, situated, subjective, speculative, and qualitative nature of design knowledge which is compatible with visual methods.

The emergence of pictorials within these popular HCI conferences is a clear advancement in the field towards the inclusion of visual methods as a respected and rigorous approach to research. The ACM DIS call for Papers and Pictorials describes them as:

> "DIS pictorials are archival publications in which the visual components (e.g., diagrams, sketches, illustrations, renderings, photographs, annotated photographs, and collages) play a significant role in conveying the ideas and contributions in addition to the accompanying text. Pictorials leverage the power of visual communication with the effective use of high-quality images. They may have a practical or theoretical nature or both. As design perspectives have increasingly become integrated in HCI practice and research, new approaches are needed to communicate design practices, processes, products, and artefacts to the HCI community. Through pictorials, researchers, practitioners, industry professionals, artists, designers, and students from various disciplines, including interaction design, engineering, computer science, product design, social science, media studies, and the arts are encouraged to express and unpack their design practices and projects in visually rich ways. The pictorials format helps foster discussions among authors, conference attendees, and the wider community by sharing novel methods, insights, and lessons learned from engaging in or with the design of interactive systems and artefacts." [10]

At the ACM C&C conference the following is found: *"Pictorials are papers in which the visual components (e.g. annotated photographs, art work, collages, diagrams, field notes, illustrations, photographs, renderings, sketches) are the primary means of conveying information with at least, if not more, importance as the accompanying text. Pictorials are part of the technical program. Pictorials are equivalent contributions to Full Papers in every way (e.g. production standards, archival qualities, reviewing standards, presentation times, institutional reporting). The differences are in the format."* [11]

Therefore, to fully emerge myself in the explorations of visual knowledge in HCI, I have included two pictorials as part of the appended papers in this thesis. In the context of my research in HDI, the relevance of visual knowledge can not

[8] https://tei.acm.org/2023/participate/pictorials/
[9] https://cc.acm.org/2022/pictorials/
[10] https://dis.acm.org/2022/papers-and-pictorials/
[11] https://cc.acm.org/2023/pictorials/

be neglected. Drones themselves are often used as tools for the production of photography or other imagery.

1.2.2.3 Narratives

Stories are a cornerstone of life. *"Story is central to human understanding—it makes life livable, because without a story, there is no identity, no self, no other."* [141, p.505] Hence, storytelling ought to be a natural component of research. Many common methods within HCI – such as for example use cases, personas, and scenarios – already make use of narratives as an essential component.

Narratives are a natural result of ethnographic methods – and exhibit some resistance in their analysis. They tend often be analysed and summarised into themes through thematic analysis (TA) [142]. Preserving narratives along with the themes is a good strategy to present reflexive thematic analysis [143] – allowing for the above-mentioned tensions between ethnography and the knowledge it produces. Braun and Clarke note that *"Reflexive TA has been used in case study research, where the focus is on a small number of cases, or even one case (e.g., [144], [145]). Furthermore, some researchers have combined reflexive TA with narrative methodologies and procedures to produce distinct 'hybrid' methods that are concerned with both narrative structure and 'across case' patterning of meaning (e.g., [146], [147])"* [143, p.13]. These hybrid approaches have the potential of being helpful in design research, which is usually not concerned with the narrative structure or use of language, but rather dedicated to understanding experience in its many forms.

It is important to remember that:

> "The narrative text refuses the impulse to abstract and explain, stressing the journey over the destination, and thus eclipses the scientific illusion of control and mastery; and the episodic portrayal of the ebb and flow of relationship experience dramatises the motion of connected lives across the curve of time, and thus resists the standard practice of portraying social life and relationships as a snapshot. Evocative stories activate subjectivity and compile emotional response. They long to be used rather than analysed; to be told and retold rather than theorised and settled; to offer lessons for further conversation rather than undebatable conclusions; and to substitute the companionship of intimate detail for the loneliness of abstracted facts." [148, p.744]

As HCI moved from the lab to the field, qualitative research surfaced often in the form of narratives. Methods pertaining the social sciences have an increasingly prevalent role in HCI – the project I belong to is dedicated to understanding technology from a societies and humanities perspective. It is undoubtedly relevant to my work: *"narrative research is particularly useful for exploratory research projects, which seek to engage with experience and meaning-making processes of diverse individuals or groups"* [149, p.299]. Golsteijn and Wright note however, how although narratives are fairly popular in HCI, they are often restricted to an outcome or goal of design research *"rather than being fully embraced as a research approach across the entire process"* [149, p.299]. However, with the raising popularity of a variety of longitudinal ethnographic and autoethnographic methods, we see more holistic narratives surface in the field. Núñez Pacheco and Loke for

example, present narratives of use through focusing as a method to facilitate articulation of tacit experiences [150]. Narratives are a favoured way to explain intricate embodied experiences, particularly when they challenge the mainstream or the familiar [151]. They can be composed of text, imagery, or most likely in HCI through the use of designed artefacts, a combination of both [e.g. 92].

The practice of design is also strongly grounded in fiction: *"Some HCI work also included entirely fictional narratives developed in the process of design. Design is a fundamentally imaginative act that involves picturing the world as other than it is. Many forms of design (e.g. scenarios, personas, sketches, speculative design and design fictions) can be thought of as research fictions, in the sense that they are imaginative responses to questions"* [152, p.5400]. In an *Interactions* column, Tanenbaum explains why HCI should care about stories: *"The interpretation of a reader or viewer – what we might call the user experience – is equally important. Good design fictions incorporate the elements of good storytelling alongside an understanding of how readers interpret and understand narratives to create compelling (and believable) fictional worlds around an imagined technology."* [153, p.23]. Blythe analysed which types of plots researchers make in HCI design fiction [152], and calling for more proficiency in becoming more purposeful in picking which plots we construct in our research.

Stories and narratives generated through ethnography and situated engagements with technology bring the great advantage of opening up for relatable and more engaging representations of research. But they are not without ethical issues of their own in terms of for example vulnerability of participants [e.g. 149], [154]. It is the role and duty of the researcher to be able to negotiate disclosure and consent during the research process – always remembering that the stories captured in research are often presented with ending conclusions – but all of these are provisional. The stories do not stop beyond research, and the lives of those researched keep being lived.

1.2.2.4 Research through Design

The theory-practice tensions presented above are also represented in the type of work that is produced in research. Frayling identifies three ways of approaching research in arts and design: research *into* design, research *through* design, and research *for* design. The first encompasses the ground-laying work of information and reference material gathering done to feed into the design itself in order inspire and justify design decisions. Research *into* design is the work dedicated to studying the practice of design. Much of the work presented in this thesis falls within these two categories. But along with them, there is research *through* design – research done through practice and craft, through exploration and manipulation of the design material.

Research through Design (RtD) is now a substantial tradition within HCI, owing largely to the theoretical scaffolding established in the last two decades [49], [155]–[158]. Said manipulation of materiality is precisely what defines RtD. While it is easy to understand why exploring materiality is important for example to a furniture maker, it is less obvious what its role is in computational matter. However, materiality is precisely as important, as argued by Wiberg, materiality transcends any distinction between the physical and digital [159]. The definition of materiality in interaction encompasses things such as time [160]. Much of what is RtD is exploring materiality without one unified objective or hypothesis. RtD

is important to the research field precisely because it implies a closing of the gap between practice and theory through making. For a commercial designer, the value is in the artefact itself, but for a researcher there are two important notions to consider: research products and intermediate level knowledge.

To probe into forms of knowledge without a commercial motivation, [161] discuss the difference between a prototype and a research product. A research product is one that exhibits qualities such as: inquiry-driven, finish, fit, and independent [161]. While prototypes are provisional, unfinished, and exploratory, design products are artefacts that are independent[12] and with a finished quality and intention for design inquiry. Research products are designed for actuality, focusing on the design product as is rather than what they may become [161]. But research products are not just about 'use' – they are meant to inform theoretical framings of design. For example, Hauser, Oogjes, Wakkary *et al.* use research products *"to advance the idea of seeing the empirical efforts of research products as an experimental way of doing postphenomenology or in other words doing philosophy through things by making this theoretical framework more intelligible and actionable to other HCI researchers"* [162, p.468]. Research products have in this sense a similarity with 'provotypes', which are provocative prototypes that *"embody tensions surrounding an area of interest, in order to support collaborative analysis of that area and to collaboratively explore design possibilities"* [163, p.389].

The ways of knowing in RtD are not straightforward. Research through Design's produced knowledge is provisional, contingent, and aspirational [164]. One specific way of creating bridges between design knowledge, theory, and exchanges between practitioners and a wider audience is through what is called *Intermediate Level Knowledge*. The design-oriented and playful practice presented in this thesis brings implications in terms of knowledge creation, which must be contemplated throughout the research by supporting a transparent documentation of the RtD process but also a careful consideration of the 'showroom' as a possible platform for the interpretation of our design experiments and how it can inform the development of different forms of intermediate-level knowledge. Koskinen, Zimmerman, Binder *et al.* suggest that RtD in the 'showroom' tradition *"relies on debate,"* enriching communication about how we experience the material world [158]. The work in this thesis includes well studied approaches to the problem of intermediate-level knowledge [31] which *"is more abstracted than particular instances, yet does not aspire to the generality of a theory"* [165]. Beyond guidelines, patterns, methods, and other tools; a common approach to the creation of this abstraction is Gaver and Bowers's *Annotated Portfolios* where visual explanations are paired with reasoning and reflections by the designers [49], [166], [167]. Another example is Höök and Löwgren's *Strong Concepts* which focuses on the expression of abstract ideas that can be appropriated by other designers in a generative manner [165].

However, key many challenges and lost opportunities remain, including the following: (a) The realities of the design process are 'messy' – mismatches between how RtD ensues and how it is reported in scholarly publications are unavoidable. (b) RtD is difficult to penetrate for novices. Practitioners are challenged when they must simultaneously acquire knowledge in its philosophy, in addition to the design challenge at hand, as well as material and craft knowledge. (c) Practitioners are largely disconnected from the world of academic RtD – the nomenclature and

[12] As an architect I would call this an artefact that speaks for itself.

ethos of commercial design research is quite different[13].

Hence, while the overarching philosophy and certain genres of RtD are currently well-articulated, I see a need to advance the discussion on the *process* and *purpose* of it – how and why it is done. Rationales for the value of need-driven (i.e. user-centered), vision-driven [168], and concept-driven [32] design research have been well-defined by scholars; while the notion that exploratory research in itself is a valuable contribution [169] is comparatively rare. Indeed, Ishii, Leithinger, Yao *et al.* imply that 'technology-driven' research meant to explore materialities of design is inferior to approaches with specific humanistic, artistic, or philosophical ambitions [168].

But many design researchers would agree that a research project can *begin* as an open-ended 'playful' exploration and converge to a purpose over its course. Exploratory design research can itself generate research contributions, for example: unfinished or discarded prototypes can be picked up by the research community in future work [169]. What we need to understand is instead how to encourage the community to engage with these discarded ideas in a productive way.

When approaching design projects with a RtD agenda, we must understand that the designer themselves are deeply embedded into the process. But at times it may be difficult for the designers to identify what is relevant for their positionality. Therefore, the use of autoethnographic methods tightly weaved with RtD is beneficial, as exemplified by the practice of autobiographical design mentioned above. Ellingson [170] emphasises the importance of considering the embodied experiences of the researcher, including how they feel and how their body is positioned and understood in space. This first-person perspective is particularly important when defining the design space in RtD. However, there can be challenges in analysing the outcomes generated by the researcher themselves and in communicating design knowledge that can be applied in future research.

1.2.2.5 Concept-Driven Interaction Design Programs

As mentioned above in Section 1.2.1.2, the paradigms in HCI have changed. Within these traditions, user-centered design became a favoured approach for most researchers and practitioners. Stolterman and Wiberg argue however that a concept-driven approach (which has been implicit for a long time in the field) can explicitly contribute to a valuable exchange between the production of design artefacts and the development of design theory [32]. They propose *concept-driven interaction design* as defined by:

- "The point of departure is conceptual/theoretical rather than empirical.
- The research furthers conceptual and theoretical explorations through hands-on design and development of artifacts.
- The end result – that is, the final design – is optimized in relation to a specific idea, concept, or theory rather than to a specific problem, user, or a particular use context." [32, p.98]

Here, the distinction is made towards situation driven research: *"Although situation-driven research has a client and a problem to solve, concept-driven*

[13]See: the 'research/practice barrier' described in [155].

research is an exploratory investigation of established theories with the overall aim of improving and widening the range of theory and knowledge." [32, p.102]

In agreement with Stolterman and Wiberg, I consider that many of the design approaches in HCI fall partially or entirely under the category of concept-driven. My research agenda is mostly worried with the construction of future worlds, and the re-framing of the role of drones in society. Therefore, I need to recruit a combination of theories and practices that allow for a plurality and negotiation between particular use contexts and the formulation of theories for future design.

Below, I present a set of design research programs that favour the exchange between concept-driven and situation-driven design. Research programs, as described by Redström, *"characterizes a research programme that it contains a hard core of theories and beliefs that are held to be true"* [41, p.88]. Accordingly, design research programs are provisional combinations of defining world views and design experiments, in constructive expansion (or alternatively, the defining world views no longer suit, discarded). Below, I present some of these programs which have had a strong influence in the papers appended to this thesis.

Soma Design is a design programme [171] framed by phenomenology. It is informed by a philosophy of somaesthetics [172], [173], emphasising subjective knowledge and favouring the 'felt dimension' of experiences. In this philosophy, the division of body and mind (the cartesian dualism) is rejected: we are one unified bodymind – *"the soma – the living, sentient, purposive body – as the indispensable medium for all perception"* [174]. Within soma design, anyone involved in the process of designing or using interactive 'things' [175] are expected to cultivate and be engaged in their sense of (soma)aesthetic appreciation towards living better lives. Therefore, it is central to this design program to engage in movement, feeling, and in curiously exploring the connections between our soma, the world, and others. Teaching soma design [176] exhibits dimensions of temporal considerations, involving exercises that vary from slow to fast, contradicting much of what is favoured in many trends of design thinking (e.g.: agile and sprints). Soma design does not try to generalise experience, instead focusing on the pluralism of bodies [177] and how well documented experiences can contribute to a generative collective understanding of what designs are desirable. There are a number of methods habitual within this program, one example being body maps [178]: a technique for discussing bodily experiences through drawing them on a piece of paper prepared with prompts and the outline of a human body. Another common method is expert interviews with somatic connoisseurs [179]: people with in-depth knowledge of a bodily practice. First-person methods are also favoured and embraced [180]. It is also common to attempt to disrupt habitual [181] through defamirialisation methods [182] and estrangement [183].

Soma design relies on a number of conceptual and foundational groundings such as the concept of *Somaesthetic Appreciation* [184] – four qualities to be considered both during the design process but also expressed in the final artefact: 'subtle guidance,'making space,' 'intimate correspondence,' and 'articulating experience'. Another guiding pillar is the Soma Design Manifesto as developed by Höök [171]:

- "We design for better lives - not for dying
- We design to move the passions in others and ourselves
- We are movement, through and through

- We design with ourselves - through empathy and compassion
- We design slowly
- We cultivate our aesthetic appreciation
- We disrupt the habitual & engage with the familiar"

This manifesto connects well with Slow Technology, and is a useful set of thought-provoking and challenging prompts to design in HDI.

Slow Technology is *"a design agenda for technology aimed at reflection and moments of mental rest rather than efficiency"* [185] proposed by Hallnäs and Redström. In short, this design program departs from conventional approaches to interaction design such as optimisation for efficiency and usability. It instead puts *"focus on slowness of appearance (materialisation, manifestation) and presence – the slow materialisation and design presence of form"* (F); and *"focus on aesthetics of material and use simple basic tools of modern technology – the clear and simple design presence of material"* (M) [185]. Slow technology seeks to develop artefacts that support meaningful reflection, presence, and at times inefficiency rather than 'use' [186], [187]. There are three conceptual themes that support this core vision: 'reflective technology', 'time technology', and 'amplified environments' [185]. [188] extended on Hallnäs and Redström's initial ideas through the analysis of artefacts produced within the program and produced eight key qualities to them: implicit slowness, explicit slowness, ongoingness, temporal drift, pre-interaction, temporal modality, temporal interconnectedness, and temporal granularity [188]. While I will not develop on these qualities here, it is evident that the interest in this design program continues to produce both design particulars and extensions of the theory. Considering this design program within HDI is valuable as a contrasting stance to a rapidly expanding technology.

Critical and Speculative Design [189]–[191] initially coined by Anthony Dunne, has been discussed and redefined by many authors within HCI [192]–[194]. There is no unified agreement on what it entails, but most authors seem to agree that design as provocation is one of its most important pillars. Dunne & Raby explain their design approach in their A/B manifesto[14], contrasting the design program with conventional ideas of the role of design. This manifesto (see Figure 1.5) is particularly useful when creating designs that seek to challenge rather than solve, in the spirit of anti-solutionism [195], at times producing essentially useless (but not worthless [196]) applications, probes, or 'provotypes' [163]. Here, researchers intentionally generate probes and artefacts that pose questions rather than offering answers, supporting critical enquiry through actual artefacts (see also *material speculation* [197]).

Critical design is connected with speculative design – at times used interchangeably with design fiction [198] – an approach to design through the development of probes that belong in fictional worlds. Drones play a significant role in our imaginary worlds, and there is research dedicated to creating probes to critically question the future of the technology [199], [200]. Blythe uses design fiction to create abstracts of imaginary research through design articles [201]. For example

[14]Work in progress since 2009 available at http://dunneandraby.co.uk/content/projects/476

(a)	(b)
affirmative	critical
problem solving	problem finding
design as process	design as medium
provides answers	asks questions
in the service of industry	in the service of society
for how the world is	for how the world could be
science fiction	social fiction
futures	parallel worlds
fictional functions	functional fictions
change the world to suit us	change us to suit the world
narratives of production	narratives of consumption
anti-art	applied art
research for design	research through design
applications	implications
design for production	design for debate
fun	satire
concept design	conceptual design
consumer	citizen
user	person
training	education
makes us buy	makes us think
innovation	provocation
ergonomics	rhetoric

Figure 1.5: The Dunne & Raby Design Manifesto: *"a manifesto that positions what we do in relation to how most people understand design."* Work in progress since 2009 available at http://dunneandraby.co.uk/content/projects/476

Lindley and Coulton develop a fictional world involving drones only to reveal at the end of the paper that it *"presents a fictional account of plausible future HCI research its purpose is not only to highlight potential usability or utility issues such systems might present but to also create a discursive space in which researchers can consider the wider societal and ethical issues of technological futures in which drones might be widely adopted"* [202, p.618].

1.3 A Narrative Literature Review of Human-Drone Interaction

Propelled by the research agenda in my project, I needed to focus on understanding in what ways current HCI research in drones applies design knowledge, approaches, and methods. I do not seek to find or offer a converged definition of social drones[15] – instead, I am concerned with understanding what is the impact of design knowledge in the drones currently studied within HCI (and usually described as studies in HDI). In this section, I build on previous drone research through a narrative literature review [203], in order to understand the role of design knowledge and processes in HDI.

Drones are an emerging technology with an established research domain of their own on Human-Drone Interaction (HDI). They are undeniably becoming integrated in society as tools in a variety of work practices, such as mining, energy engineering, forestry, cinematography and police work [3] and in leisure activities such as photography (see e.g. [2]). This ongoing and advanced development suggests that we need to understand the different types of practices of drone use in society to guide future design. For example, several new application areas are emerging which utilise drones, including non-military surveillance, navigation, delivery, photography, and more, and researchers are currently exploring new drone concepts and contexts of use. There is also an increasing research interest in the area of so called social drones or domestic drones [204]–[206] – drones being used in inhabited environments such as public spaces, the home, and the workplace, leading complex interactions in social settings.

While there are survey and review articles focusing on drones, none are fully invested in understanding the surrounding situation of the studies and the design methods used. Arafat and Moh [207] focus on technical aspects of drone control, building a comprehensive list of routing protocols for Unmanned Aerial Vehicle (UAV) networks. Also from a technical perspective, Cai, Dias and Seneviratne [208] report on the advances of small scale drones based on the analysis of 132 models available worldwide, forecasting possible applications. Other surveys put an emphasis on applications, such as Otto, Agatz, Campbell *et al.* [209], who conducted a literature survey on optimization within civil applications of drones, offering a number of interesting application areas. There are also user-centered surveys exploring users' perception of drones and their attitude towards possible applications [e.g. 210]–[214]. In these surveys, a nuanced perspective of drones is offered, with space for negative impressions on the technology, and the opportunity to poise critical questions on the use of drones in society. Baytaş, Çay, Zhang *et al.* [205] present a literature review resulting in the collection of human-centered design knowledge on social drones, particularly focused on the evaluation of these drones. This specific review defines social drones as applications where autonomous agents cohabit the same spaces as humans [205]. They then present their findings as a set of drone design concerns and human-centered concerns, although these are

[15] Similarly to finding a definition of design, in the words of Redström: *"we do not settle for just one definition of design is not because we do not understand the essence of design, but because it is much more powerful to work with difference as a basis when coping with complexity and change. And to work on the basis of (making a) difference, we need alternatives, and we need diversity. This is still a conversation between us about what design is , but it is one centered on its potentials for change, not its eventual convergence."* [41, p.141]. Just replace the word 'design' with 'social drones' for the same effect.

not directly connected to actual applications. Other surveys focus on particular applications, such as for example Liew and Yairi [215] who centre their efforts on companion drones, defining these as autonomous social drones, and Kim, Kim, Ju *et al.* [216], who offer a literature review of specific applications within agriculture, including control technologies. Obaid, Johal and Mubin [206] look into domestic applications. In their review, Obaid, Johal and Mubin [206] explore applications and context of use, identifying trends in the research and identifying future work on interaction modalities and novel contexts.

My work however, is more concerned with finding more detailed descriptions of how these applications are taken in account in the research processes and build further on how design knowledge is essential to properly approach these opportunities. Also, Herdel, Yamin and Cauchard [217] offer a comprehensive scoping review, resulting in 16 domains of applications where drones and humans interact. I argue this brings the need to identify design factors beyond applications. Herdel, Yamin and Cauchard [217] concluded with under-explored use cases with great potential, while I am more preoccupied with finding underused design methods, approaches, and perspectives that may be used to research those use cases.

1.3.1 A Summary of Applications and Interaction Modes in HDI

As mentioned, the field has had considerable advances in studying drones as agents for a number of useful applications in society such as delivering, guiding, leading, and safety [e.g. 218]–[228]). They seem to be perceived as a good platform for emergency situations [e.g. 229]–[236].

But within my work, I focus on the design dimensions of these drones [237]–[240]. Previous work in the design aspects of HDI have suggested a variety of applications for drones which are described as 'social'. In particular, there are mentions to the posibility of developing personal 'companion drones'. Karjalainen, Romell, Ratsamee *et al.* [204] identified some of these possible denominations such as 'butler', 'assistant', 'toy', 'pet', and others. In terms of accessibility, there is a relevant body of work suggesting drones as a technology to guide people with visual impairments, or used as assistance in leisurely activities by people with disabilities [241]–[244]. The pairing of drones with an assisting role brings many challenges to the table, and opens many research gaps to be filled in terms of how the drones are perceived, controlled, and how they navigate the environment.

These gaps in control and perception are essential to HDI. Kim, Kim and Kim [222] show how participants in their study favoured teaching drones rather than expected full autonomy – just as one would with a pet. There is research zoomorphic assignments to drone behaviour [245], offering possibility for developing user-friendly metaphors. Wojciechowska, Frey, Mandelblum *et al.*'s paper is dedicated to the design aspects of drones (such as the need to design better propeller guards), and agrees once more with a certain preference for animal-like appearance.

Drones afford many modalities of interaction, which can be made bespoke to different applications. The body of the research in HDI uses headsets, controllers, or mobile phones, including studies dedicated precisely to these modalities (e.g. Pittman and LaViola [247] compare a game controller to a head mounted display). There is an interest in 'natural interfaces' with drones which are usually approached through hand/foot gestures (e.g. [224], [248]–[252]), to body movements (e.g. [253]–

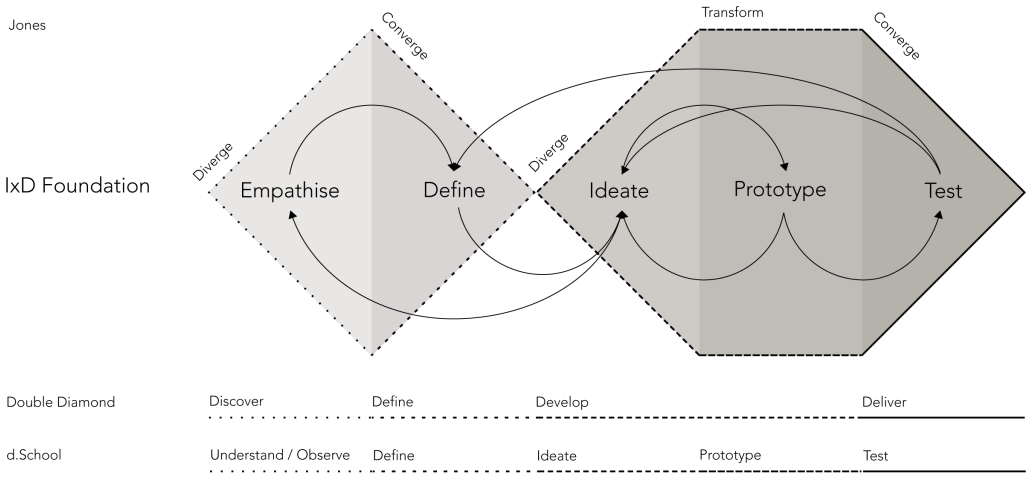


Figure 1.6: A diagram combining different models of the design process. The models are mostly overlapping and can be superimposed without major conflict. We mean to illustrate that a design process does not necessarily follow a linear progression between phases, but can instead take place in messy ways, with iterative transitions back and forth through the phases.

[255]), and proxemics (e.g. [256]–[260]). There are other less common approaches to control drones such as brain-control [261] and muscle and motion sensors [262]. Most notably for my work, the combination of soma design and Tai Chi has inspired coordinated gesture control in deep embodied engagement [253] and creating personal close experiences with micro-drones [253], [263], [264].

1.3.2 Design Processes in HDI

The following results were built on examples of drone research found in the literature. I paid particular attention to articles explicitly describing the design of drones and resulting in robotic artefacts. It appears there is a large focus on prototyping and testing in HDI, while ideation activities were rarely described. I found a severe lack of diversity among recruited participants in the user testing. Some articles had complete descriptions of their design process [204], [234], [253], [259], [265]–[268] acknowledging specifics of design knowledge by pairing the research with HCI design programmes and theories such as, for example, soma design.

Keeping in mind a user-centred design perspective, I sorted some of the HDI literature contemplated here under the five phases of the design process as initially introduced by the Hasso Plattner Institute of Design and described by the Interaction Design Foundation. These are: Empathise, Define, Ideate, Prototype, and Test. There are many models of the design process, and the one I adopted is but one example. Figure 1.6 shows the chosen process, but pairs it with many other common approaches such as the understanding of design as a space of divergence, convergence and transformation [269]; an inspiration to the famous double diamond model. Most complete design projects will fit any model of the design process, with an important feature being the iterative nature of design. Here, I am less interested in the sequential steps of the process or in promoting a specific model, and more invested in understanding to what extent there were different drone-specific design challenges in each step of a process.

1.3.2.1 Empathise

This is the phase of the design process where user needs and other details on the context are gathered. A great portion of a user-centred design process happens during this phase. This phase is not exclusive to the start of a project; it can be repeated at any point in the design process whenever a need for insight is discovered. When looking into the applications suggested, I regularly noted that the publications would only briefly mention a potential drone application without presenting any type of formative user-centred data collection [e.g. 270], [271]. Many of the applications in literature have tone of speculation. While commercial drones already take part in many different work and hobby practices in society, the current trend in HDI research is to focus on generic applications with no or little connection to contexts where drones are already in use.

The reason why design research on the current use of consumer drones is missing in HDI could be partially explained by this lack of reporting on explicit empathise phases. The mismatch between how drones are currently used and proposed research applications has previously been pointed out, grounded in interviews with professional drone pilots [3]. Another example, offered by Wojciechowska, Frey, Mandelblum *et al.* [246], used a questionnaire to evaluate the current perception of the form factor of existing drones in order to establish design guidelines. The lack of user-centred design processes and ethnography applied into design importantly, illuminates a gap between current research and society. I believe that this is a missed opportunity, hindering successful applied research. While Herdel, Yamin and Cauchard [217] advocates for mapping all potential roles of drones, I believe that research in existing real-world practice would contribute to developing new roles in a nuanced manner where, for example, drones may transition between several roles.

1.3.2.2 Define

In the define phase, the analysis and synthesis of the previous phase is developed to synthesise the overall goal and key questions guiding the project (i.e a design brief [272]). The absence of reported define phases in the papers reviewed often resulted in a lack of clarity on what a real-life application would be like, whereas a possible application of drones and their intended contexts of operation and target users should clearly go hand in hand. However, even when no specific application was mentioned, I found distinctions being made in terms of the context the drones were being developed and tested for. Since drones are particularly sensitive to environmental changes, this justifies that the research focuses primarily on either indoor or outdoor use, without considering a transition between environments. Much of the work found required a complicated technical setup which would not be possible outdoors nor accessible to a large pool of users (e.g. studies with VR applications requiring motion capture for tracking the drone and wearables to interact with it, such as SlingDrone presented by Tsykunov, Ibrahimov, Vasquez *et al.* [273]).

Most of the publications discussed a context of use, albeit from different levels of detail. While the majority only offered a distinction between indoor (74 mentions) and outdoor (27 mentions) use, others offered a more detailed account of what the expected context of use would be. It is noteworthy that a great number of publications indicated that the drones would be operating in public

spaces (31 mentions). Furthermore, it is relevant to mention that although context is important for a stable control of the drone, it was seldom noticed that the research included a thorough analysis of constraints specific to the context where the technology would ideally operate. (e.g. FlyingHand by Duan, Punpongsanon, Iwai *et al.* [249] suggests a drone to create haptics for a remote museum visit, but does not include constraints or current restrictions that could support defining the overall design, such as museum rules and goals, or the safety of artworks and visitors).

1.3.2.3 Ideate

Ideation is about the creation of multiple ideas and concepts, preferably divergent or even provocative options. Ideation should be grounded in the synthesised knowledge from the empathise and define phases (the user needs, context, business and other prerequisites). Some ideation activities and alternative designs could be found [225], [226], [274]–[286].

Reporting on early studies and ideation would indeed be useful for other researchers who intend to explore the same design spaces, while expanding on the contribution and overall research knowledge. There are research approaches surrounding design and evaluation in HCI and HRI which also contribute to a more holistic understanding of drones from a user experience perspective. For example, research through design [155], [164] is important for HRI. In this type of work, ideas appear in the making and explorative tinkering with the technology. In La Delfa, Baytaş, Luke *et al.* [264] all the phases of the design process come from a strong theoretical standpoint such as somaesthetics, applying theories of interaction design into a design particular. This theoretical framing is a strong aid when creating ideas.

There is a lack of drone-specific methods for ideation. It may be helpful for example to develop an ideation kit tailored to drone technology shaped by an interdisciplinary design team. Such a kit could be composed of cards representing some of the most interesting challenges with drones, such as international laws, common payloads, levels of noise during flight, etc.

1.3.2.4 Prototype

Prototyping is about implementing ideas into materialisation, with the intention to test design assumptions and ideas. It is common for HDI publications to describe their prototyping activities. The interaction modes concerned types of input and output in the system have a major impact in how prototyping was conducted.

The modalities prototyped for input included either a device dependency or a natural interface. Most of the studies either relied on some type of XR Headset or mobile device to control and interact with the drone. The most popular ways of interacting with the drone without depending on an external device and supporting a more natural interface were hand/foot gestures and body movements or proxemics. It is noteworthy that touch, speech, and facial recognition were not particularly prevalent, unlike many other fields of HRI. There is a great variety of possible devices, often combined in the same study, or even evaluated in comparison (e.g. Pittman and LaViola [247] compare controlling a drone through a head mounted display with a more traditional game controller).

There was not as much variance in the feedback or output supported by the drones as there was in the prototyped modes of interaction. Most contemplated only the movement (flight) of the drone, and a smaller portion the output of images or videos, either directly as a display or to a another peripheral device. Audio feedback was not common, but also, unexpectedly, neither was feedback through lights. Two interesting examples are Ibrahimov, Zherdev and Tsetserukou's DroneLight [287] which allowed users to create long exposure light paintings with drones to communicate messages to others; and Szafir, Mutlu and Fong [282] who explored lights as an output to communicate directionality.

The core reason for prototyping is to create design instances that can be tested empirically. Even if testing is preferably done with users and in realistic settings, the prototype itself can affect the possible set up for testing. This is why it is important to consider how the choice of prototypes may impact the choice of evaluation studies. The majority of the evaluation studies in the publications took place in labs and (mostly) controlled environments. As mentioned by Obaid, Johal and Mubin [206], a likely reason for this is that many of the drone control set-ups are reliant on hardware systems that can only be installed indoors (e.g. motion capture systems [238]), or heavily impacted by the difficulties or legal limitations in operating drones outdoors [259]. Many applications with an intended outdoor operation still had studies conducted in a lab context. In many studies involving visual projections, it was necessary to ensure controlled lighting and stable weather conditions for flight. However, the majority of the indoor study settings reported were not only indoors, but also in a lab rather than in other naturalistic settings such as homes, schools, or offices. The uncertainties surrounding drones are likely a heavy factor leading to the decision to operate these robots in invigilated and highly constrained environments, but remain a necessary factor to consider in research. Oversimplification of the environmental factors in combination with technically fixed prototypes may hinder rather than aid the design process. A better match between the prototypes and expected contexts of use is the only plausible way to understand the real constraints pertaining drones that can inform design.

1.3.2.5 Test

Testing concerns the evaluation of one or several prototypes (or parts of them) with people, preferably relevant stakeholders such as intended users. Testing was a fairly common phase to be found: 79 publications conducted some form of testing. However, only 11 reported on an evaluation with users, and only six actually involved target users. For most publications, the methods used to test the system were typically well established quantitative evaluation methods conducted in labs, such as SAM [e.g. 260], SUS [e.g. 270], and NASA-TLX. For example, NASA-TLX was often used to measure cognitive load related to the use of drones [e.g. 225], [277], [288]–[291]. It seems to be most usual to test drones during the test phase took place in a lab. In contrast but when conducting empathising studies, I found a more widespread naturalistic context is indicated.

Many of the evaluations in HDI do not involve target users, and tend to be one time studies. Two exceptions were Eriksson, Höök, Shusterman *et al.* [255], and Kim and Landay [292], who conducted long-term studies of drones used in artistic performances. Another longitudinal approach was described together with participatory design activities, to achieve speculative design of drone supported

foraging [280] and emergency response system design [234]. Garcia, Chevrier, Jestin *et al.* [244] investigated more accessible drone interaction and conducted two sequential studies, in which the second was a follow up study with the same participants. There were several examples of sequential studies, where different groups took part in studies or trials at different points in the process [e.g. 204], [219], [257], [277].

There is also a lack of diversity in the reported participants during testing. Most of the user studies reported on an adult user pool with a rather low median age, usually recruited on campus and consisting of able students with good vision and no reported accessibility needs. Some publications with a specific application area had a paired target user group, but most other studies did not investigate a target audience or identified who the target audience would be. Some cases present possible applications as assistive technologies, such as controlling a drone with gaze developed by Hansen, Alapetite, MacKenzie *et al.* [293], where the recruited participants were young (mean age 27.7 years, SD = 5.4) video game players rather than disabled people. Garcia, Chevrier, Jestin *et al.*'s HandiFly [244] on the other hand, studies the accessibility needs of a group of target users when designing a remote control, including experts, both when gathering requirements and when pilot testing.

As reported, many of the publications tested through the use of standardised questionnaires within HRI. These methods are not usually focused on understanding or incorporating the context of use, which needs to be complemented with other qualitative methods. This is particularly relevant for HDI given that drones interact in multiple dimensions within their context of use as they have an increased level of movement flexibility. Additionally, it is not guaranteed that the use of well established methods will match the phenomena to be tested. The possible levels of anthropomorphism afforded by flying robots are necessarily limited, but the use of the Negative Attitude Towards Robots (NARS) questionnaire [294] could potentially be more tailored to drones. For example, one of the NARS scales reads *"I would feel very nervous just standing in front of a robot."*, which could be extended to HDI as drones afford other approaches such as from above. Furthermore, as reported by Nomura, Kanda and Suzuki [294], *"...novel types of robots or robots related to battle evoke negative attitudes toward human interaction with robots."* Thus it is particularly important to consider the cultural context of drones and how they are perceived by the users, as UAVs are a technology with a heavy history of military applications. Many of these aspects can only be tapped into through qualitative studies.

The lack of specific methods to study the user experience of drones, combined with the near absence of longitudinal studies, suggests the need for field-specific methods tailored to the design and evaluation of flying systems, as well as a critical review of the methods currently being used. It is worthwhile to consider how complementary methods could be developed. Herdel, Yamin and Cauchard [217] call for the need to *"identify metrics to quantify the value of HDI across various situations of use to provide ecological validity to current and future research works"*. While I recognise the need for metrics, I also see the need for a broader qualitative understanding which can also provide ecological validity. Questionnaires, interview methods, co-design tools, and heuristics shaped to drones could together contribute to a more informed approach to design in HDI. For example, an interview paired with a flying session, and a set of heuristics that would include the constraints of

drones such as weather sensitivity and reduced battery life would be beneficial.

Drones are often tested with one participant at a time, without taking into consideration an environment with obstacles or multiple bystanders. Thus, the complexity of environments is currently largely missing. Herdel, Yamin and Cauchard [217] mentions this transition from user to bystander as a research challenge for HDI [217]. I reiterate the need for understanding different roles and would also like to suggest this as a strong argument for qualitative studies in less controlled environments, including ethnography, where results can be transferred to similar situations rather than generalised and replicated. Situated edge cases can also contribute to design work, such as through the use of design probes where users engage in more extreme practices or demonstrate specific needs.

Typically, young and non-disabled participants took part in the tests; which means that people without impairment in vision, hearing, or motoric function etc participated in the great majority of the studies. Thus, the studies did not adequately address diversity or the multitude of accessibility needs that exist in society. Among the surveyed publications, there were some exceptions where the studies actually did involve people with disabilities. This included Avila Soto and Funk [221], who tested how a drone could navigate blind people, and Garcia, Chevrier, Jestin *et al.* [244], who involved people with motoric and cognitive disabilities to develop an accessible drone controller. Regulatory, safety, ethical, and other obstacles could be behind the reduced number of papers in health and accessibility. For example, recruiting and involving vulnerable groups in empirical studies poses a number of challenges [295], which may become particularly complex in the case of drones where there are already legal frameworks to navigate, and considerable risk of physical damage exists. Still, as these are unavoidable aspects in the use of drones, they should also be covered in research. I foresee the need of HDI research addressing ethics, accessibility and other related areas as the increasing presence of drones in society will necessarily also involve contact with a more diverse set of participants. Continued work in involving disabled individuals in the role of experts, for example through participatory design practice is necessary.

1.4 Designerly Perspectives on Human-Drone Interaction

In the combination of the theoretical framing of designerly knowledge, the literature review of HDI, and my personal experience, I identified a set of perspectives on HDI which which were inspiring to the work of this thesis. In my view, HDI is currently missing out on knowledge that could strengthen the research through the use of designerly methods and perspectives [e.g. 25]. The experiential qualities of drones should preferably be studied through a plurality of interdisciplinary approaches.

Below, I summarise a set of perspectives pertaining HDI, identified as methodological and epistemological opportunities in the research. I present suggestions of methods for involving design knowledge in HDI in relation to previous work and leave space for the same categories to fill in with their own perspectives. The presented perspectives are but examples of what can be done throughout the design process, and include a non-exhaustive list of design methods. Each design perspective brings different wicked problems [7] to the table, which must be tackled in a bespoke and careful manner.

These perspectives are offered from my own understanding of the ongoing research work, combined with my background and perceptions of the field. Hence, I see a need to expand on these notions in a transdisciplinary way. The intention of the list presented below is to give examples of perspectives, but most of all, to also leave room for others to fill with their own understanding and suggestions.

The methods and approaches presented can be applied throughout the design research process, and can be helpful towards many of the aspects of HDI; not only limited to the perspective they are described presented under. Many of these suggestions are the seed to the work I have conducted in this thesis.

Figure 1.7: The first Designerly Perspective on Human-Drone Interaction: Drones are Here Now. The icons reveal the two important aspects of drones – they are both already situated in our real world under active use, and hence, studying them in a situated manner is an urgent endeavour.

1.4.1 Drones are Here Now

Drones are already used in society in many work practices and as a hobby, which is currently not reflected in the HDI field. This suggests that ethnographic methods are a highly appropriate approach to complement existing methods in HDI and could thus be used more extensively: only in the field can the intricate relationship between users, technology, weather conditions, legal frameworks, and other factors be understood in a critical manner. Further, while interview studies are important, participatory observation is likely to bring a more qualitative, rich, and contextual understanding of the impact of drones. Unlike other robots, drone pilots can already be easily accessed in the real world. Cyberethnography [296] may, for example, be an appropriate and accessible method for capturing the already existing nuances in the intimate [86] relationships between drones and humans.

Some examples of research using this method can already be found in the field [2]. For example Pometko, Dagan, Altarriba Bertran *et al.* [297] illustrate examples of drone-based play potentials found on social media in a pictorial. The commercial availability of drones also allows the researchers to have first-person experiences with several types of drones and evoke more embodied perceptions of the research material.

Figure 1.8: The second Designerly Perspective on Human-Drone Interaction: Drones are Technically Complex. The icons reveal that the development of drones does not only include the need for advanced engineering competences, but they also come with a set of limitations regarding the context where they fly – naturally bringing implications as to where and how they can be tested.

1.4.2 Drones are Technically Complex

Drones bring particular design challenges to the table – and such complexity often steer methods away from situated research. Their technical complexity is naturally different from many other robots, and as any drone developer or researcher could report, bring considerable frustration with them. While frustration can be universal when developing robots, the ones associated with drone development are of a complex and under-explored nature, including for example extremely limited battery power, fragile parts such as propellers, omnidirectionality, low payload, the need for offloading sensors, unpredictable flight paths, and more. Many of these limitations (along with ethical ones such as the physical risks for participants) result in the impossibility of conducting studies in uncontrolled environments. Drones cannot easily be directly implemented in their intended context of use without massive technical considerations. It may therefore be valuable to consider the development and research of designs based on off-the-shelf systems.

But whenever field testing is not possible or desirable and new technological approaches are applied, I find an interesting space for considering the showroom as an excellent alternative to the lab. As pointed out by Koskinen, Zimmerman, Binder *et al.* [158], not all design problems are appropriate to the lab, and the issue is understanding which are. In their book, they bring attention to the showroom as a space for HCI research. Drawing from the context of art, the showroom can also be interpreted as a semi-controlled space where technology can be engaged with in ways that promote critical thinking rather than allowing for the strict measurement of variables. It combines the controlled technological context with the freedom of qualitative research. The *"showroom relies on debate rather than statistics, like Lab, or precedents and replication, like Field. It questions the way in which people see and experience the material world and elicits change through debate"* [158, p.94]. Openness to a showroom-like testing affords research with a wider user group. For example, Rubens, Braley, Torpegaard *et al.* [298] do this by working together with the toy company LEGO®, to design and evaluate a 'build and fly' experience with 240 children in a public exhibition. Such collaborations and settings are fortuitous to the study of drones.

Figure 1.9: The third Human-Drone Interaction Design Consideration: Drones Engage the Body. The icons represent both the current issue with research not considering accessibility and inclusiveness enough to have an appropriate view of the different bodies in HDI, as well as the fact that drones fly in 3D space creating unique opportunities for truly engaging with theories of embodiment.

1.4.3 Drones Engage the Body

A clear trend that could be noticed was the increased interest in using drones in combination with extended reality, for example as as mediation for haptics [e.g. 299], [300], remote exploration [e.g. 301], [302], or even representing forces [e.g. 303]–[306]. This type of research is likely not as common with other robotic forms (e.g. humanoid robots), as it is the flight capability of drones that affords this type of application (i.e. they can maneuver around the user freely). In a sense, these applications open up HDI to a rich set of possibilities, where the drone can become a platform to support other entities. Games in particular are an area of interest which could contribute positively to the variance of possible relationships that can be formed between users and drones. Overall, I consider that applications could open up design spaces between sports, games and art, for example employing drones designed for engaging body movements [e.g. 253], [255], [292], or as sports companions [254] could be combined with a variety of cage designs [307] to open up new perspectives and experiences of sports, games or art supporting movement.

Using either hand gestures, foot gestures, proxemics, facial expressions or a combination of these is quite common in HDI [243], [253], [254], [307]–[309]). Such embodied interactions, are usually described as being user-friendly and intuitive, with the argument of also supporting the development of a sense of social empathy with the robot in certain use scenarios. However, I find it vital to remember that they can also result in even more conflict when different bodies are not considered. Spiel [310] tackles precisely this issue by reviewing the International Conference on Tangible Embedded and Embodied Interaction (TEI) proceedings and identifying *"a fairly constrained set of represented bodies, generally normativising tendencies on expected embodiments, an implicitly imagined body ideal that is never made explicit"*. While I did not analyse the literature in search for norms, I could not find great variance in the bodies considered as the humans in HDI – in this case, one must consider if research is incorporating an inclusive and comprehensive view of the bodies (i.e. young, old, disabled, non-human) involved in the interaction.

Furthermore, the 'natural interface' trend brings methodological difficulties which also require their own research – most methods do not acknowledge the multiplicities of the human body. The theoretical framing of the aforementioned research seldom builds on existing theory and practice on embodied interaction (as presented by, for example, Dourish [45], Svanæs [311], or Höök [171]). I believe an approach to the strongly embodied aspects of the interactions between humans and drones is a valuable starting point to bridge this gap. Body Maps (or body sheets) are one example of a qualitative method successfully used in combination with drones by La Delfa, Baytas, Patibanda *et al.* [253] (see the example of a filled in body map by a participant on page 6). This method offers a visual support for

participants in the research, including the researchers themselves, to report on felt embodied experiences by drawing on paper. The template includes the outline of a human body, and can be used before and after the experience, for example. Anne Cochrane, Mah, Ståhl *et al.* [178] offer a detailed description of the method and how it can be applied.

Figure 1.10: The fourth Designerly Perspective on Human-Drone Interaction: Drones are More-than-Human. The icons depict two actors in More-than-Human-Drone Interaction: the sea and a bird. As drones populate the sky and collide with flying creatures, they also collapse into the sea, or into the far reaches of a forest.

1.4.4 Drones are More-than-human

The free flight capacity of most commercial drones means they can reach contexts unusual for other personal technologies. Drones navigate the skies, but also occasionally collapse into the sea or crash into remote obstacles. This unique capacity causes encounters with more than just humans – similarly to what we have already seen with other robots in the wild such as lawnmowers and vacuum cleaners. From birds to sea creatures, the stakeholders in the development of drones goes beyond just human-drone interaction. In HCI, the attention given to these more-than-human actors and the entangled nature of being human, i.e. how natural phenomena and other beings need to be taken into consideration in research, is in definite growth [52], [53], [197], [312], and HRI will certainly follow. Within design research, an important approach is critical design [189]–[194], focusing on critical and societal implications rather than simply applications. It already has a history of use within HRI, serving for example to promote children's critical thinking [313]. This approach connects to art and there are examples of drones being developed outside of academic research for the purpose of provoking discussion [199], [200]. This type of work opens up for situated and innovative understandings of drones, which definitely plays a role in expanding the perspectives included in HDI.

Figure 1.11: The fifth Designerly Perspective on Human-Drone Interaction: Drones are Framed by Law. The icons show how legal frameworks will often play a role on what is prohibited or allowed, generating a frame surrounding the possible research in HDI, while simultaneously bringing the need for further transdisciplinary research.

1.4.5 Drones are Framed by Law

Because drones already exist in many shapes and forms in society, a legal framework is in place. Such frameworks are in constant change, however, and often struggling to keep up with the technical development. However, the fact that laws have

an impact on the design of drones is nearly absent from the research. A clear example is how many drones are purposely designed to weigh less than 250 grams. This is constraint led by international legislation requiring specific licences to fly robots heavier than 250 grams. Legislation and public opinion go hand in hand, and drones potentially carry their fair share of negative attitudes due to, among others, military associations [6]. It is noteworthy that there are helpful user-centred surveys within HDI exploring users' existing perceptions of drones and their attitude towards possible applications [5], [210]–[214]. In these surveys, a nuanced perspective of drones is offered, with space for negative impressions on the technology, and the opportunity to poise critical questions on the use of drones in society and which design values should be considered. It is necessary for researchers in HDI to incorporate these user-centred perspectives into their design work by acknowledging the non-positivist stance often seen in society.

As exemplified by Ljungblad, Yemao, Baytaş *et al.* [3], probing professional drone pilots raises issues which research could otherwise ignore. In this interview study, many issues with legal grounding are lifted. To move beyond interviews, researchers should consider engaging in more designerly ways through applied design work with other participants. One particularly helpful approach for creating connections between different stakeholders is participatory design. This approach is already present in HDI. Wojciechowska, Hamidi, Lucero *et al.* [274] ran a co-design study with experts from sub-Saharan countries. Similarly, Agrawal, Abraham, Burger *et al.* [234] presented a particularly interesting example where they engaged with emergency responders in a series of sessions constructing scenarios grounded in real-life challenges. As opinions and laws are in constant change, through engaging in a participatory manner with people, researchers tap into the serendipitous encounters with opinions and laws. I suggest that participatory design with applied design tasks involving a diversity of participants is a strong resource for HDI, purposely involving participants with informed negative attitudes towards drones, with broad knowledge of the applied legal frameworks in different countries, along with those with deep technical knowledge of the technology.

Chapter 2

Designerly Views of Drones

Tackling the social aspects of drones is a massive endeavour. When I first approached this project, I planned to design drone probes (those initial intentions can be found in a short abstract [314]) to be sent into other people's homes, following an accepted way of producing knowledge in HCI. However, I first needed to orient myself with the technology at hand. This thesis weaves the story of my first encounters with drones as a research material, and how that process generated unexpected implications. Along with Desjardins and Key [137], I viewed my first-person research as a stepping stone for the rest of my work: *"Although the use of first-person research is not new it is often one of the stories left out – perhaps because it is sometimes seen as preparatory work for upcoming RtD researchers activities. Instead, we argue that the knowledge produced in moments of 'getting up to speed' is as relevant and insightful as what will come next. We challenge RtD as well as other practitioners to recognize and validate these first-hand knowledges as much as participant knowledge during both formal and informal dissemination"* [137, p.2144]. Following this call, I have dedicated the first year and a half of my PhD to formally disseminate these first engagements not as background work, but as research on their own. These encounters took the form of autoethnography and research through design probe-making. Both of them are seen here as a type of design deployment.

As Gaver notes: *"Deploying our designs allows us both to discover the questions we should ask about their use, and some of the answers to those questions."* [315, p.17]. Assessing design through deployment is not led by hypothesis, but is rather motivated by the need to find a plurality of experiences. It is precisely through multiple accounts – often from the fringes rather than the central tendency – that the most inspiring design spaces are formulated. *"Given that designs can be appreciated from a number of different perspectives, and that different people may find different ways to engage and make meaning with them – or fail to do so – multiple, inconsistent and even incompatible accounts may all be equally true"* [315, p.17]. The aim here for me is therefore not to contribute to a converging view of social drones, but rather to diffract the possible relationships and notions surrounding them. Diffraction as a way of thinking is used as a metaphor by many theorists such as Barad [66]. But to not get lost in theorising, I stand on the approach proposed by Sanches, Howell, Tsaknaki *et al.*[316], which builds on Schön's reflection-in-action, and proposes diffraction-in-action as a way to engage with 'lived data'. Sanches, Howell, Tsaknaki *et al.* offer three guiding principles for engaging with lived data out of their own design projects: (a) *"engaging with data*

can be an open-ended and undefined process. Resisting the impulse for actionable insights early on, design researchers can surface more nuanced or alternative meanings of data", (b) *"difractively engaging data in a slow, long-term process and resisting the impulse for efficiency, can help surface, articulate, and explore practices around data"* and (c) *"designers can hold space for messy, ambiguous data that requires active interpretation, resisting the impulse for clean and tidy data. This shifts the goal from designing to provide expedient insights with data toward designing for a process of balancing open interpretation with scaffolding interpretation"* [316, p.2]. These principles are essential to my results. In my work, I have used minimal interventions (autoethnography and minimal concept-driven RtD) to provoke waves of diffraction – and the data resulting often shows the qualities mentioned above. Said diffraction is essential to the notion of re-framing as presented in my research goal.

This is the point in the thesis where I report on the answer to the research questions previously presented. I will therefore resist the urge to point out that design knowledge does very poorly at answering research questions, as it tends to generate more. As Redström puts it: *"In design, we seem to feel a similar urge, as when we struggle to formulate a research question to guide and define the purpose of design experimentation, or as when we for some reason still encourage students to account for theory first in their theses, even when we know the work unfolded the other way around"* [41, p.103]. At the end of this degree, I find myself with more questions rather than any answers – and that is precisely as it should be. We return to the stated goal and research questions:

G: Re-framing human-drone interaction research through a designerly lens.

RQ1: How might ethnographic methods and narratives ground design knowledge in human-drone interaction?

RQ2: How might visual and concept-driven approaches inform human-drone interaction design?

To aid the navigation of the questions in combination with the methodology and designerly perspectives presented above, and how they contributed to the appended publications, I offer a diagram that puts all these terms together (Figure 2.1).

Through the HDI literature review presented above in Section 1.3, I attempted to identify which design knowledge and methodology is already present in the field. The aim here was to navigate the stated goal. In the following sections I present the papers that compose this dissertation, each of them exploring a small point of view towards Human-Drone Interaction. Each publication is an important piece in a picture that is *not converging to a better definition of social drones, or even attempting to give concise guidelines on how drones should be developed.* Rather, they present narratives that question the grounding and assumptions surrounding the design of drones. Design knowledge thrives in a plurality of perspectives, in intricate narratives, and sometimes in tiny insights. In this work, I have experimented with combinations of methods, impressions, and expressions of design knowledge in connection to drones, but also to many other agents in the sociotechnical systems/assemblages surrounding the technology. There are two different tracks simultaneously followed. Both have in common a combination of

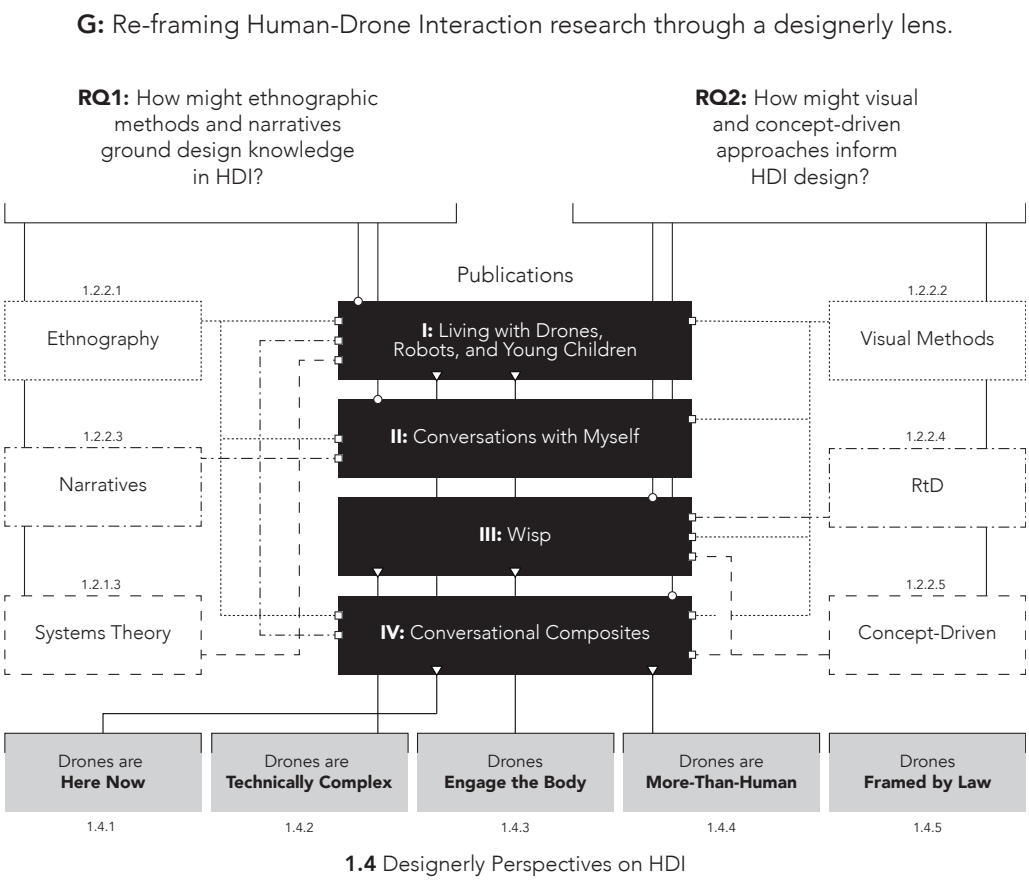


Figure 2.1: Diagram representing the goal of the research along with the research questions, as well as how the publications relate to them. Connected to each paper there is a list of methods with their section number, as well as the set of Designerly Perspectives on HDI.

techniques and theories that find ways to surface the importance of first-person perspectives in a convincing manner, as well as to argue for the value of combining design approaches and theories in HDI.

I argue that a designerly way of approaching research is critical to re-framing HDI. There are several ways of achieving a more reflective and design oriented research practice, and one central gap is, as pointed out by previous research [317], [318], the unrecognised importance of design epistemology within HRI. When knowledge from the design process is not expected in publications, important situated, reflective, nuanced, and critical knowledge on user needs and context can be missed. This type of design knowledge may point towards otherwise missed aspects or important questions and circumstances, which can support other researchers within the same domain to take a more holistic perspective. In the work presented here, I have shown how some of the applied designerly approaches surfaced critical knowledge for HDI. A pluralistic reporting of design work in research could be promoted by varying publication formats, for example through the inclusion of forms of visual knowledge. I exemplify how visual knowledge pertaining HDI can be expressed in publications. For example, page limitations currently discourage the inclusion of images. Many of the methods suggested above rely on visual format, for example, ethnography is often documented through still and moving pictures. Blevis [319] stresses the importance of photography in

HCI research, and to that end uses a photograph of a drone flying over a crowd watching a performance. He presents the combination of text and image as an example that demonstrates how *"a carefully produced editorial record of a specific instance of a disruptive technology is design knowledge"* [319, p.987].

To explore the first research question I used autoethnography and sketching to build my own understanding of drones. These are described in Section 2.1 and Section 2.2. I have – of course – not explored all ethnographic methods available. But I can confidently say, for example through my autoethnography, that these methods are appropriate to HDI, and resulted in knowledge that is not only designerly by nature, but both generative and critical. The results of these two papers are narratives and images, together painting a non-positivist picture of drones. The design opportunities surfaced in these two papers stay away from prescribing action or dreaming application worlds for drones – the type of results that would make researchers critically question their work rather than justify it. They show value in grounding design knowledge as having a definitive place and importance in re-framing HDI.

To tackle the second question, I applied RtD in combination with concept-driven design research programs as described in Section 2.3. These programs come with a set of assumptions, approaches, framings, and philosophies. I have – naturally – not tried all existing interaction design approaches and philosophies. I can however describe how they have been helpful in re-framing what role drones ought to (or not to) play in society. I also looked into how the design of drones could be analysed with attention to ambiguity through a novel visual approach to user data, as explained in Section 2.4. These approaches and philosophies were essential in inserting design values (ambiguity, critical thinking, etc) into HDI. Both of these tracks paved the way to the suggestions for future work explained in Section 3.

2.1 Living with Drones, Robots, and Young Children: Informing Research through Design with Autoethnography

Fringe phenomena and 'users', and in particular children, are difficult to study [320]. There are not only intricate ethical issues to be tackled, but it is also incredibly hard to engage field study participants in ways generate genuine insight [321]. These fringes also call for unusual ethnographic methods. In this paper, I consider the research gap in Child-Drone Interaction, as well as the gap in first-person methods in Human-Drone Interaction.

Problem

A simple search on Amazon for 'toy drone' generates thousands of results. The market for small flying robots is growing. For example, the DJI Ryze Tello[1], priced just under 100USD, is marketed as a tool for education. According to their website: *"We set out to build the most fun drone ever, and we came up with Tello: an impressive little drone for kids and adults that's a blast to fly and helps users learn about drones with coding education"*. The small drone, weighing only 80g, is said to work in many contexts: "Whether you're at a park, in the office, or hanging out at home, you can always take off and experience the world from exciting new perspectives". The website offers a big tagline stating: *"Relax! Tello's super safe"* (See Figure 2.2).

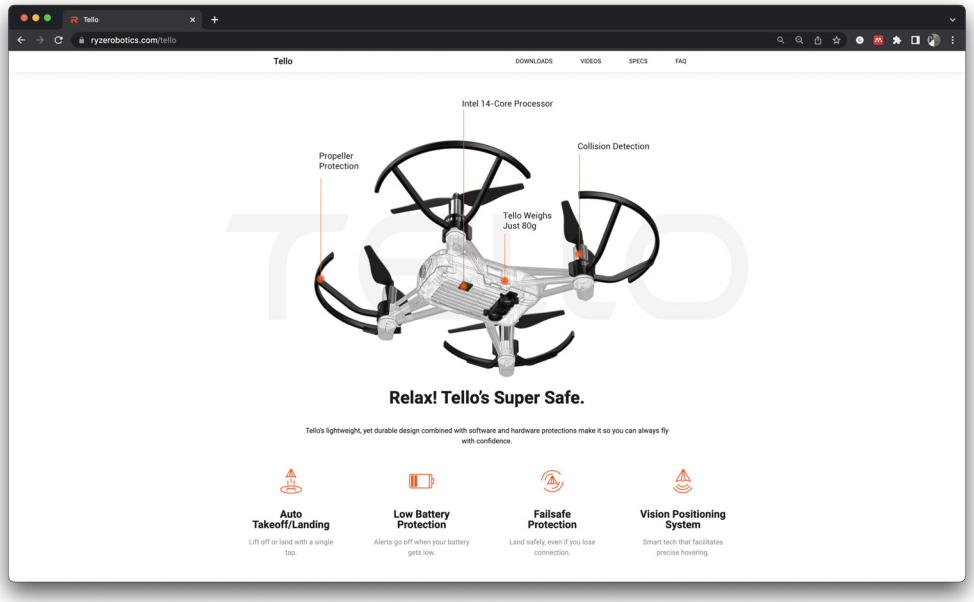


Figure 2.2: A screenshot of the Ryze Tello website showing the tagline "Relax! Tello's super safe. Tello's lightweight, yet durable design combined with software and hardware protections make it so you can always fly with confidence." https://www.ryzerobotics.com/tello captured on the 13th of December 2022.

When looking into the research field, the interactions between children and drones seem to be predominantly perceived as educational, connecting learning

[1]https://www.ryzerobotics.com/tello

goals with the activities the drones support such as racing, photography, or programming [298], [322], [323]. This is not surprising, as there is plenty of research with other robots leaning in the same direction. A variety of social robots such as Pepper and Nao, are currently being explored as tools or companions in education and critical thinking [e.g. 313], [324]–[327]. But children are encountering drones in their daily lives, outside of the educational framing. There is a lack of research in Child-Drone Interaction [206] which may be due to safety, ethical, and privacy regulations when considering children as users. A valuable research direction would be to include children as participants in most studies, including opinion surveys.

However, an utilitarian perspective does not cover the full spectrum of drone encounters. Methods that are not seeking to optimise are particularly helpful here. How can we study genuine and situated interactions between children and drones? What happens when a parent is driving a drone at home? There are many potential applications and dimensions of what drones may be. Through a literature review, Herdel, Yamin and Cauchard [217] present drones as 'helpful', 'amicable', 'functional', 'knowing', 'sensational', 'reliable', and 'unusual'. While the unusual category could fit a lot of drones, there is a gap in researching the 'creepy', the 'unreliable', the 'invading', the 'unsustainable', the 'unwanted' drone.

Methodology

At the time I started this study, I had planned other interventions with families and RtD probes. But before sending out drones to people's homes, I wanted to find my own understanding of what it would mean to incorporate this technology in a domestic setting. Studying children is definitely not without ethical issues, and I felt that I had better control of consent in my own home. I was both afraid and eager to learn about which troubles would surface.

The issue of studying child-drone interaction could be tackled in many ways. I chose to dive deep into an autoethnographic study, serving both a a first encounter for me with a longitudinal interaction with a drone, but also as a way to experience those interactions along with my two children (aged 6 and 3 at the time). Choosing autoethnography was only made possible to me because I was already a mother. But since I had the opportunity and my family was in agreement with it, I found it to be the method that could best translate in situated, intimate, and honest accounts of engagements with the technology.

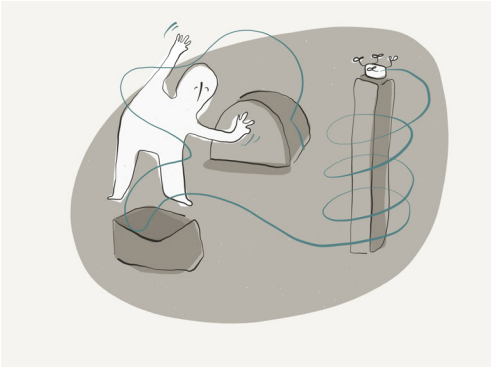
However, I did not want my small scale, statistically insignificant study to result in the alienation of a community that does not fully understand autoethnography. Therefore, for my own organisation and following Desjardins and Ball's call for inventiveness in autobiographical design, I decided to pair the autoethnography with a sociotechnical systems framework. This framing is well explained in the paper itself.

Contribution

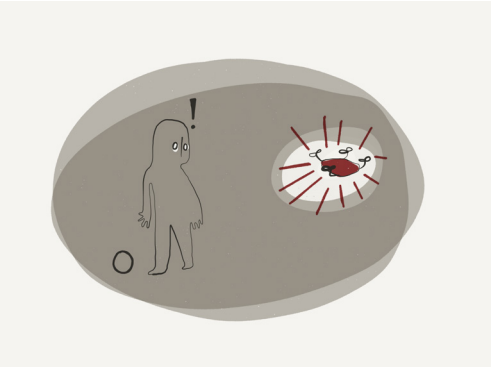
The year-long autoethnographic study generated a number of narratives which can be read in the original paper. This paper contributes with one of the first studies seen in research in Child-Drone Interaction. Here, I will dedicate this space to some of the ideas that were left out. The summary of the study takes the form of **design opportunities for Child-Drone Interaction Design**. As I describe in

((a)) Touch

((b)) Enactment in 3D Space



((c)) Directed Play in 3D Space

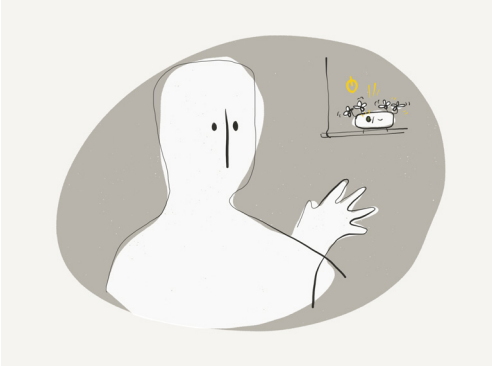


((d)) Wickedness and Attention

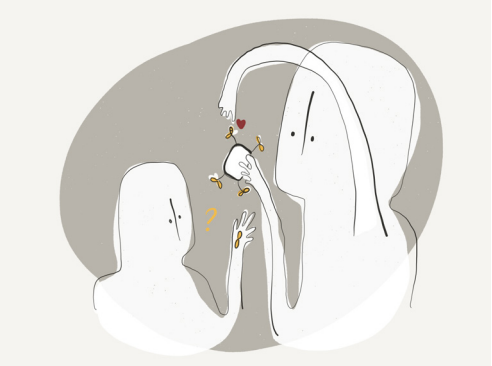
Figure 2.3: Four out of the Nine Opportunities for Child-Drone Interaction

the paper, these are not to be seen as guidelines, and have no prescriptive value. Rather, they should be used as ideas to challenge and problematise the interactions we design for – they are not implications for design [77], but problematisations in design. I made a set of illustrations, one for each challenge, which are not included in the publication. As I produced these images, the implications of the challenges became clearer to me, so I will dedicate this space to expanding on what can be read in the published paper. In Figure 2.4(a) the drone can be seen poised as a bird-like metaphor – that metaphor can be generative and inspiring [328] as to what types of idle actions a drone could embody. Birds are not either flying or dead. For example, in Figure 2.4(c), there is a reinforcement of the user-bystander dichotomy as it could be assumed – a user driving the drone in the foreground, while a bystander is shrinking faded into the background. I will discuss some issues with this dichotomy below, but I wonder why I decided to represent this opportunity as such. This illustration surfaced the damaging values that such a relationship could generatee.

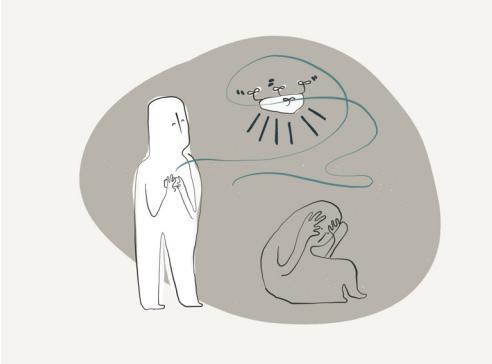
One important contribution of this paper is the **deconstruction of the user-bystander dichotomy in HDI**. For example Baytaş, Çay, Zhang *et al.* define social drones as *"applications where fully autonomous drones operate in spaces populated by human users or bystanders"* [205]. We are far from reaching fully autonomous drones, but even within the clearly visionary definition, there is a mention to users or bystanders. The choice of the word bystander comes with some assumptions such as perceptions of passivity which could derive from ideas such as the 'bystander effect'. Are we really placed as either users or bystanders in



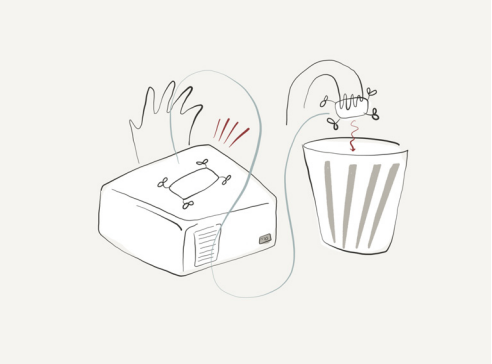
((a)) In-between States



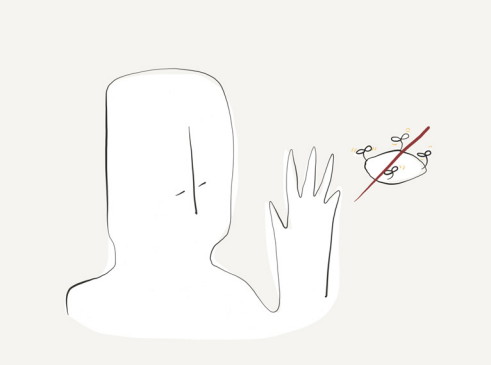
((b)) Difficult Ownership, Safety, and Right to Repair



((c)) Culture, Values, and Type of Play



((d)) Anticipated Experience and Death of the Drone



((e)) Unmaking

Figure 2.4: Five out of the Nine Opportunities for Child-Drone Interaction

interactions with drones? Or is it the way drones are designed that will eventually create bystanders? These questions could warrant a whole other PhD dissertation.

There is one detail I left out of the original paper which has to do with autonomy. At first, and without me noticing, the children were unaware that I was the one driving the drone. And not once did they act as bystanders. They tried actively either fully avoid the drone, or try to communicate with it. The user-bystander dichotomy was irrelevant in our interactions with the drones at home. As noted by Höök, Eriksson, Louise Juul Søndergaard *et al.*, our reasoning often uses dichotomies such as the one presented, but more dangerously, through our design processes, we tend to reinforce the patterns [177]. Moving away from dichotomies in design (in this case through soma design) should mean that our work should be grounded in experience rather than *"in preconceptions about how to divide the world into conceptual categories. On the other hand, those concepts are deeply ingrained in our whole ways of being and will be enacted and re-enacted in our design work, unless we are able to 'see' them, deconstruct them, attend to them, and thereby design in novels ways"* [177]. My autoethnography helped me clearly 'see' these concepts and seek to deconstruct them whenever possible. **It is a worthwhile research agenda to design drones that do not assign anyone the role of a bystander.**

A Post-Publication Reflection

This autoethnography in this paper was conducted while I was pregnant with our third child. I had considered the reason as to why I had suddenly decided this study was over one year after it started. But the reason was no other than the fact that he was born. When the paper was submitted I had not yet arrived at this conclusion – but it is quite interesting from a sociotechnical systems perspective. In the words of Kayany and Yelsma: *"Humans and technologies in households are interconnected as members or elements of the same system. When a new element is introduced to the system, the system goes through a process of integration that may result in the re-organization of roles, relationships and functions"* [329]. Indeed, the system was reshuffled and thrown into a state where a drone could not continue to fly indoors. We had a fragile baby to consider – hence it was no longer ethical for me to continue the study (see Figure 2.5 for an illustration of this).

This surfaced one of the true values of autoethnography. The study was long over, the narratives told, and yet insight was still generated. I wonder how often participants in studies care to, or are given the opportunity, to retell and re-frame their understandings. This change in the system is a type of micro-ethics which is necessary when doing research with children [81].

After my presentation of this paper at NordiCHI'2022, I was approached by a researcher. He said, in a friendly manner, *"you present this work so convincingly, it makes me wonder if I am taking my research too seriously"*. At the time I laughed and confirmed that he probably did so. But months later I still think often about this statement. Autoethnography is still widely perceived as 'not serious'. My attempt with this paper was precisely to find ways to make this method more approachable, and understood as indeed rigorous. The notion of the distance between research and researcher is visible in many forms. I take my research so seriously that I dedicated one year of my life documenting my interactions with my children, finally exposing them to the community in open access. Helms reflects precisely on some of these troubles, in her own research [101]. As she states *"I am*

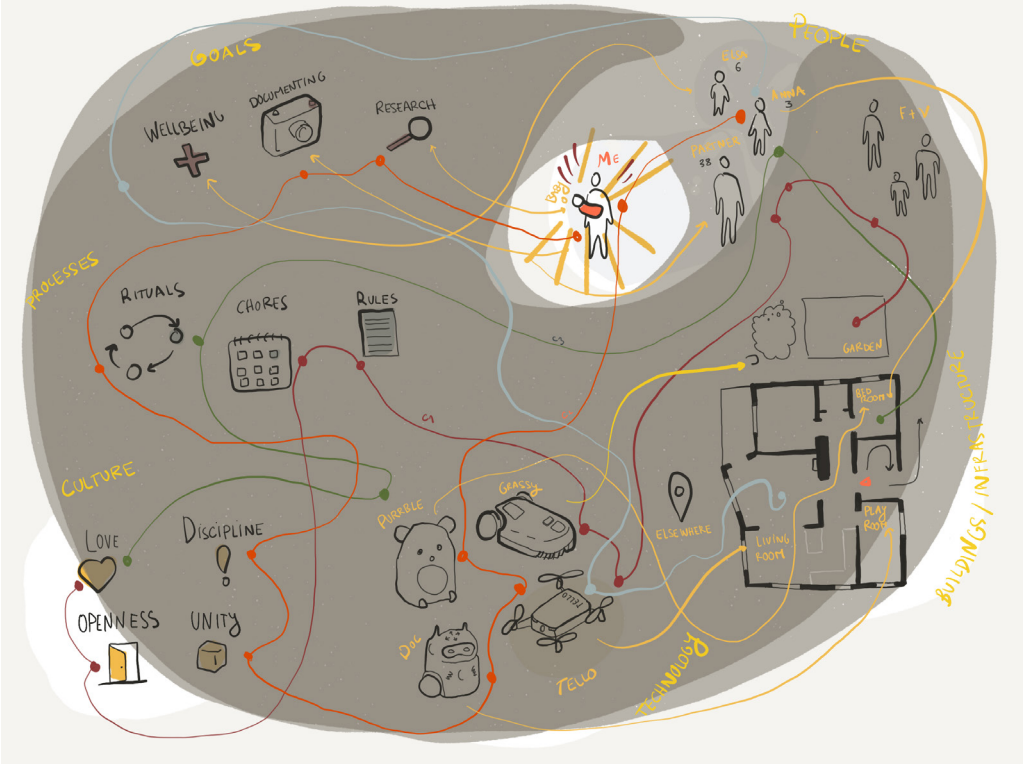


Figure 2.5: A new image of the sociotechnical system that is our family as described in the paper. Here, what matters is our new baby.

not in a position to speculate or fully understand the diverse possibilities of how my work might be misread, or even interpreted as intended within its full academic context, and still give rise to feelings of discomfort or harm for people external to my family. This might happen now or later. Yet as I reasoned for that publication and my child's potential later interpretations of it, I anticipate opportunities to discuss them in person with her" [101, p.9]. There is still a lot to be done in the HCI community in appreciating the intricacies of autoethnography.

2.2 Conversations with Myself: Sketching Workshop Experiences in Design Epistemology

Often – and particularly at the start of a career or education – we are expected to navigate complex social situations in a way that generates and supports what can be reproduced as useful knowledge or expressed as valuable experiences. At the start of my own PhD, I found it challenging to negotiate certain situations, colliding with difficulties in communicating my intentions, and finding my own path. A philosophical and theoretical framing of one's knowledge is essential to a career in academia, but finding a place and a standing relies on questioning more than just the solidity of one's methods.

Figure 2.6: A sketch of me, presenting a sketch of me presenting the pictorial at the venue.

Problem

The pictorial presented in this section covers ideas that go beyond a particular design problem, and are instead focused on a meta-reflection with relevance to HCI. Within the field, it is common to participate and organise workshops, either within research projects or as a part of conferences. As professionals in academia, we are often part or host workshops with educational or research purposes. While visual knowledge and methods are discussed in HCI (see Section 1.2.2.2), they are often neglected or less prioritised even when organising such events. As a budding researcher, I was invited to participant in a week long workshop to explore 'soma design' as a research approach, together with other researchers. The group was composed of an interdisciplinary mixture of academics, with varying levels of familiarity with the philosophy, and different seniority. As a result of participating

in this workshop, I summarised my graphic diary of the experience as a pictorial, discussing tensions in incorporating the presented philosophy, accommodating my tendency for visual methods as focusing and how they collided with notions of the body, and negotiations with drones as a design material.

Methodology

This pictorial represents a bridge to surface the value of visual methods as a fruitful approach to research. Rather than taking notes, my presence at the workshops was truly dedicated to being present and feeling, experiencing through my lived body. But my own background is an expression of a living necessity to sketch and perceive knowledge through illustration – through the dialogical nature of drawing [114], [118]. The work is grounded on an autoethnographic account of a workshop experience, documented through a graphic diary composed of sketches paired with narratives embedded in the paper's text but also through the use of ALT text (a digital accessibility tool for describing images).

Contribution

The contributions of provocative papers are difficult to pinpoint. It may take a long time before they can actually be recognised. Conversations with myself is a pictorial grounded on the assumption of sketches as a formulation of knowledge, an expression of lived data. The work presented both in sketching and in making sense of my own feelings during the workshop was essential to the development of my own path. As an expression of transparency, this pictorial is seminal to my approach to research. This insight is at least twofold:

First, the encounters I had with other people's designs and prototypes revealed unexpected dimensions of care; in the ways they unpacked them, presented them, handled them. Joseph La Delfa, another researcher working with similar drones as mine (see [253]), trusted me with assembling parts of the drones for his demo. He said: *"I hope you do not think I am too protective of my drones"*. But I did not think so – the way he had minutiose manner in which he unpacked each small drone, the way his hands moved, carefully putting together each piece, trying each interaction – all his mannerisms around the probes were inspiring to me. I had brought my own drones but they were so unfinished I was, at that point, embarrassed to even bring them out of the bag. I craved to find that relationship to a design probe myself, and I suspected this was a vision of the effect of an intricate combination of the 'soma design' framing and a dedicated process of research through design. These ritualistic gestures of preparation of the drones were reminiscent what I could observe online in hobby drone pilots, which further justified the necessity for the studies described as future work in this thesis.

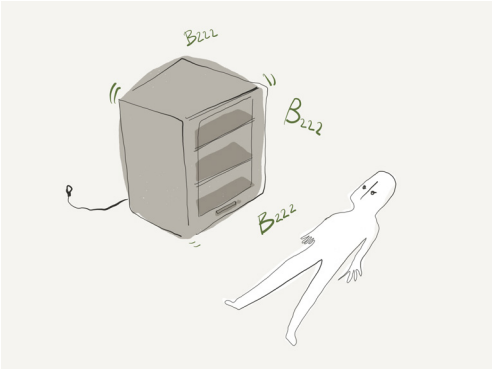
Second, I faced an important methodological insight. I had, at that point, already organised countless workshops with students, colleagues, or research participants. How often had I, however, organised for enough time and space for the workshop participants to engage through their own tools, facilitating conversations with themselves rather than just among them. During the 'soma design' workshop, I had neglected the importance of sketching for me – I avoided it because I saw it as a tool and technique that contradicted the somatic ways of knowing privileged. But as the week progressed I understood that that meant not talking to myself, and that I needed to advocate for sketching as a way of

focusing on my body, an activity in designerly ways of knowing, and I needed no other excuse than my own to stick to it. In the precise same way as others used verbal expression or written notes, I needed to sketch to make sense of the world. And as an inexperienced researcher, I needed the encouragement to take the time to myself, to take a break. I now remind others and myself to afford the time and space needed to support conversations with themselves in multiple ways and in the schedule of their workshops.

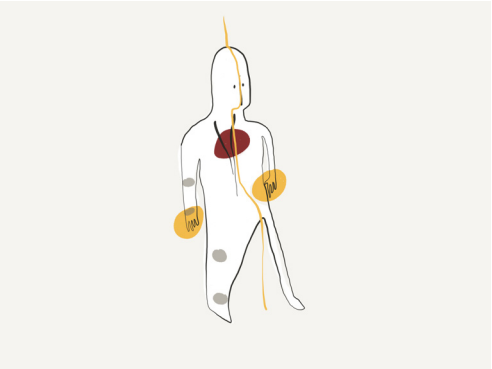
Curiously, some time after, I attended yet another course in 'soma design'. During the sessions planned, there was generous time and a safe space for reflection through whatever tools we found useful. We were encouraged to use that time to ourselves, rather than engage in conversations with others. I produced then some of the sketches that still represent most of what I find valuable in 'soma design' to my own work. Some of these images can be seen in Figure 2.7.

Being Human in Academia

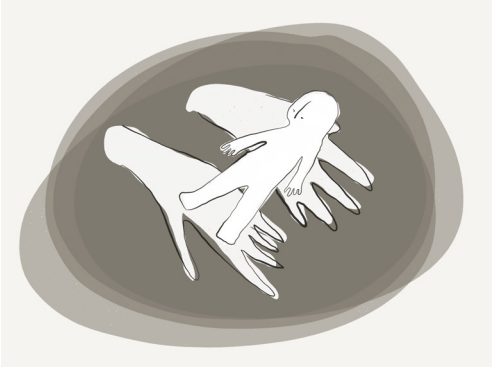
After presenting this pictorial at 15th ACM conference on Creativity & Cognition, I was approached by more than one researcher. It was my first time presenting a paper at a conference, so I did not know what to expect (see my opening slide in Figure 2.6). I was particularly tense since the pictorial was recognised with the Best Pictorial award. Perhaps I thought the narrative would not resonate with anyone in the audience, but the opposite happened – I was asked questions and given praise that related to the researcher's own struggles with their research topics and ways of knowing. Somehow, what was noteworthy, was that revealing a human side in research, making the difficulties with a workshop a real component of the research assembly visible, was enough to evoke insight. It is not that the knowledge in the pictorial was generalisable, or that my expressions of doubt and difficulties were universal, but rather that they were evocative enough to generate reflection through the visual and textual narrative presented (see section 1.2.2.3 on the importance of the use of narratives). This pictorial became therefore an expression of what I found rewarding in the field of academia – a possibility of artistic, autoethnographic, honest accounts of experiences as something of value in community making and in developing intentions of care when organising workshops. It became a gateway for me to be approached by other researchers navigating the same waters.



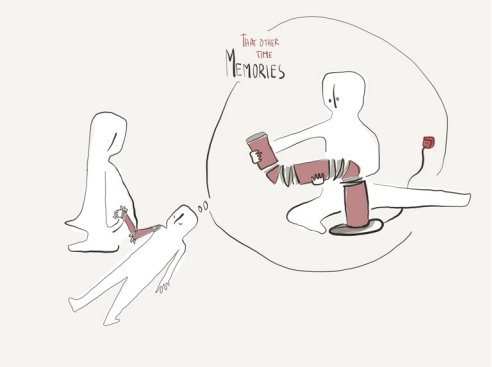
((a)) The machines in the room interrupt the focusing states.



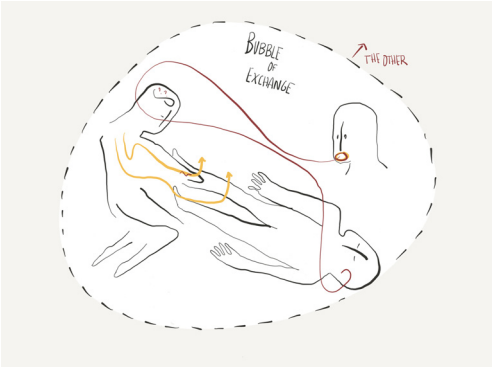
((b)) Doing a body map in another way, feeling out of balance.



((c)) Imagining myself in the care of others, as a probe, lying as a small animal on a giant's hands.



((d)) A Feldenkrais exercise in moving someone else's legs and arms.



((e)) In a Feldenkrais exercise, I felt as in a bubble with two others, through touch, sound, and breathing.

((f)) During an exercise, we explored notions of the other through touch in unfamiliar ways.

Figure 2.7: Sketches produced during a 'soma design' course.

2.3 Wisp: Drones as Companions for Breathing

Most research within human-drone interaction is connected to solving usability, efficiency, safety, and reliability issues, or dreaming of worlds with future useful applications. But there are also examples of the use of drones within art [199], [200] and well-being [253]. In this project, we shift the focus away from usability through exploring minimal somatic interactions with drones. We pay particular attention to using design philosophies to develop alternative interaction forms, specifically slow technology and soma design. These theories supported the research through design development of a provocative probe – *Wisp* – (a provotype [163]), by designing a micro-drone controlled by a human's breathing, creating space and opportunity for reflection and sense-making in the understanding of what drones are or ought to be.

Problem

As drones become commercially available, and applied in a variety of social contexts, the perceptions and ideas surrounding their use will be very different – as well as what (social) drones will be defined as. As noted by Johan Redström: *"These experiences of when a familiar category is (partially) redefined by a new design are individual and of course dependent on one's previous encounters with that category. While it is difficult to see a familiar thing we take for granted, like a camera, a bike, or a mobile phone, as a kind of ongoing and highly active 'definition' of what these things are to us, is there not a glimpse of this idea in the experience of something familiar being redefined through the introduction of a significant difference? 'So this is a camera,' 'I have never experienced biking like that before,' 'I would never have thought that phones would become this ,' and so on."* [41].

There is considerable work in HCI surveying current perceptions of drones through placing participants in contact with drones or images of drones – many of them with findings related to privacy issues, as well as the fear of damage or injury, and even which design aspects impact such perceptions [e.g. 246], [330], [331]. It is however, a worthwhile research endeavour to create platforms for discussion of what roles are desirable for drones, and for the design-led definition of what drones are to us. To that end, it is necessary at times to create defamiliarising experiences [151]. We could identify many ways of interacting with drones – focused on playfulness or precision of command. However, we decided to use breathing as an input mode, grounded on the conceptual idea of breathe as an accessible and primary mode of interacting with the world.

The *Wisp* project is presented in its first steps and slowness, further arguing for the need to share early steps in RtD processes. In this paper, we describe the steps from conceptual groundings to first informal evaluation, leaving space for alternative paths and an open discussion space for the HCI community, rather than presenting a 'finalised' design.

Methodology

The prominent research questions in this thesis are related to the design aspects of fringe applications (e.g. artistic uses, toys, etc.) involving the likelihood of more prevalent drone usage on a personal and commercial level. To engage in these issues, a situated methodology is necessary, in contact with both the

technology and participants over extended periods of time (as exemplified by my autoethnographic study [42]). In the case of this paper, we applied a 'research through design' (RtD) approach, by actually deploying probes in order to explore and research the experience of drones [155], [158], [164]. Using co-located robots in this context is important, as research shows significant differences in the perception of embodied robots versus tele-presential or simulated robots [332]. We recruited many designerly ways of researching, reporting on expert interviews, technical issues, first-person perspectives, and conceptual groundings. We make extensive use of visual media, showing photographs, diagrams, and sketches.

Contribution

This article describes the importance of a design research framing for human-drone interaction, as well as the benefits of developing drone concepts as prototypes of possible worlds. Through recruiting a critical posture in developing a minimal interaction with a drone, paired with a strong connection to concept-driven design, we offered an article that is dedicated to presenting designerly ways of thinking and re-imagining drones. Through our process, we report on the various steps of the design – presenting the rigorous description as a contribution in itself. For example, the results from the expert interviews can be re-used into other RtD projects. Through the informal pilot study we present, we generated a composite framework of soma design and slow technology, combining them into a generative tool for advancing somatic slow interactions. We present drones, through our work, as an intricate design material with aesthetic qualities evocative to the re-framing and re-definition of social robotics.

The next steps for this project are described in Section 3.2.

The Problem of Intermediate-Level Knowledge in Wisp

Left outside this paper is a seed for future work. It is remarkable that this publication became an example of how it is possible to deliver unfinished design artefacts as a vessel for knowledge and how preliminary and transitional results have a place in academic discourse. To tackle how these results can be developed and grasped, I see the need for further examples of intermediate-level design knowledge strongly grounded on understanding the artefact itself as a knowledge contribution. The design-oriented approached generated a large number of prototypes, which were valuable from a first-person perspective as an ongoing exploration on how drones can or should be designed, materialized through artefacts and narratives. This led me into a possible crossroads at this point: either develop an *ultimate particular* [31] to be studied in more detail as a product, or a collection of *instances* represented in an annotated portfolio and paired with strong concepts [165]. Both of these approaches presented some shortcomings, which resulted in a solution based on a strong emphasis on ambiguity as a resource [109] for interpretation and formulation of knowledge placed in a 'showroom' version of *Wisp*. *Wisp* is therefore a design abstraction of the first-person perspectives acquired through the project: a platform and interpretable portal towards further design-oriented knowledge and serves in on itself as the result of our research. When documenting *Wisp* we faced the following difficulties:

- Annotated portfolios [49], which have crystallised as the archetypal presentation of RtD intermediate-level knowledge, have come to emphasize the

products rather than process of design. They can, furthermore, be difficult to interpret even by other designers as they are static views of the instances without describing where the annotations come from. This creates issues for the communication of knowledge in the community (for more on annotated portfolios see section 1.2.2.2).

- Strong Concepts [165], could incorporate the process of design, but formulated to offer solutions to design spaces. While strong concepts are undeniably useful to the design community, they are demanding to formulate to guarantee their *contestable*, *defensible* and *substantive* dimensions. They rely on a multitude of different designs and neglect the presence of the designer themselves. This creates issues to designers intending to contribute in informal yet informative ways, and still leave space for ambiguity.

I argue that the finesse and characteristics of the 'showroom' opens for a different set of possible intermediate-level knowledge. The ability to summarise the knowledge gained throughout the process into an exhibition is in on itself an ambiguity-compatible way of presenting intermediate-level knowledge which can be interpreted and appropriated by designers and non-designers alike. Artefacts can at times afford the understanding of the design process – they are actual design decisions embedded in the ultimate particular that transpire the knowledge behind. For example, in the same way as an article refers to another one, so can a design refer to previous knowledge. Within architecture, a brutalist building can be recognised through the use of patterns (such as raw concrete, or a strict grid-based floor plan), but also through a combination of aesthetics that speak for themselves – at least to other architects.

2.4 Conversational Composites: A Method for Tangible Illustration Layering

In this pictorial, we present a method for conversations through visual techniques. We suggest the use of a combination of tangible and digital media as a platform for exchanging interpretations of narratives surrounding a given prompt. In this case, we used narratives of hobby drone pilots as the starting point.

Problem

Conversations held between researchers are often verbal or in written format. We tend to neglect other forms of communication – for example through visual tools such as photography and drawing. These forms of communication are, as described in Section 1.2.2.2, excellent at allowing for ambiguous thoughts to come into play in the dialogue [113], [114] rather than prioritising clarity at all costs. As mentioned by Yurman, the 'loose' nature of sketching is like a metaphor for an invitation.

At this point in the research, most of my work had taken the form of textual discourse. However, thankfully, when the pictorial presented in Section 2.2 was accepted at the ACM Creativity and Cognition conference in 2022, I took a look at which workshops would take place in the same conference – and found Yurman, Juul Søndergaard, Pierce *et al.*'s workshop entitled 'Venetian Drawing Conversations'. Their call for submissions included developing *"visual dialogues resulting from the merging of drawings created by different people"* [333]. They encouraged applications from researchers, scientists and creative practitioners working in or interested in areas such as:

- "Experimental design methods
- Drawing as research
- Research through design: artefacts as knowledge production
- Speculative and critical design
- Ambiguity and defamiliarization
- Visualizations as design methods
- Ideation and futuring techniques
- Aesthetic interactions" [333]

As a reminder – one of my research questions revolves around the relevance of designerly approaches to HDI. So this call was tailored to my interests. I suggested to my supervisor that we should put together a submission, finally having an excellent excuse to put into practice some of our artistic practice as part of our project. Sara has extensive practice in watercolour and other painting as a hobby. We decided to combine the two topics we most care about: ethnographic data and artistic/designerly approaches.

We were inspired by the idea of *exquisite corpse*, a playful technique invented by surrealists, where one image is collectively created in the folding of paper. In *exquisite corpse*, a group of people share the task of creating a human figure, and

each participant is assigned a fragment of the composition, starting for example at the head, and folding the piece of paper so that the next participant continues with the shoulders without having seen the previous drawing. At the end, the revealing of the whole picture is usually quite amusing, a mixture of ideas mashed together into one body. This game has been inspiring to other researchers in HCI [334]–[336].

Abstract novelty and amusement were not exactly our priority – we wanted to create a method that would allow for turntaking and still preserve some of the revelation elements of *exquisite corpse*.

So we needed a prompt. We decided to make use of an online forum we had been members of since the start of the project. We put together a simple anonymous questionnaire asking hobby drone pilots from the Swedish DJI drone owners Facebook group, prompting them to give us short stories from incidents they have had with their drones. Here are two examples of the prompts we ended up using:

> "It flew away. I used the app litchi and had created a route it would follow, but it never came back. It turned out that I did not think that the stated height is in relation to the starting point and when the ground rose, it came closer and closer to the ground and finally stopped in front of a large spruce and did not know where it would go. There it hovered until the batteries ran out. A resident in the area found it after 1 1/2 years and when I checked the film on the memory card it was clear what had happened."

> "I'm on my 5th drone. I have crashed three drones and that is of course due to the way I use the drone. My drone is a camera dolly and the best movie clip is when you drive backwards and sideways. Unfortunately, you do not see in the direction of travel either. I usually film my grandson, who engages in kite surfing and kite foiling, 2-3 m above the water is usually the best and safest, but sometimes you end up below 1 m and then there is a crisis."

Methodology

The pictorial describes a method of data analysis through the use of sketching and illustration: *Conversational Composites*. To be able to understand the potential of the method, we applied it as a conversation between me and my supervisor (Sara Ljungblad). Together with Miriam Sturdee, we developed a vision for this method as we move on from our experience and present it as a valuable tool for others. Therefore – we put considerate work into illustrating the process, opening up for alternative appropriations of the method.

Conversational Composites involves a back-and-forth exchange of sketches and drawings between multiple participants. It's unique because it focuses on the physical creation and modification of a composite piece, which allows for the traceability of each participant's perspectives and interpretations. The final product is made up of distinct layers, each with its own identity, but all contributing to the overall composite. This method can be used by any number of participants – as many as the number of layers. The process begins with a prompt, which serves as the starting point. These prompts can be research questions, requirements, stories,

photos of events, user quotes, diary entries, design artefacts, design guidelines, manifestos, and more. Once a suitable prompt for conversation has been selected, the next step is to determine the layers of the composite. It's important to consider the physical properties of the chosen media and techniques when defining each layer. For example, if translucent paper is being used, it may not be suitable to use watercolor as a technique. The method involves creating and exchanging each layer with the next participant. Each step should build upon the previous content and make use of the current layer's media and technique.

After completing their assigned layers, participants should annotate their work and reflect on any new insights that arose. It's suggested that participants read each other's annotations and discuss the composite as a whole, noting any changes or similarities between layers, and how each image was built upon, redrawn, ignored, or left unchanged. The method also allows for the examination of each layer on its own and the rearrangement of the layers to potentially uncover new meanings.

Contribution

Our method is an example of how visual tools can be generative for academic knowledge. Indeed – much of the relevance of designerly approaches in researching HDI comes from their ability in dealing with complex relationships and making visible what otherwise was invisible. Design research, as exemplified by *Conversational Composites*, thrives in the possibility of bringing a multitude of voices onto the discussion in multiple ways. In this pictorial, we presented a set of directions but most of all we noted how its use supported previously unexplored directions. For me, in particular, it made me question some of the future work I was planning.

The importance of more-than-human actors in HDI became more evident to me. Curiously, there was great value in discussing the resulting images with the other participants at the workshop. Their questions were generative to our work with drones, and indeed showed how incorporating designerly ways of knowing made us move forward in our HDI research. In the re-interpretation of the textual narratives given to us by actual hobby drone pilots, we expanded and rebuilt the stories. The new depictions conveyed other meanings – but more importantly, they became an excellent prompt for further discussion for the workshops this method was envisioned for. The pictorial offers the method to the HCI community in its raw form, although we propose a number of alternatives that can be put into place. We suggest that the technique may be used with other prompts and media. The final artefact generated through our method relies strongly on transparency and collaboration, while still affording a large variance in backgrounds and number of participants.

We envision *Conversational Composites* as a method that promotes interdisciplinary collaboration, helps to flatten hierarchies, and allows for design research discussions to occur in alternative forms that facilitate a deeper and more novel understanding. The inherent ambiguity and equal influence of each participant in this method creates a rich conversation that can be productive at levels beyond speech or text. The final step of this method involves analysing and discussing the composite, interpreting it through conversation. This allows the composite to be viewed as a whole and to mindfully consider which elements are visible through the layers and which fade into the background during this process. We plan on the continued use of our method, particularly when engaging in other ethnographies.

An Invitation

If you happen to be holding a physical copy of this thesis in your hands, I leave below a bespoke prompt with a sketch for you to continue drawing your thoughts at this point – is there a way you could use this method? I invite you to add slowly [185] to the conversation by putting your mark on this paper, and returning the copy to a shelf, or sending me a picture of your addition to my email. If you have done this, feel free to make a mark on the fore edge too! Perhaps others will join your conversation.

Chapter 3

Future Work

Did you arrive here without having read the previous chapters? That is fine. No – really – this is the most important chapter. A licentiate degree should be about where I am headed, and because I have learnt so much in the process of getting here, I would have redone everything in the appended publications. Are you reading this after I am done with my PhD? That is even better, you can check in how many ways this plan failed.

I could summarise the work in this thesis as follows: studying the design of social drones[1] is significantly more complicated than anticipated. Drones resist playful design explorations due to their technical complexity as we could see through the *Wisp* project. The engineering of drones is arguably still in its infancy – and so is their design. My work so far has leveraged what could be described as a design sensibility-driven approach, formulating encounters that happen in society as deeply relational. Drones are not only in the air, they take up our attention and create grounding notions that are relevant to what should be considered when designing and researching them.

Because the funding of this project is targeted towards AI[2], my own work goes hand-in-hand with the developments in automatisation. In fact, many commercial drones already incorporate advancements in AI. As pointed out in the literature review, the field of HCI seems to expect drones to quickly become autonomous, but the truth is that there are more than technological issues in this – to fully make a judgement on the risks of autonomous drones in order to create a valid legal framework for them will likely take decades. There is, however, considerate peril in the fast development of autonomous features and potential applications. The work so far does not focus on the development towards automation, but is oriented towards discussing the current relationships between humans, drones, and other actors. One of the questions posed within the project is whether or not the risks of using drones outweighs the benefits. This question can not possibly be answered by one researcher alone – rather, it needs a combination of multiple perspectives.

[1] It is unfortunate that I am still using this expression at this point. I am uninterested in further definitions of what a social drone is. In line with agential realism [66] none of my work relies on a demarcated understanding of what exactly a social drone is. Rather, a drone can be both social and something else at the same time, both of them being true. The whole drone can be social, or the way it moves. Its propellers can be agents of social interaction. And I would like to keep that open-endedness that way.

[2] https://wasp-hs.org/projects/the-rise-of-social-drones-a-constructive-design-research-agenda/

As shown by the autoethnography appended [42], there are complex relationships of care created by the presence of a drone. It is of the essence to keep making space for the role of designers as facilitators and champions of alternative values in Human-Drone Interaction. For me, a good dose of anti-technopositivism is necessary in any research conducted. Further ethnographic studies will continue to inform just how important designers are in this context.

Drones are an excellent technology for challenging the *status quo* of research within Human-Robot Interaction. I see them as the harbingers of more-than-human design knowledge into the field – where much of the focus could be unmaking the technology rather than developing it. The idea of drone concepts that pose problems (such as *Wisp*) is helpful in figuring out what is desirable or not – not only for humans, but for other actors.

There are two important frames for my work moving on: Bellacasa's matters of care [67], and Stolterman and Wiberg's notion of concept-driven design. My research in the following years will, informed by the work presented in this thesis, leap from first-person narratives towards representations of other's relationships to drones.

Bellacasa grounds her argumentation on Latour's notion of the negotiation between matters of fact and matters of concern [68], [337], stepping further into the discussion of what she names *matters of care* [67]. Informed by Haraway's call to *stay with the trouble* [28], Bellacasa *"raises the issue of how 'we' are contributing to the construction of the world. How does respect for concerns in the things we re-present encourage attention to the effects of our accounts on the composition of things?"* [67]

Hence, I propose the two tracks a a continuation of my previous work: ethnographies of care and concept-driven explorations of drones – both of these resulting in developing narratives and designs for the showroom.

3.1 Ethnographies of Care

After two years of researching drones, I have come in contact with many stories and examples of how they are used. I have throughout the years joined a number of online fora (for example on social media) and been particularly attentive to news about drones. In the combination of the stories I have heard, the reactions I have seen online, and my previous work in autoethnography [338], I have found that there are many dimensions of care transmitted in the interactions with drones. As already mentioned, drones challenge the notion of the user-bystander dichotomy, producing many layers of matters of concern (from safety to legal) but more importantly for my research, creating worlds where neglect becomes evident.

One example of this is how drones often end up in accidents, either submerged or colliding with trees or even animals. Market leader DJI even offers an after-sales service curiously called 'DJI Care Refresh'[3] covering protection for collision, water damage, flyaway, and natural wear. This service offers, for a 1 year plan *"Two replacements in one year: Usable twice for damage, Usable once for flyaway"*. This is a quite significant service offering brand new drones at the cost of a replacement fee. But what happens to these drones that flyaway or are drowned in the sea. Our previous work [339] asked in an online forum for short stories of drone accidents. In these stories we could identify many dimensions of matters of care, from expressions

[3]https://www.dji.com/se/support/service/djicare-refresh

of worry for privacy, drones returned after many years thanks to the kindness and curiosity of the finders, and collisions with more-than-human agents.

Once, while scrolling a forum for DJI drone owners in Sweden, there was a post that caught my attention. There was an image in it: a submerged drone in an old lime quarry. The post was written by a group of divers and it read: *"During the morning today we found a Mavic 2 drone. The owner had filmed the quarry, but even themselves. Help us find the owner so they can find their drone back. Share share share."* The initial post gathered more than 120 shares. There were a number of comments, many with suggestions on how to track the owner through the SD card inside the drone. Some asked if there was no operator ID, as this is usually required in Sweden. Many pointed out, the propellers were gone, find it it suspicious. Some theorised that the drone was just dumped, while others thought perhaps a fish or crayfish had taken them. One week later, the diver's group posted a photo of the owner reunited with the drone. I can't help but be curious – what was the story? Who took the propellers? What happens to the drone now? Stories such as this one show the complexity of the sociotechnical assemblage surrounding that one drone. Because these robots are in the wild interacting with humans and more-than-human agents, they have become invaluable objects to research. This story surfaces many dimensions of care, which can not be neglected in research.

I propose therefore a series of studies, making use of online ethnography and participatory ethnography (See Section 1.2.2.1) with hobby drone drivers. I am interested in those that engage with commercial drones out of own volition and interest, either using or building them in their free time. This group of people include teachers using drones in their classroom, racers, repairers, you-tubers, and others that I do not yet know of. The aim is to gather many stories surrounding drones in order to preserve their complexity and making visible the labour of care associated with them, along with signs of neglect. Here, a variety of 'matters of care' should surface, giving voice to agents beyond the drone and the human, such as the crayfish at the bottom of the lime quarry.

3.2 Drone Concepts

Another thread in my work is centred on the development of minimal and experimental interactions with drones. The work with *Wisp* was a first step in this progressing idea [43]. Through concept-driven interaction design, I propose continuing the discussion on what roles drones ought to play in the world. Initially – the objective was to create probes that could be used in domestic contexts. However, through the work presented in this thesis, I have found that forcing the domestication of drones through design probes may be intensely undesirable [42]. Instead, exhibitions presents themselves as an excellent platform for discussing drone concepts and making advancements in (More-than-)Human-Drone Interaction.

Creating *Drone Concepts* (regardless if for the showroom or, for example, for online publications), brings issues pertaining the discussion on Intermediate-Level Knowledge as derived from Wisp and explained in Section 2.3. These concepts to be exhibited need to negotiate the need for interpretation of the design knowledge behind them while simultaneously being ambiguous enough to provoke – they need to afford discussion that contributes to the research aims and the theory surrounding the design of drones.

Within these concepts, I see space for the creation of actual interactive prototypes (as exemplified by *Wisp*), but also the development of critical designs and artworks that question and reveal the tensions of the real-world assemblages surrounding drones as discovered through the above suggested ethnographies of care. I propose therefore the development of critical signage, dioramas, posters, paintings, sculptures, and many other types of conceptual design and artistic artefacts. These contributions are to be developed as research-through-design, with continued rigorous documentation of their process.

3.3 Drones Stories and Concepts in The Showroom

The connection between these two (ethnographies and concepts) may at first be unclear, but they collide in the creation of artefact-oriented narratives and exhibition pieces. I propose that the first ethnographic studies result in pieces with drone-centred rich narratives, where the drone plays the hero (or the villain). For example, the drone that visited the bottom of the lime quarry is certainly no longer functional. Its shell could be turned into an exhibit, paired with a story of its life and those it has touched. The drone we have used at home with my children is definitely one of those pieces [42]. Similarly, *Wisp* [43] is a prototype designed to be experienced in order to question what an interaction with a drone is or may be. The development of the concepts mentioned above, such as signage for future worlds, comes together in visions and narratives to be discussed with a wider audience. Here, it is important to note that the notion of wider audience must be an inclusive one, reaching out to anyone, from children to disabled people, regardless of language or age. The aim of my research is to culminate in an accessible exhibition rich enough to make all visitors question and converse on the future of drones in our society, be that that they should thrive, or that they should be unmade.

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Part II

Appended Papers

Paper I

Living with Drones, Robots, and Young Children: Informing Research through Design with Autoethnography

M.Gamboa

NordiCHI'22, October 2022

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Abstract

Supporting the study of child-drone interaction in domestic spaces is a difficult endeavour, but of value to the development of this robotic platform. This paper presents an autoethnographic study, serving as an exploratory first-person method to surface issues and opportunities in this design space. Autoethnography is increasingly popular in HCI, but to further support its application, I combine it with a Sociotechnical Systems (StS) perspective, informing the analysis and development of descriptive narratives with systems theory. This paper is based on a year-long documentation of the interaction between my family and a set of three land robots and one flying robot. I present work in the form of critical incidents and lessons learned, and a set of design opportunities for child-drone interaction to inform a research through design probe development. The combination between StS and autoethnography proved fruitful in understanding how drones may currently be brought or gifted into the home without fully considering the effects and implications of their use. Furthermore, I offer reflections on the use of autoethnography for other researchers when living and involving their family with their research material.

Living with Drones, Robots, and Young Children: Informing Research through Design with Autoethnography

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Figure 1: The DJI Tello Drone, picked up by the small hands of a three year old.

ABSTRACT

Supporting the study of child-drone interaction in domestic spaces is a difficult endeavour, but of value to the development of this robotic platform. This paper presents an autoethnographic study, serving as an exploratory first-person method to surface issues and opportunities in this design space. Autoethnography is increasingly popular in HCI, but to further support its application, I combine it with a Sociotechnical Systems (StS) perspective, informing the analysis and development of descriptive narratives with systems theory. This paper is based on a year-long documentation of the interaction between my family and a set of three land robots and one flying robot. I present work in the form of critical incidents and lessons learned, and a set of design opportunities for child-drone interaction to inform a research through design probe development. The combination between StS and autoethnography proved fruitful in understanding how drones may currently be brought or gifted into the home without fully considering the effects and implications of their use. Furthermore, I offer reflections on the use of autoethnography for other researchers when living and involving their family with their research material.

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CCS CONCEPTS

• **Human-centered computing** → **Field studies**.

KEYWORDS

human-drone interaction, human-robot interaction, autoethnography

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1 INTRODUCTION

Drones are becoming increasingly common in public and domestic spaces, and bring with them a set of complex challenges in, for example, design, legislation, engineering, and ethics. It is fundamental to research how this technology is impacting society and what considerations should be taken when designing drones. To support research within Human-Drone Interaction (HDI) I present an autoethnographic study as a first step towards a research through design (RtD) approach: putting emphasis on detailed and evocative qualitative data to support work on small provocative RtD probes

[17]. To inform the design, I have been conducting a year-long longitudinal study at home, with my own children (aged 6 and 3) and four commercially available robots, one of them being a drone. While the focus of this paper is drones, the combination of different robots aimed at supporting a variety of perspectives, and finding potential common or divergent characteristics between flying robots and other types of domestic robots. The study contributes with a description of experienced qualities of flying robots in a natural domestic setting.

Figure 2: An image of the three indoor robots: Doc, the humanoid robot; Tello with feathers (the drone); and Purrble, the stuffed animal robot. Elsa's and Anna's hands can be seen for scale.

This article is grounded on my own first-person knowledge as part of the system being studied, conducted as an autoethnography. In order to structure and facilitate the systematisation the knowledge acquired through the autoethnographic method, I have combined it with a Sociotechnical Systems (StS) approach. I define and describe my family as a micro-sociotechnical system (micro-StS) supported by an existing StS framework. The novel combination between the method and the StS perspective aims to be translated into an experimental system approach to design research [7].

The combination of methods resulted in valuable and intimate insights which might have been otherwise missed, aiming to understand aspects of the incorporation of (potentially disruptive) robots into everyday family life, and what implications they bring. What are the expectations of a grandparent who buys a toy drone for their grandchild? What is the impact such technologies have within a family? While policy-making and regulations are important, and should be informed by research within HDI, this autoethnographic approach instead puts emphasis on unpacking some of the values and qualities materialised into the design drones [47] for children from a micro-ethics perspective [42]. Through this study, I have found how my home was impacted in this manner and witnessed unexpected changes in the relationships between family members.

2 BACKGROUND

In this section I give insight into the theoretical and methodological background of this work, starting with a departure from an epistemological description of Third-Wave HCI. This is followed by the suggested role of autoethnography as an essential part of the designerly work within Research through Design (RtD), and finally a novel combination between Sociotechnical Systems perspective and autoethnography to facilitate sense-making and analysis as well as a description of the family as a micro-StS. This combination is framed by two research questions: *"What is the contribution of an auto-ethnographic study, supported by Sociotechnical Systems, in formulating design considerations for Research through Design?"* and *"What is the impact of incorporating toy drones in a domestic environment with small children?"*.

2.1 Situated Perspectives

The present research is placed within the third wave of HCI [3, 18, 27], which is informed by many perspectives grounded on understanding interaction as phenomenologically situated. "The goal for interaction is to support situated action and meaning-making in specific contexts, and the questions that arise revolve around how to complement formalized, computational representations and actions with the rich, complex, and messy situations at hand around them. Because of its emphasis on multiple meanings made in context, we term the third paradigm situated perspectives." [18]. In short, the third wave recognises the prominence of relationships and meaning-making between humans and machines in context. This wave brings an emphasis on experience as the primary object of study, which has a relevant impact on what methods are suitable.

Design problems are generally wicked [5, 38], and therefore, can only be tackled with a large degree of flexibility, where methods need to often be adapted to the specific and unique issue at hand, with more interest in their direct applicability than in generalisation [43]. This justifies a shift towards a less strict use of methods, where pragmatism is the rule. If all knowledge, use, and experience is assumed to be situated and contextualised, then it is not surprising that ethnographic methods saw a rise in acceptance in this third wave HCI, particularly as a set of approaches that inform system requirements [24].

Ethnography is a common way to tackle the situated nature of these interactions, including longitudinal studies being applied to families in their homes, in order to reveal the intricacies of their experiences. Fernaeus et al. [15] for example, describe a longitudinal study where a robotic toy animal was sent to six families. Petrelli and Light [37] on the other hand presents an intricate study of eight families in Northern England, where the results are presented in the manner of rich and detailed histories of how these families celebrate Christmas, without any new technology being the main object of study. Mazmanian and Lanette [34] set out to understand the difficulties of parenting in a digital age through ethnography stating even that "as with all ethnographic research, the ideal of a large and 'representative' sample size is replaced with depth of insight and nuance of findings.". Derix and Leong [9] uses probes to understand different perspectives within sets of parents. While all these studies support a rich and phenomenological situated understanding of the interactions, they do not serve to give a first-person

perspective to the researcher, nor to inform a RtD process from a unique personalised and intimate standpoint. The detail in the reports in the third person may lack some of the more interesting critical challenges which surface through autoethnographic approaches.

2.2 Autoethnography in RtD

Autoethnography is an increasingly popular approach within third wave (and potentially fourth wave [16]) HCI, which takes into consideration the importance of first-person understanding of the technology at hand and uses the personal experience as research material [13]. Ellis et al. [13] describe how autoethnography is a merging of an autobiographical method with the ethnographical one, while challenging ideas about the separability of researcher and research product. Within HCI, Ljungblad [31] used a life-logging passive camera alongside her participants, while Höök [22], for example, transfers many of the qualities she found in her own practice of horseback riding into design. Lucero [33] reports on living without a mobile phone, offering important themes to be considered when designing for that technology. Homewood et al. [21] propose removal of technologies as a method for fourth wave HCI based on two autoethnographies on self tracking. A similar approach, connected to RtD, is named autobiographical design, where probes are used by the designers themselves [35]. Yang and Neustaedter [49] reports on a three month period use of a telepresence robot to support a long distance relationship, and Lockton et al. [32] develop the notion of autoethnographic 'kits' through the work of undergraduates related to their sleep routines. In a more intimate context, Helms [19] uses autobiographical design to discuss more-than-human materials and agencies in the context of breastfeeding.

In this privileged position as a researcher, we are endowed with the capability to tell stories. But this process is not without ethical and epistemological trouble, which could end up in severe difficulties to be executed and published [48]. Desjardins and Ball [10] present sincerity, collaboration and authority, and inventiveness as recommendations for autobiographical design projects. I incorporated these into my work in the form of values to be followed while reporting the results.

When approaching design projects with a RtD agenda [17, 29, 51], we must understand that designers "make all kinds of decisions and judgments, such as, how to frame the situation, who to listen to, what to pay attention to, what to dismiss, and how to explore, extract, recognize, and choose useful information from all of these potential sources." [43]. Ellingson [12] describes how autoethnography incorporates embodied experiences directing attention not only on what is said or done, but how it is felt, how the researcher's body is positioned and understood in space. Therefore, it is vital to incorporate the first-person perspective of the designer into the research process, particularly when defining the design space. Hence, I consider autoethnography necessarily and directly connected to RtD. However, I recognise a difficulty in analysing data generated by the researchers themselves, and in articulating design considerations which can be applied in further research. Therefore, I set out to experiment on a combination of methods which would work to this end, and recruited a perspective I had been interested in: Sociotechnical Systems.

2.3 Sociotechnical Systems

Sociotechnical Systems (StS[1]) is an example of a holistic theory compatible with design research. It can be combined with an understanding of 'soft systems', which opens up for not only focusing on the system itself, but on one's methodological approach to it [6]. 'Soft systems' are open and ill-defined systems, where there are divergent views of what constitutes a problem, and even on what the system boundaries are (what elements constitute the system). In the context of this research, studying social drones could encompass a large number of specific goals to be tackled. Social drones, as defined by Baytaş et al. [2] are "applications where fully autonomous drones operate in spaces populated by human users or bystanders". In the case of current research we depart from teleoperated drones to study relationships built in society which will eventually inform the design of fully autonomous drones. In the case at hand, I advocate for an approach where a singular research goal is not primary, and that the wicked nature of the research field of social drones requires alternative methods.

By combining StS with autoethnography, the aim is not to abstract knowledge or reduce designer bias into the design process, but instead to incite deep phenomenological first-person experiences as a part of the design process and a factor to consider as part of the system itself [23]. The main aim of this paper is to inform a detailed understanding of a design space, and to that end I propose and engage with autoethnography combined with StS as a suitable method for designers, as it allows for a deep, personal, and detailed understanding of the systems themselves. To be able to study other families, it is important to consider one's own standpoint as a researcher and designer as a first threshold in sensibility towards other engagements with emerging micro-interactions. Applying methods and frameworks pertaining to StS when planning, conducting, analysing, and presenting ethnography may be a suitable approach.

As exemplified by Kirwan [28], the application of StS and 'soft systems' is more clearly connected to industries and work places [28] [2]. In this paper, I argue that a family is a 'soft' multi-level (albeit small) system. Due to the relatively small number of elements in families and the tacit nature of the relationship built between them, I denominate the system being studied a micro-sociotechnical system (micro-StS). The distinction between StS and micro-StS is made to allow for systems with much more limited boundaries to be studied and analysed while indicating a high degree of variability and flexibility stemming from the volatility of the elements. The emphasis on a micro-StS is on short emergent and tacit situations which may at first seem nearly insignificant.

[1] STS can also be an abbreviation for Science and Technology Studies, which is not to be confused with the use of StS in this paper for Sociotechnical Systems

[2] I feel however that I must take an epistemological stance against Kirwan's understanding of soft science as described: "The paper itself is written in less formal style than is usually the case for journal articles; this is partly because it is very much a condensation of practical experience rather than of scientific knowledge or data, and also because a more formal style may lose some of the impact of the lessons that have been learned." [28] Practical experience is most definitely worthwhile knowledge which should not be directly connected to informality or lack of rigour.

Silverstone [40] refers to "domestic socio-technical systems" while studying in detail the intricate network of computers, televisions, telephones, all of which have shifted from having a particular place in the domestic environment to now being mobile. The domestic space has been extended outside the walls of the home, and therefore, the StS I am studying considers the family its core, rather than the technologies. Even without always explicitly mentioning StS, there are studies that already describe families as system. An example is provided by Taylor and Swan [44], where the systems created by caregivers to organise their own families result in design artefacts in the home. One of the robots appropriated in this study (Purrble) is the result of a well developed design process informed by StS [41, 45]. Multiple stakeholders in families inform the design, becoming an example of how the whole family ought to be taken in consideration when creating domestic probes "The principles of socio-technical design then apply on multiple levels: how the (technology-enabled) intervention becomes embedded into the current practices of an individual or the family unit; which mechanisms are assumed to lead to shift of these practices; and on which timescales and through which 'levers' this happens in the family context." [41]

3 METHOD

To gain a deep understanding of incorporating small drones into domesticity, I have conducted a longitudinal autoethnographic study with my family and the places where we live as a unit. As pointed out by Leite et al. [30], longitudinal studies are helpful to explore beyond the novelty value of social robots, particularly in a domestic setting. In this article, I report on a year long introduction of off-the-shelf remotely controlled DJI Tello drones into the micro-StS (our family). The goal was to understand how a drone may be experienced and used by a family in everyday life over a longer time period. The insertion of new technologies into the existing micro-StS results in new interactions which can be turned into important design insight: "Humans and technologies in households are interconnected as members or elements of the same system. When a new element is introduced to the system, the system goes through a process of integration that may result in the re-organization of roles, relationships and functions." [26]

The studies started in December 2020 and span so far until November 2021. I have documented the events through photo, video, and diary notes. The results presented stem from the most relevant events and opportunities to serve the definition of the design space. I identified and organised elements in the sociotechnical system as shown on Figure 3. Each of these elements or nodes is described in the following subsection.

As a novel approach to autoethnography and an aid to guide the reporting and documenting of the results, I have used representations of the system based on the framework presented by Davis et al., which stems from a schema that has been developed by a number of authors. For Davis et al. "the core idea is that any complex organizational system can be represented in the form of a hexagon" [8]. The framework is described as: "(...)a work system will usually have a set of goals and metrics, involve people (with varying attitudes and skills), using a range of technologies and tools, working within a physical infrastructure, operating with a set of cultural assumptions, and using sets of processes and working practices. The system sits within a wider context, incorporating a regulatory framework, sets of stakeholders (including customers), and an economic/financial environment." [8]

This framework is used in this paper to support the reader's interpretation of the narratives exposed which can be highly tacit and difficult to pinpoint. The advantage of this framework in particular is that it focuses not only on accident analysis which is important for many work systems, it instead "is an attempt to provide a simple yet powerful representation of the interdependent nature of work systems, providing a framework for analyzing the linkages and relationships between the different social and technical aspects. The potential value of applying such an approach is that it provides a structured and systematic way of analyzing a variety of complex systems, problems and events."[8]

In the current work, the wider context is given by the research project it is framed within, and driven by the academic and research expectations described in the background.

3.1 Description of the System

In this section I describe the elements or nodes represented in Figure 3. Each of the elements or nodes can also be found on Table 3.1. The study was conducted with our core family of four, composed of the **people** mentioned on Table 3.1. This description was developed at the start of the study in order to support a reflective analysis of the context at hand. As the system is being researched through autoethnography, I based the description on my own perception of our family and of my goals with the study. While the use of an StS approach attempts to make the representation of the autoethnographic context more systematic, it is also not possible to read this description as an objective characterisation of my family. As a member of the system myself, my views are undoubtedly biased, and the forging of the system does not attempt to hide that fact.

The **buildings/infrastructure** involved are mostly our apartment, but also a couple of other family vacation locations. Our apartment is a three bedroom on the second floor, 95 square meters, but located in a three family villa where we share a garden and outside space.

The **robots or technology** studied can also be seen on Table 3.1. There are 3 land robots and 1 flying robot. Firstly, Grassy [3] is an outdoor lawn mower and existed in our home before the study started. Doc [4] is an educational humanoid robot with a simple set of tasks and games to support learning programming, and had also been bought at least two years previous. Since the research is focused on drones, Tello [5] represented the most relevant robot and was acquired at the start of the study. The Tello drone is sold and advertised as a drone for children, also supporting activities to learn programming. To match it with another robot, I brought home Purrble [6] as an important addition due to the research background behind its development [41, 45] and contrasting characteristics to the drone (soft, quiet, static).

The main **goals** for the system for this particular study are threefold: wellbeing, documenting, and research. Wellbeing is an

[3]https://www.worx-europe.com
[4]https://www.clementoni.com/fi/78281-doc-educational-talking-robot/
[5]https://www.ryzerobotics.com/tello-edu
[6]https://www.purrble.com/

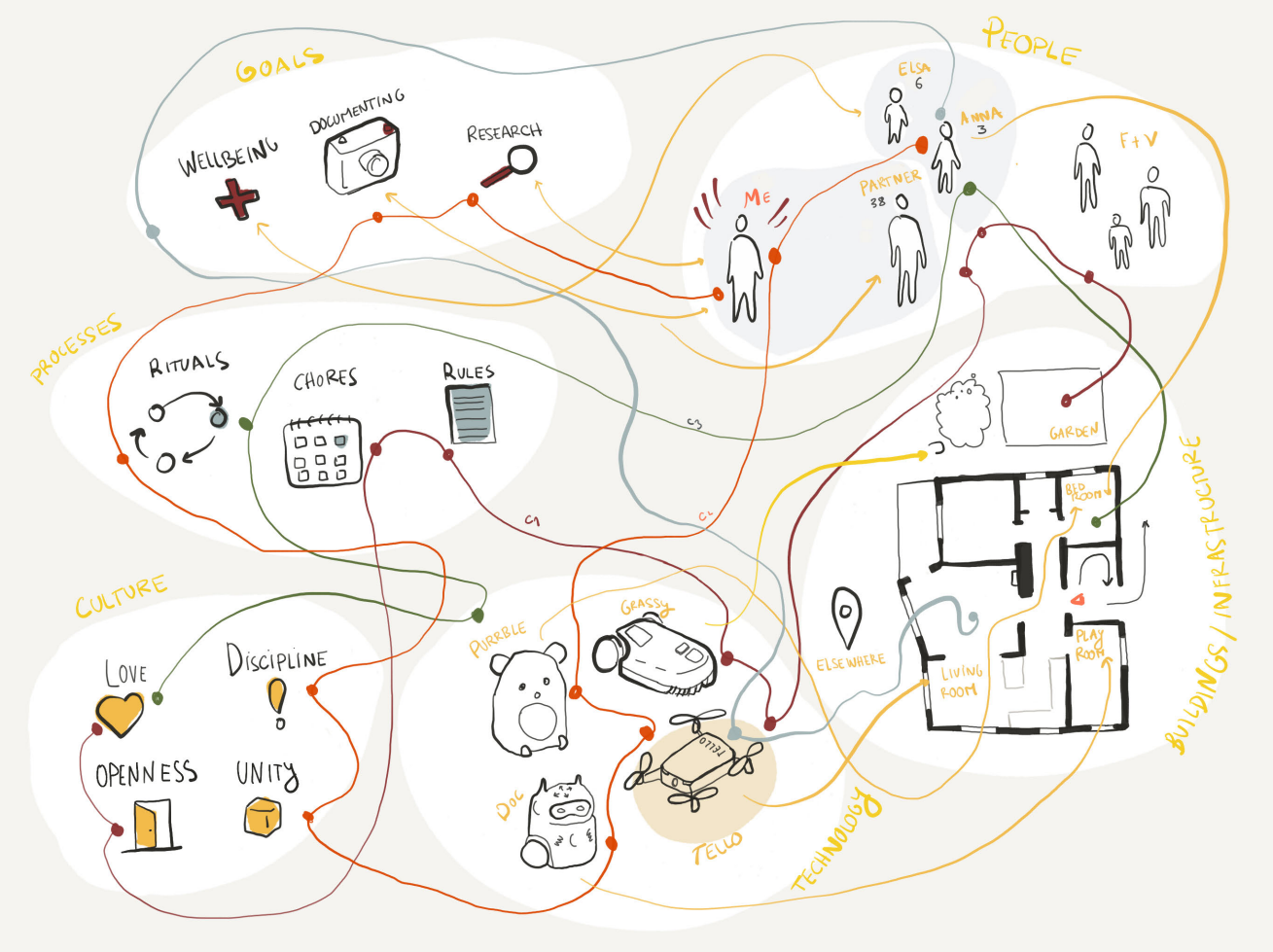

Figure 3: To the left, the autoethnographic study as a micro-sociotechnical system based on the StS framework presented by Davis et al. [8]

overarching goal for our family and can include sub-goals such as play, feeding, supporting, or even supporting a quiet environment. The goals as a family are a lot more difficult to describe – these particular three were chosen as the ones leading the interactions and initiatives we take in our home in the context of this study. Therefore, DOCUMENTING and RESEARCH became the primary aim.

The **culture** in our home is relevant to the interactions that surfaced. I identified love, discipline, openness, and unity as essential principles for our family. In general, our parenting is focused on having open relationships where we discuss emotions without hiding them from the children, and promoting their sharing. Furthermore, we consider our home an open environment where friends are welcome spontaneously, but we still make sure to communicate that we are one unit in acting and making decisions. An important value is discipline, which results in clear rules and boundaries and rules everyone follows, such as keeping order and cleanliness in the apartment.

The most relevant **processes** in the study are rituals, chores, and rules. Related to the value of discipline, there are clear rules that we follow at home (e.g. shoes are left in the hallway, no candy during week days). Life with younger children is filled with rituals (e.g. bath-time, bed-time, story-time), but also chores (e.g. cleaning after play, taking plates from the table to the kitchen sink). Examples of these processes are relevant to the descriptions of the interactions that emerged.

4 RESULTS

The results are presented in two sections: (a) micro-StS system driven critical incidents which are "documented incidents of use; and careful articulation of the impact of design decisions on experiential qualities of the system in use" [35] and (b) opportunities for child-drone interaction design probes. The first section includes the description of critical incidents informed by the different categories in the StS system described above. Figure 3 shows particular threads

People	
Me	Me, aged 33, researcher and mother to Anna and Elsa
Partner	My husband, aged 39, father to Anna and Elsa
Elsa	Oldest daughter, aged 6, older sister to Anna
Anna	Youngest daughter, aged 3, younger sister to Elsa
F	Other close family members
V	Visitors

Buildings/Infrastructure	
Living Room	Kitchen, living room and dining room in open space
Bedroom	Elsa and Anna's bedroom
Playroom	Elsa and Anna's Playroom
Garden	Outdoor space in a garden / terrace
Elsewhere	Other outdoor locations

Culture	
Love	We care for one another.
Discipline	We respect each other and follow rules.
Openness	Our doors are always open, we share our experiences.
Unity	We value our small family as a priority.

Technology	
Tello	DJI Tello Drone
Purrble	Purrble, a stuffed animal robot
Grassy	Worx Landroid, robot grass mower
Doc	Clementoni DOC, educational talking robot

Processes	
Rituals	We have set rituals and routines we follow together.
Chores	We have tasks to do in the household.
Rules	We have set rules to respect.

Goals	
Wellbeing	The physical and mental health of all members.
Documenting	Producing documents our interactions.
Research	Producing valuable research.

Table 1: A table describing the identified elements in the six categories of the system as represented on Figure 3. These categories are as presented by Davis et al. [8].

connecting elements of the system which are described below as narratives.

4.1 Critical Incidents and Narratives

In the following sub-section I present diary extracts from incidents that happened, either during short phases or as repeated behaviour. The results presented are analysed through the StS framing, by first gathering and describing the situations through the diary logs, identifying the StS elements present, and developing a narrative of sense-making grounded in both the narrative and the pinpointed elements. Therefore, some of the extracts were written in one session, while others are composed from a set of different events. The selection of incidents to be included was curated to support and illustrate the understanding of the subsequent opportunities for child-drone interaction.

4.1.1 ***Not in bed:*** As we were going to bed, after brushing our teeth, Purrble was lying in Elsa's bed together with a number of other stuffed toys. Usually, we read a book before falling asleep but Elsa was more interested in arguing as to why we should get a pet, a real one, not a fake one like Purrble. This small discussion had entirely disrupted our usual bed-time ritual but since I was interested in her reflections I let it continue. As she was overcome by sleepiness, she asked me to turn off the robot and put it away but still in bed. When I asked her why, she said: "I am afraid it will wake me up.", Are you not afraid a real pet would also wake you up?,"Maybe...", But you are not afraid I will wake you up?, "I know you want me to sleep.", Do you still want a pet?, "Maybe not, not if it wakes me up.".

StS Elements: Goals: Wellbeing; People: Me, Elsa; Culture: Love; Processes: Rituals; Technology: Purrble; Building: Bedroom;

Sense-making: Even though the aim of this robot is to support children's self-regulation of strong emotions through a comforting heartbeat, the sound was not a welcoming factor in Elsa's most intimate moment of sleep. Its soft body made it a logical addition to all the other stuffed toys which "watch over" the children in bed, but its interactive abilities set it apart. Luckily, this led into a discussion about companionship and pet ownership which was valuable for our family.

4.1.2 ***Visitors, Fear, and Enactment:*** On a particularly sunny summer day, we had visitors over, including two girls aged 8 and 6. The father was interested in the research I am doing and immediately started touching and asking about the drones. We went outdoors to our garden, and I took with me some extra batteries. The visiting children were interested in being able to control the drone, but the father was very hesitant. We played for some minutes a game where the drone chased the kids, which had become the number one activity we did. The father in the visiting family suggested the kids would try driving the drone, but it became clear the drone was too difficult to drive for the visiting child. Instead, the children ended up pretending they were driving on the phone, while Elsa held the drone in her hand, enacting flight. An image of this enactment can be seen on Figure 4. A similar situation happened when we were out, during the winter, and I took the drone for a visit to the children's grandparents where we went snow sledging. Both of the grandparents never showed any inclination to fly the drone, and were genuinely afraid of driving it. The drone was seen as more of an annoyance rather than an interesting way to document the day.

StS Elements: Goals: Wellbeing ; People: Core Family plus Visitors; Culture: Love, Discipline; Processes: Rules; Technology: Tello Building: Garden and Elsewhere;

Sense-making: While the children had no reservations towards the drones, the adults were more careful. Upon further inquiry, I noticed they were either afraid the children would get hurt or the drone would be destroyed. Remarkably, children themselves found ways around the limitations, through deeply embodied enactment

of the technical interactions they could not perform. Their activity made the drone active even though it was turned off. Furthermore, the fact that I did not even consider flying the drone indoors with that many children at home made me realise I was afraid of doing so – would I not be afraid as well to conduct other ethnographic studies with other children?

4.1.3 ***A Broken Pool:*** Since its installation, the robot lawn mower (Grassy) had been an object of entertainment for the family. I found myself and the neighbour downstairs often staring at it as it moved around the garden. When it was first installed, the path it would follow was rather defective, and the children found it amusing to wake up in the morning and check where the robot had gotten stuck, and would say "Poor little robot". On a summer evening, we filled a small inflatable pool with water and left it outdoors over the night. The next morning, the robot had cut through the plastic and the pool was ruined. The feelings of the children towards the robot changed somewhat after this event, and in the morning, they were no longer as worried about the robot, but rather more concerned to remove things from its path. Curiously, Anna is a lot more comfortable with the mower than with the drone. When I asked her about it, she was unable to say why. But as time passed, I noted how she knew exactly what the lawn mower could do and where she would be safe from it, which she never could with the drone. Its predictability became a reassurance.

StS Elements: Goals: Wellbeing ; People: Core family ; Culture: Discipline, Openness ; Processes: Rules; Technology: Grassy; Building: Garden;

Sense-making: Both the children and adults in our household often laughed at the small troubles Grassy would find itself in during its grass-cutting tours (An example lawn mower in trouble can be seen on Figure 4). The mishaps became part of a constructed personality. But once it started harming their ownership, the children quickly started rearranging their environment around it because they could better understand where the robot would go: the predictability of the path of the lawn mower is a safety point and a quality. They never asked if the robot could be put away or turned off, they instead adapted their lives to its presence. What could be the potential accommodations made towards a companion drone in the home?

4.1.4 ***Talking About Robots, Autonomy, and Ownership:*** Six months after the drone was brought into our apartment, the children had been talking about robots in school. They came home imitating a robot (talking slowly, moving with stiff arms). We had repeatedly tried to talk about what a robot is or is not, but their opinions changed throughout the year. According to Elsa, of the robots we had at home, only the drone was not one. Why is that? "This one can speak.", she says, picking up Doc. But the other ones do not "Yes, the fluffy one does. Just a little. Like this.", and she starts imitating the gibberish Purrble does when happy or sad. But what about the lawn mower? "It is also a robot, it does what it wants.". When further questioned, the drone seemed to lack agency in her eyes, even if the humanoid robot (Doc) also needed to be controlled through the buttons on its head, the fact that it could talk back was perceived as agency. Another interesting piece of this conversation had to do with ownership. While the robots that lived in our home were seen by the children as ours, the lawn mower seemed to own itself, which contributed to its robotic status. It was clear to Elsa that the drone was mine, Doc was hers, and the Purrble was everyone's. Doc was therefore a toy robot, the Purrble a pet robot, and the drone just mom's stuff, therefore not a robot.

StS Elements: Goals: Wellbeing, Research; People: Me, Elsa; Culture: Openness; Processes: Rules; Technology: All; Building: Living Room;

Sense-making: The repetitions of ownership continued beyond this journal entry. Both the children had a hard time ever perceiving the drone as a robot: what was constant was the argument of ownership. This made me reconsider the way the drone was introduced to the family – perhaps I made a mistake not gifting it to one of the children. The Purrble, for example, has a very well designed box where the transfer of ownership is made to the children in a careful manner. In what way could the sense of autonomy and ownership be developed with the drone?

4.1.5 ***Excluding the Small One:*** During this year of engaging with robots, Anna, who has been between 2,5 and 3,5 years old has developed a complicated relationship with the drone. While at first both children were equally excited when the drone was flying, as time passed, Anna became wary of the robot. Her body language showed clearly that she was not up to any closer contact (e.g. the second image in Figure 6, where Anna holds her arms up. Picture taken from the drone's perspective), and very seldom asked for the drone to be active. In comparison, she was always happy to engage with the other robots at home. Anna is particularly sensitive to noise, and therefore she would often hide in another room when the drone was flying. Her mistrust of the robot eventually became just an annoyance for her (e.g. the third image on Figure 6 shows how she used the drone's box as a resting place for her pacifier, while every time I moved the box, Elsa would ask me to turn on the drone). The first image in Figure 6 shows Anna in the background and playing around me, my partner, and her sister while we figure out how to program the drone. Anna was completely uninterested in the situation. Because of this, I used the drone less and less in our family as I felt it was excluding Anna from participating in our activities, coming into conflict with our culture of unity. This was much unlike the use of Purrble, where Anna's interest developed during this year and she would more and more often reach out to it, and even have it close to her body. The last image on Figure 7 shows Anna holding the robot next to her face while petting it.

StS Elements: Goals: Wellbeing, Research; People: Core family towards Anna; Culture: Love, Unity; Processes: Rituals; Technology: Tello; Building: Indoors;

Sense-making: When a drone is introduced into a home – even if the robot is age appropriate for one of the children or adults – there is a strong bystander effect where many others may be affected. Unlike the other robots, the drone strongly impacted the feelings in our home and created conflict where the younger child found herself being excluded. In this moment, the wellbeing of our family came over the other goals, and the lack of care we had had with our youngest became evident. This is an important factor to be considered when developing drones. While all robots may be

Figure 4: Three images showing (left) two 6 year old girls enacting the control and flight of a drone, (middle) a snow sled ride on a winter day, and (right) a lawn mower stuck on a net.

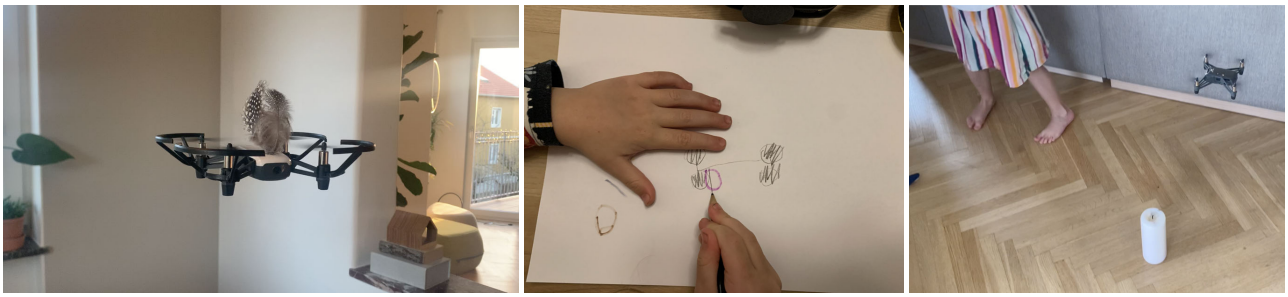

Figure 5: Three images showing (left) a drone decorated with feathers, (middle) Elsa's drawing of a drone, (right) Tello putting out candles on a flying track conceived by Elsa.

appropriate for different ages, the drone is the one which caused the most harm outside of the recommended age group. Should age appropriateness therefore include potential harm to other groups, particularly in a home context?

4.1.6 ***Command and Embodied Interactions with the Drone.*** Elsa was from the start eager to be able to control the drone herself, but I was hesitant. The times she tried, it was too difficult for her to remote control the drone, which eventually felt unsafe in her hands. She had difficulties programming the drone from its perspective, and not hers. Her enthusiasm for the drone was great at first and we could even start to see representations of it in her drawings (See Figure 5). To try to compensate for her own lack of potential direct control, Elsa came up with games and obstacles in our living room which she would then ask me to overcome with the drone. The hurdle tracks she would create included furniture and pillows, and one time, it even included candles that the drone should blow off through the air movements of the propellers (Figure 5, on the right, shows a drone flying over a candle). While she could eventually understand how Doc was programmed (step-wise, in a grid), the drone was always too complicated for her, with too many dimensions and granularity of movement. But because of its intricate movement, the paths she imagined the drone could fly were more interesting than any of the spaces of the other robots. The drone had the capacity to make her imagine worlds where it could do things by her pointing, following gestural command, but even to be able to engage with other toys in our home. For example, she imagined the drone could turn off the lights, carry other toys to her, or even be part of the stories in the games. On Figure 6, Elsa can be seen trying to program the drone with me, but her most important contribution was picking up a small figurine that would ride the drone (it can be seen lying next to the drone in the image).

StS Elements: Goals: Research People: Elsa, Me; Culture: Openness; Processes: Rules; Technology: Tello; Building: Indoors;

Sense-making: The clear advantage of the drone over the other robots is its freedom of movement. While the other robots did not seem to inspire any other possible interactions, the drone supported a creation of worlds and functions in a three dimensional space. Is there an opportunity for truly engaged embodied interactions in the home, expanding the space of the home from the floor to the ceiling? This particular situation made me reflect on the antiquated user-bystander dichotomy. In this situation, who was the user and who was the bystander? To me, Elsa was the user and I was merely a translator between her and the drone. This means any age limit in the box of the drone is rendered almost irrelevant – even if the Tello drone is not advised for such small children, the actual user (me) was well above the age recommendation.

4.1.7 ***My Own Relationship with the Research Material.*** As this year of autoethnography started, I would fiddle with the drone often. I was excited to get started, and recruited my partner to start documenting if he saw anything interesting. The enthusiasm wore off on our oldest daughter, who showed a lot of interest at

Figure 6: Three images showing (left) Elsa and I setting up the drone for programmed flight, in the background, Anna can be seen playing, (middle) picture taken by the drone where Anna covers her face from the drone, (right) Anna leaves her pacifier on top of the drone box

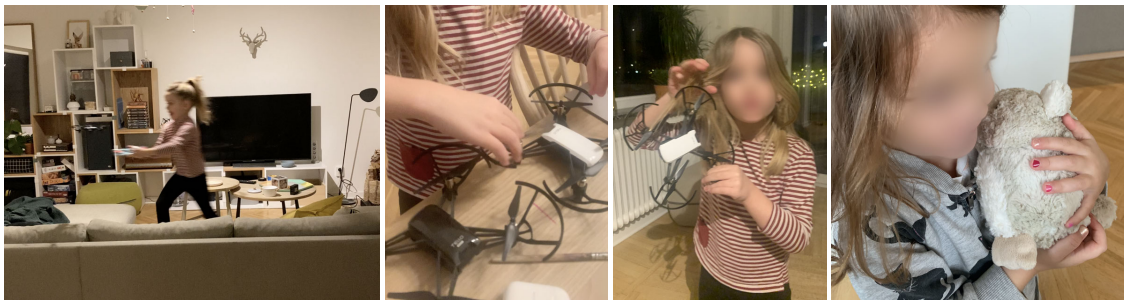

Figure 7: Four images showing (left) Elsa chasing the drone to help it land by climbing on furniture, (middle-left) Elsa fiddling with the drone propellers, (middle-right) Elsa with the drone stuck to her hair and (right) Anna holding Purrble close to her face.

first on what the drone was and could do. But as time went by, I found less and less patience to cope with yet another noisy element in our home during the evenings. Living with small children leads to a hectic environment, and the noise of the drone became too much to bear at times. When taking the drone with us to interact with others, I often felt as if the people around me were bothered by the presence of the drone and showed a lack of interest in it - it was my research object and not theirs. It was extremely rare that anyone asked or was willing to control the drone themselves. So as time passed, I too lost interest in being engaged with the drone, and as I lost interest, nobody else picked it up. The drone started gathering dust, while both me and the children often engage with Purrble. Its calm nature helps in creating peaceful relationships with the children, while both Doc and the Tello contribute to a noisy but more active environment. Elsa did often ask if we could fly the drone, but in our busy lives, the addition of another moment of exciting and noisy activity in the evenings became less and less desirable. The documentation process was easier due to the drone's camera: when conducting autoethnography with children and robots, if there is no assistance in documenting, the act of documenting itself can be disruptive. Therefore, many of the interactions with the other robots were only registered through diaries, and many of the interesting quotes the children said were lost. I had expected the robots to be embedded into our rituals and routines, but this never happened, and alas, each documentation session felt somewhat forced.

StS Elements: Goals: Documenting, Research; People: Me, Partner; Culture: Love, Unity; Processes: Rituals, Chores; Technology: Tello, Purrble; Building: Indoors;

Sense-making: The novelty effect wore off quickly for the drone, not only because of our hectic lives, but also because of its disruptive nature. This resulted in some guilt on my side, where I felt like I was disconnecting from the technology I was meant to research. But most of all I did not know what to do with the drone itself as it started fading into the background of our home: was there an appropriate way to unmake its presence?

4.2 Opportunities for Child-Drone Interaction Design

Through the relationship created between the drone and my children I have extracted design opportunities for child-drone Interaction as a guiding compass for the creation of design probes. These opportunities are described as ideas to consider and do not have any prescriptive value. They seek to offer perspectives to be added to a more sensible and critical approach to HDI, rather than desirable or necessary actions.

Figure 8: The children hide from the drone behind furniture.

Touch: The children created intricate touch interactions with the drone, which were not limited to carrying it. The propellers are easy to fiddle with when the drone is inactive. However, its cold surface never led to a closer contact with any other body part. Even when decorated with feathers (which the children did touch and play with), no further closeness was exhibited. The most exciting of activities were connected with the drone landing or taking off on body parts, such as on the hand. Although the ability to touch does not seem to have any relationship to the childrens perception of autonomy, it still promoted a clearer path to ownership. Carefully manipulating the materiality of the drone is a relevant endeavour to consider.

Enactment in 3D Space: A unique characteristic of the drone is its ability to be enacted as a flying robot. From an embodied perspective, the play that it generates is more interesting than what land robots do. The children were able to stretch their arms to the sky, and relate to the spaces higher above, while when interacting with all other robots, their bodily positioning was either crouched or curled up. Therefore the drone clearly opens up for a varied experience in the kinaesthetic relationship between the children and the robotic agent.

Directed Play in 3D Space: While the children were interested in learning how to program the robots, they were even more interested in being able to give it commands to follow verbally. While the land robots could easily reach the points the children wanted them to, the drone engaged them in a much richer repertoire of play. Because of its ability to move in all directions, move air, make noise, and collapse catastrophically, the children came up with paths and stories for the drone to enact around the apartment, using different obstacles and spaces in a dynamic way. Creating probes that take into consideration these substantial engagements with the context is worthwhile.

Wickedness and Attention: The drone had the ability to engage the children. While every time the drone was active there was general excitement, which was sometimes resolved by brave attempts to engage bodily in proximity with the drone, but mostly resulted in hiding or protective behaviours. The children would either hide behind furniture or an adult, and observe intensely the activity of the drone (See Figure 8). This wickedness of the drone had the great ability to fully absorb the attention of the children, and direct it elsewhere.

In-between States: Drones are either off, or on. And their off or on states are dramatic: a drone can not turn off mid-flight or it will collapse. It also does not exhibit stand-by behaviour. Therefore, when inactive, the drone appears to be entirely lifeless, when active, it is in constant movement.When constructing probes for the home it may be valuable to consider the possible spectrum of states designed for.

Difficult Ownership, Safety, and Right to Repair: The children had trouble understanding how they could independently engage with the drone. Simple tasks such as the handling of the batteries or replacement of the propellers make the drone an unlikely companion for young children. Considering independence in the design of all the stages of the interaction is fundamental to support a feeling of ownership. However, the difficulty here is to combine the possibility of ownership with the complicated task of making the drone safe or even compatible with small children, given that so many of their characteristics are inherently dangerous or inaccessible (e.g. high noise volumes, dangerous moving parts, unstable movement). There is a possibility that the care-taking necessities of the drone could contribute to the interaction, but these need to be carefully developed with all members of the families in mind. At times, the shelving of the drone was due to minor repairs that were too complex or time consuming. The right for repair to be conducted by the children is also a necessary element for the true sense of ownership to be developed through relationships of care, using simple interactions and modular open-access design.

Culture, Values, and Type of Play: When using the drone, it became clear that the structures in the family changed. Some distanced themselves, other engaged directly. Some family members were annoyed, disturbed, or even fearful of the technology. Most definitely, the drone created an impression. One must consider which cultural weight is designed into the drones, and what type of play it is supporting. Actively stating the goals, culture, and processes within StS the probe is aiming at may be helpful in appreciating which values and type of engagement the drone is creating within a family. Similarly, when designing and promoting the drones to a wider audience, it is important to clearly communicate which values the design is supporting, and inform on the potential harm it may cause.

Anticipated Experience and Death of the Drone: The packaging of the drone was not particularly appealing to the children

and required a lot of support from an adult in unpacking and making sense of all the information. When trying to store the drone, the packaging was not particularly helpful, and therefore the robot ended up literally collecting dust on a shelf. We were uncertain how to sustainably deal with the lack of interest from the children towards the drone. Ultimately – we were uncertain how to dispose of the drone in a sustainable way. It is necessary to consider how to support both the anticipated use [25], and the post-use of the drone as a part of the design. Together with work on the right to repair, the death of the drone may be more sustainably delayed.

Unmaking: Most importantly, when designing drones, one should consider if they should at all be designed for the context at hand. While a product can be labelled as not appropriate for a 3 year old, it may still be used in their vicinity, forcing them to interact with it. Through considerate reflection and the design of critical probes, designers can question unresolved issues of sustainability, safety, legislation, and ethics. The work of designers may be to aid in the unmaking of drones in certain situations, and support the discussion of issues such as the potentially obsolete user-bystander dichotomy.

5 DISCUSSION

In this section, I discuss the results as framed by the two research questions, starting with issues relating to drones, followed by methodological considerations, and a shorter discussion on the ethics of this study.

5.1 Drones and Children

The second research question that framed this study was: *"What is the impact of incorporating toy drones in a domestic environment with small children?"* After one year of cohabiting with these robots, observing, facilitating, and supporting my children's relationship with them, I have found myself in a deeply critical posture towards children-drone interaction in a domestic context. As a designer, I am concerned about which values are embedded into the systems we produce. And indeed, this ethnographic account brought forward the disturbances that the presence of a drone left in our family, and the impact in terms of relational concerns from an ethics perspective e.g. [13]. As mentioned in the introduction, it is vital for my research to understand why families bring these potentially disruptive robots into their everyday, and what value they bring. It is fair to say that the grandparent who buys a toy drone for their grandchild is unaware of the imbalance they may unwillingly bring into the home. Previous research has shown that there are concerns both on how drones may be used to stalk children, but also when regarding children as users [4]. Boucher [4] notes how a number of participants in a survey were surprised that toy drones were available on a small budget and feared deliberate and accidental misuse. As designers, it is our responsibility to clearly state and communicate the values materialised into the design [47], and seek to either prevent these risks, transparently communicate them, or work together in the potential ethical unmaking of these drones. This call for transparency is not novel within technology for children [50], but it seems to be particularly relevant for drones. The lack of studies with children and drones [36] is problematic, not only when perceiving children as users, but by merely considering their encounters with drones. It is perhaps no surprise that there are nearly no research studies with children and drones, given the ethical and safety issues they could cause. The few studies that can be found make sure, for example, to reduce all risk by casing in the drones [39]. This lack of studies seems to be in mismatch with the reality of toy drones, as a simple search on Amazon for "toy drone" generates more than 2,000 products and some with more than 15,000 reviews. But the issue with children interacting with drones exists beyond considering them users in a traditional way. My autoethnographic study could have been conducted in the same way by describing myself (an adult) as the sole user of the drone – and yet, the children would have been exactly as impacted and engaged with it. This indicates that the borders of user-bystander may be less helpful than we would think in HDI.

5.2 Autoethnography and micro-StS in RtD

I applied a combination of methods in order to answer the first research question, *"What is the contribution of an auto-ethnographic study, supported by Sociotechnical Systems, in formulating design considerations for Research through Design?"* From a methodological perspective, I found resonance with many of the difficulties presented by Wall [48], in a struggle to make the value of this study clear to my academic peers. In fact, these studies may have harmed my relationship to drones as an RtD design material: I find myself often questioning if drones and children are at all a compatible combination, and to what extent I would like to introduce these machines as objects of study in other families. Simultaneously, the knowledge gained made me acutely aware of my importance as a researcher and designer within HDI. While this study made me rather sceptical of the role of drones in the home, it also opened up for a more nuanced and techno-critical stance moving along. The conclusions presented offer a reflective longitudinal account of a shared space informed by a genuine and contextualised appropriation of the technology which can be easily translated into RtD probes, particularly ones of a provocative nature. However, any researcher considering conducting autoethnography with their own design material should be aware that while the conclusions and the process are useful and substantial, they come at the cost of an understanding of the technology at hand which will strongly impact their approach to the research material. Helms and Fernaeus [20] exemplify these struggles, mentioning for example how autobiographical design researchers may have trouble in the dual relationship between designing for loved ones and being a good researcher.

The use the novel micro-StS approach combined with autoethnography was helpful as a base to express tacit experiences, and to be able to reflect upon the interactions that emerged and make them explicit. Because the documentation and results were centred on a negotiation of the goals, processes, and values in our home, it was easier to pinpoint and report upon changes in the relationships within the system. In hindsight, for example, my ambition to make this work happen should have been regarded as a clear value in the system – this missed cultural value could have resulted in further reflections when analysing the data. As the work continues, I propose informing the method with further research done in the social sciences within autoethnography in order to inform a more

appropriate framework which could lead into evocative narratives. The attempt to summarise the findings into design implications may have reduced some of their usefulness as rich stories, as the stories themselves are tacit and derived from a daily reality which is not always appropriate or possible to express into design knowledge. The design implications may be misread without the coupling to the stories. Apropos, Dourish [11] questions the formulation of results within ethnography as implications for design, arguing that they are not necessary – furthermore, that expressing ethnographic knowledge as design requirements is instead a limitation:

> "the liaison between analytic ethnography and design could well form the field of a practical sociology committed to a serious engagement with the design problematic - the interventionist impulse. Such a practical sociology could not eschew prescriptivism, as designers frequently accuse ethnography of doing. But its prescriptions and predictions may well not match those that designers currently seek. Instead of providing yet more grist to the mill of conventional design solutions, ethnography may offer sensibilities that will cause designers to question the presuppositions of their conventional outlooks." [1]

In this aspect, the novel micro-StS approach presented is a valuable tool to document and make explicit to others what is relevant in the system being studied, rather than focusing merely on requirement gathering or even prescription of action. While the results presented are helpful from a reflective practice perspective, they are difficult to express as design knowledge. The opportunities suggested are topics to be consider rather than best practices, and have no particular intention in solving problems, but rather in offering critical perspectives which ought to be considered in future research in a sensitivity-building manner. However, to be able to transmit and represent tacit ethnographic findings in a readable manner, we can make use of StS frameworks. It is likely that this first year of ethnography was highly stained by what criteria I perceive to be important to present as results within HCI. In following work, I find the need to reconsider how to best present the work and its narrative:

> "The narrative text refuses the impulse to abstract and explain, stressing the journey over the destination, and thus eclipses the scientific illusion of control and mastery; and the episodic portrayal of the ebb and flow of relationship experience dramatises the motion of connected lives across the curve of time, and thus resists the standard practice of portraying social life and relationships as a snapshot. Evocative stories activate subjectivity and compile emotional response. They long to be used rather than analysed; to be told and retold rather than theorised and settled; to offer lessons for further conversation rather than undebatable conclusions; and to substitute the companionship of intimate detail for the loneliness of abstracted facts." [14, 744]

5.3 Ethics and Limitations

The question of ethics in this study is a complicated one – while I advocate that incorporating the perspective of children is fundamental, the process of involving them in research should be careful through and through. As a parent, I consider that my children have benefited from this autoethnographic study, but that is no guarantee that further studies would have the same result. My children learnt about and had the opportunity to discuss robots with me, and expanded on their knowledge of technology in a critical manner, but this relied heavily on my own consistent and situated understanding of the ethical approach accepted within our family. The inclusion of children in research and design processes has a long history, and their influence in the development of robotics and AI along with their own understanding of the technology should be encouraged [46]. This paper contributes to the discussion from a micro-ethics perspective [42], as autoethnography leads into a great number of smaller exchanges. Many of the interactions that emerged in our home (e.g. the exclusion of the younger child when the older is interacting with the drone) could have easily been missed or ignored in larger and more representative studies. While generalisation is not the aim, nor can it be achieved through this method, the conclusions offered are still of great relevance to the research community. Autoethnography offers a strong and important methodological contribution to the field, as the changes (from disruptive to positive) between different parts of the micro-StS ought to be considered in research, the design process, and definitely in the development of regulation for drones.

6 CONCLUSION

As drones become more prevalent in our society, younger children will have contact with them in one form or another. Studying child-drone interaction is a worthwhile endeavour, but it does bring a set of difficulties. Drones can be dangerous, and are robots with a set of characteristics that definitely make contact between them and younger children a potential hazard. Simultaneously, their capacity to capture attention and their novelty opens up for critical approaches. Now is the time to tackle these issues.

To understand the role of this technology in a domestic context, particularly in relationship to small children, I engaged in a year-long autoethnographic study with my family and my two children (aged 3 and 6). We progressively learned how to live with different robots at home, and absorbed attitudes towards these from each other. Autoethnography is a difficult method to apply, as it involves a deeply personal engagement both with the research but also with its participants. To aid in making sense of the emerging relationships, I introduce the combined use of a socio-technical systems (StS) approach and framework with autoethnography, representing this study as a set of different components and relationships which complement the existing methodology. The framing of the family as a micro-StS was helpful in supporting the analysis of the data and extracting design knowledge to be considered for the RtD of drone probes for this context, as well as developing and describing these tacit narratives to a reader. More work in making autoethnography a relevant method for RtD is needed, but in this paper, I present a set of narratives and design opportunities which can be made useful by other researchers in the field to support a more nuanced and

critical approach to child-drone interaction. They have, in many ways, already made a dramatic impact in my own understanding of this design space.

ACKNOWLEDGMENTS

Although they cannot yet author an article – this one was written in collaboration with my daughters. I thank them and the rest of my family wholeheartedly for consenting to this research and participating in it in such a generous way. Engaging confidently in autoethnography would be impossible without the gentle and caring guidance and support of my supervisor, Sara Ljungblad. The paper as is now published was significantly improved by the kind and considerate anonymous reviewers. Furthermore, I have had the irreplaceable help of a group of interdisciplinary advisers, reviewers, proofreaders, and friends: Joseph la Delfa, Mehmet Aydın Baytaş, Dominika Lisy, Sjoerd Hendriks, and Pauline Belford. This work was funded by the Wallenberg AI, Autonomous Systems and Software Program – Humanities and Society (WASP-HS) funded by the Marianne and Marcus Wallenberg Foundation and the Marcus and Amalia Wallenberg Foundation.

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Paper II

Conversations with Myself: Sketching Workshop Experiences in Design Epistemology

M.Gamboa

C&C'22: Creativity and Cognition, June 2022

https://doi.org/10.1145/3527927.3531450

Abstract

I was not born a designer – sometime this identity shift must have happened. I was unaware of it, and if asked, I would still not know how to define a "designer". Drawing and sketching are activities intrinsic to the design discipline, and are widely understood as tools for communication, documentation, or artefact-driven reasoning. But are they also essential to the understanding of design knowledge? Or a symptom of a designer's identity rather than a tool for "designerly ways of knowing"? During a week-long design workshop I dealt with difficulties making sense of a panoply of embodied design methods in the absence of a sketchbook. In this pictorial I describe my self-diagnosis as a sketch-bound designer, unable to digest abstract knowledge without holding a pen. I advocate for sketching as focusing, and a primary activity in design epistemology that needs no other than a first-person reason to be performed.

Conversations with Myself: Sketching Workshop Experiences in Design Epistemology

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ABSTRACT
I was not born a designer – sometime this identity shift must have happened. I was unaware of it, and if asked, I would still not know how to define a "designer". Drawing and sketching are activities intrinsic to the design discipline, and are widely understood as tools for communication, documentation, or artefact-driven reasoning. But are they also essential to the understanding of design knowledge? Or a symptom of a designer's identity rather than a tool for "designerly ways of knowing"? During a week-long design workshop I dealt with difficulties making sense of a panoply of embodied design methods in the absence of a sketchbook. In this pictorial I describe my self-diagnosis as a sketch-bound designer, unable to digest abstract knowledge without holding a pen. I advocate for sketching as focusing, and a primary activity in design epistemology that needs no other than a first-person reason to be performed.

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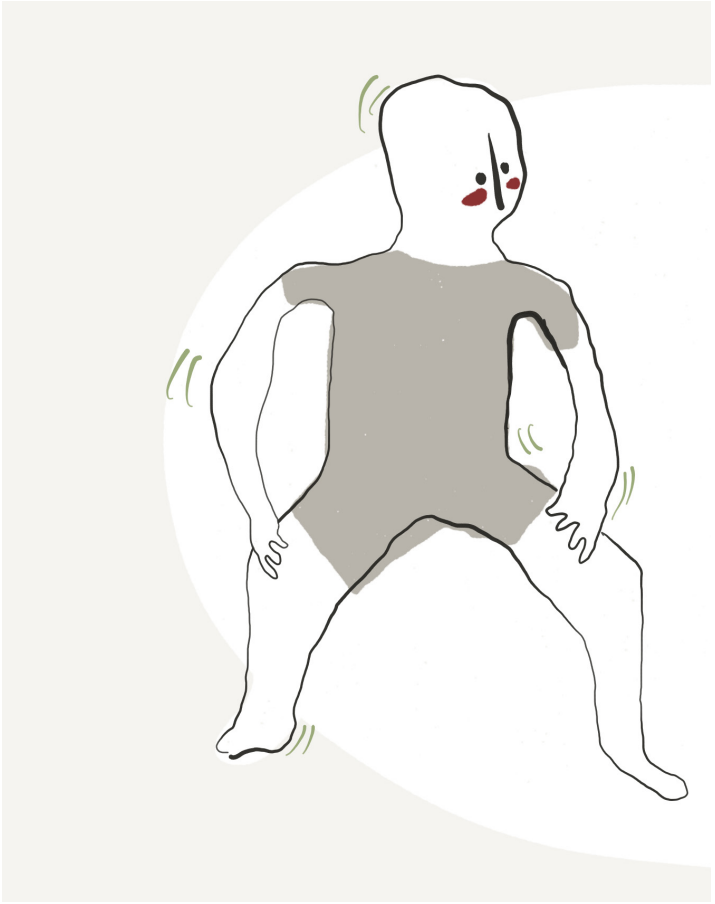
Authors Keywords
sketching; design epistemology; designerly ways of knowing; embodied interaction; design methods.

CSS Concepts
• Human-centered computing~Human computer interaction (HCI)

INTRODUCTION
In the autumn of 2021, I was kindly invited to participate in a week-long workshop with other academics centred on a specific approach to research and design: soma design. In this pictorial, I offer an autoethnographic account of this event [4]. After more than a year and a half isolated in pandemic-ridden world, I was finally granted the chance to gain new design knowledge together with others – in the same room! Packed in my bag were watercolours, a notebook, pens, some of my prototypes, and my primary platform for digital sketching: an iPad Pro. As a new PhD student, this was a golden chance to find a path for my research, and be guided through new perspectives within design epistemology.

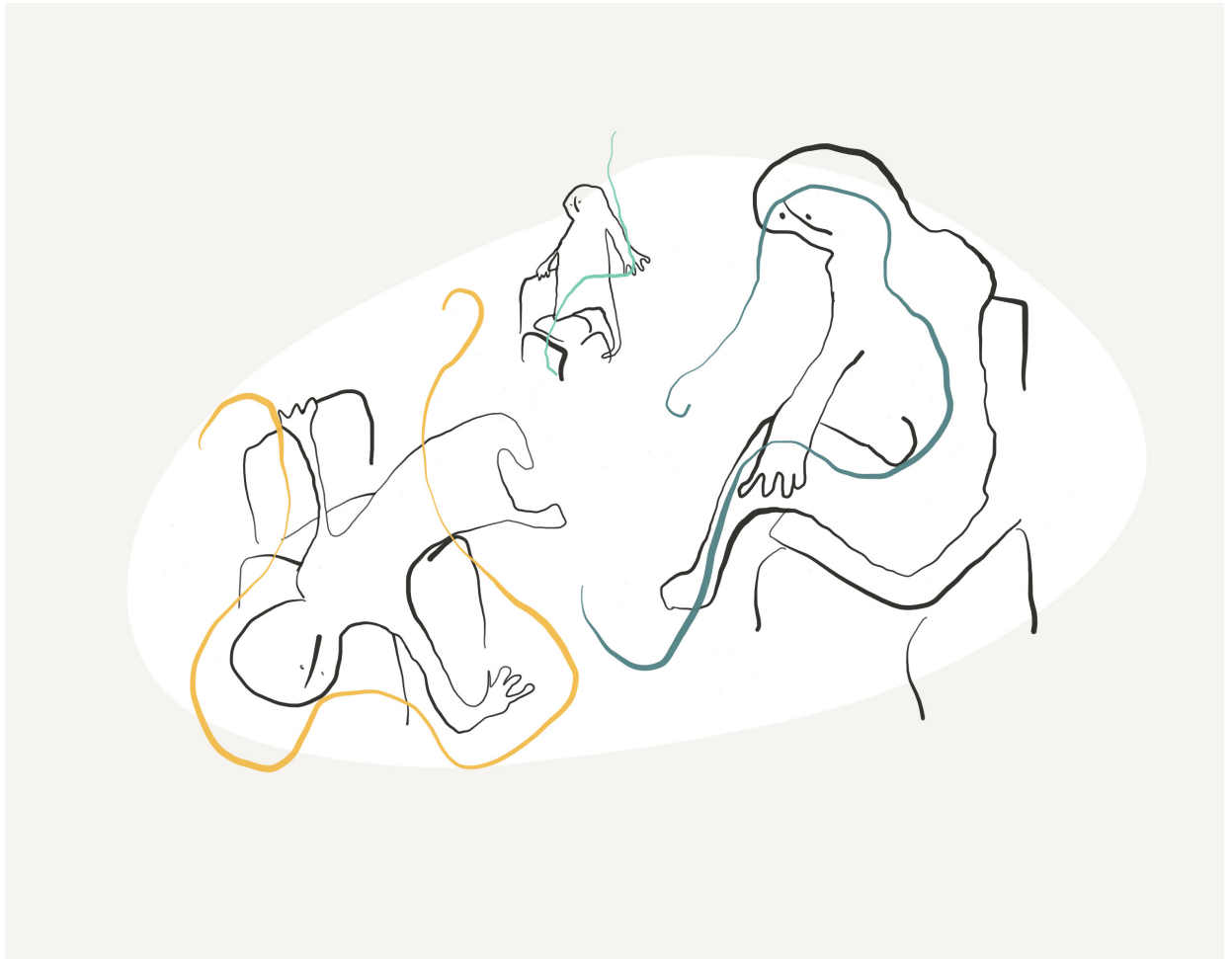
As the workshop developed, most of the activities involved an embodied engagement, using methods such as body maps, enactment, bodystorming [9]. We danced, touched, talked, punched, talked, talked, discussed, and



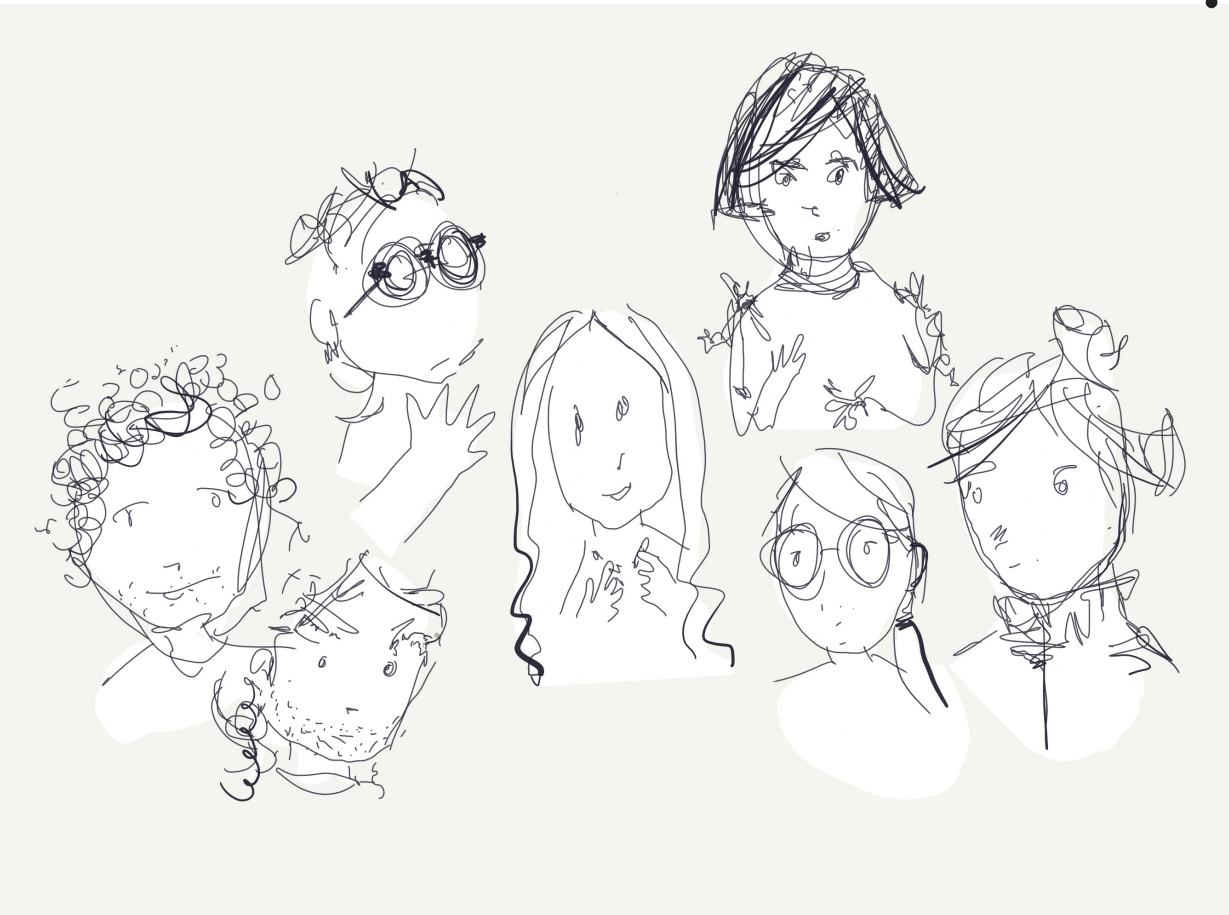
WE DANCED LIKE WE FIGHT

possibly talked some more. The majority of the sense-making happened through valuable group discussions where understanding of the design material and research approaches were thoroughly dissected.

However, by the third day, something was lacking. From my perspective, these methods were failing at reaching out new depths, and I had difficulties formulating or being able to make sense of all of these activities and discussions. To fully be emerged in the work, my mobile phone was disconnected and purposely avoided to a greater extent – many of these engagements actually made use of our entire body and therefore, taking photos was not a possibility. While we knew most workshops were being video-taped and the documentation would be available to every participant, I was haunted by the lack of first-person perspectives in these tapes (I also knew



SKETCHNOTE WITHOUT THE NOTES



I would most likely never watch them again). There was an overwhelming feeling I was missing something. While it could be expected that all the revelations would descend upon me after some days, I was afraid I would forget the details and intricacies of the discussions that had intrigued me. This, until I decided to start sketching.

In this pictorial, I offer an intimate text and a set of illustrations representing my struggles with "Ways of Seeing and Ways of Knowing, Ways of Saying and Ways of Showing". Each image is paired with a detailed description in alternate text, not immediately explicit to allow the reader to create their own interpretations before reading my own.

A DANCE WITH SKETCHING

For once, the Deweyian integral experience was failing me, I was distracted and dispersed [3], afraid of loss of both meaningfulness and memorability. It was a feeling in my body, a difficulty in expressing an anxiety. The event was engaging and very well organized. Why was I feeling so overwhelmed? I was prepared to sketch, to document this design workshop through the imagination of future artefacts and notions – I was expecting design *things* as an outcome. But the knowledge being manipulated was of a higher level – a level of introspection, not based on the practice of design of *things*, but on a deeply personal understanding of design epistemology. The workshop was not developing the familiar practice-based reflections in-action [15], rather making evident that I was struggling with "designerly ways of knowing" [2] from a researcher's perspective rather than a designer's. As Mäkelä et al. puts it: "Drawing, like dancing, is an exploratory, sense-making process where the observer, and the thing or idea observed, are inextricably bound together in a physical, material space/time relationship" [13], and that dance needed to be initiated.

Sketchnoting

Finally, I unpacked my digital sketching tools. I had decided to go back to making my usual effort of

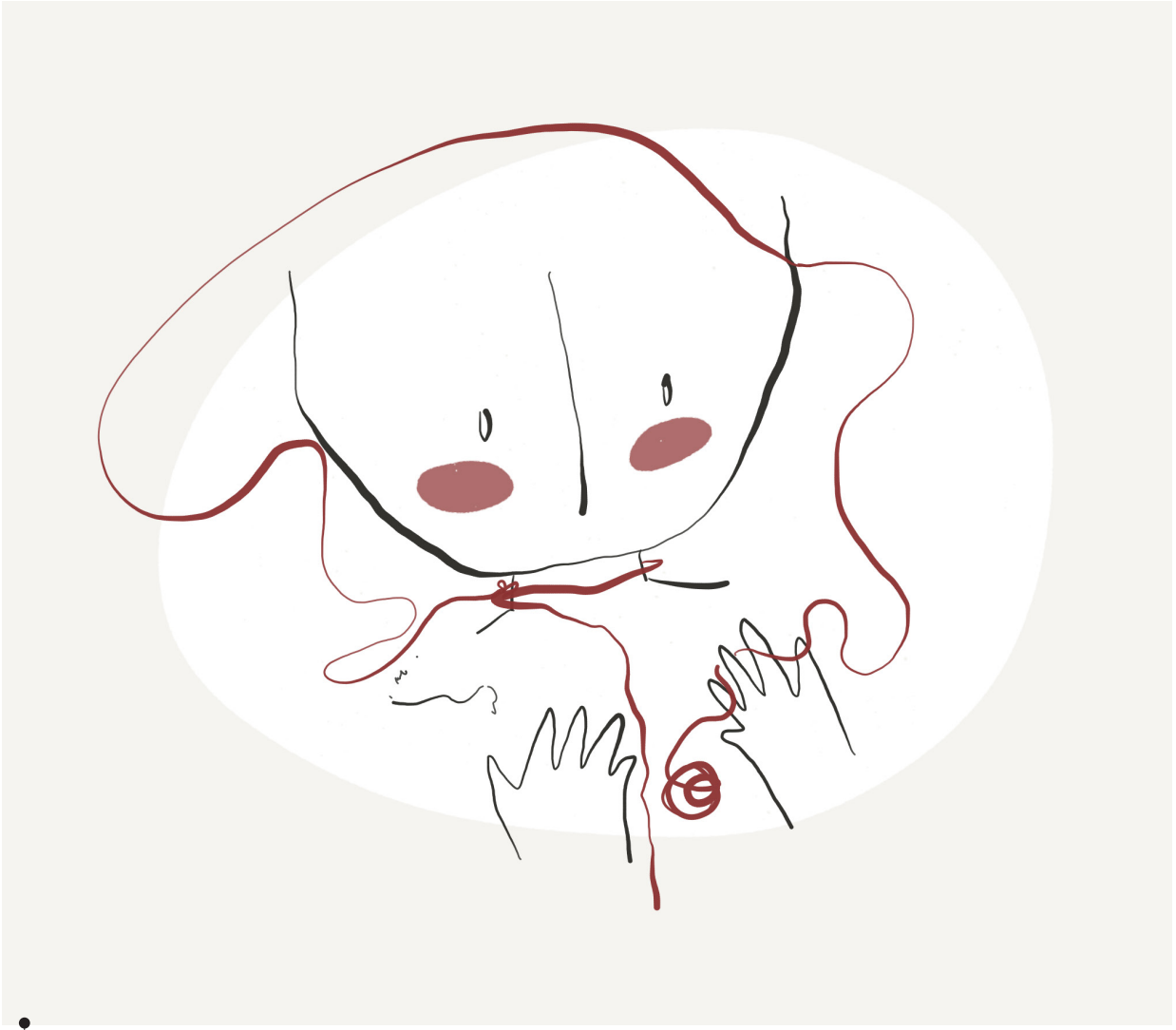
documenting discussions through sketchnoting [14]. I listened to others, and interpreted their words onto paper. I tried doodles, scribbles and diagrams. This is an ubiquitous practice in my work life. I used them for meetings, supervision, workshops – these documents are usually appreciated by the participants, and give me the chance to revisit the content of each of these experiences in a quick manner. But sketchnoting or live notes changed nothing in my struggle. While sketching has a variety of purposes and types to aid in thinking [8], I was unaware what I needed was sketching as an aid for knowing through feeling – not only live, but as a break.

Focusing

In a rare moment of alone time, I realised I had been neglecting my own personal space for reflection. I needed and craved sketching. The practice I had carried with me through years made it become a focusing activity:

> *Focusing starts with a concrete feeling in your body – in your stomach or your chest. It is a kind of inward bodily attention that a few people have naturally, but which most people don't yet know. Focusing is not being in touch with emotions or feelings and it isn't guessing or figuring things out in your head about yourself. It is a way of getting a body sense - I call it a felt sense – of how you are in a particular life situation. There is a way of staying with this feeling and coming back to it over and over again. With practice, there is actually a point at which time slows down. You may think you have stayed with this feeling for an eternity, when in fact only a few seconds on the clock have gone by. And there is also a point at which space changes. You were at first quite literally in your chair and now there is this new space. [5]*

The lack of sketching was growing as a knot inside of me: I felt it in my throat. What I needed was to engage in



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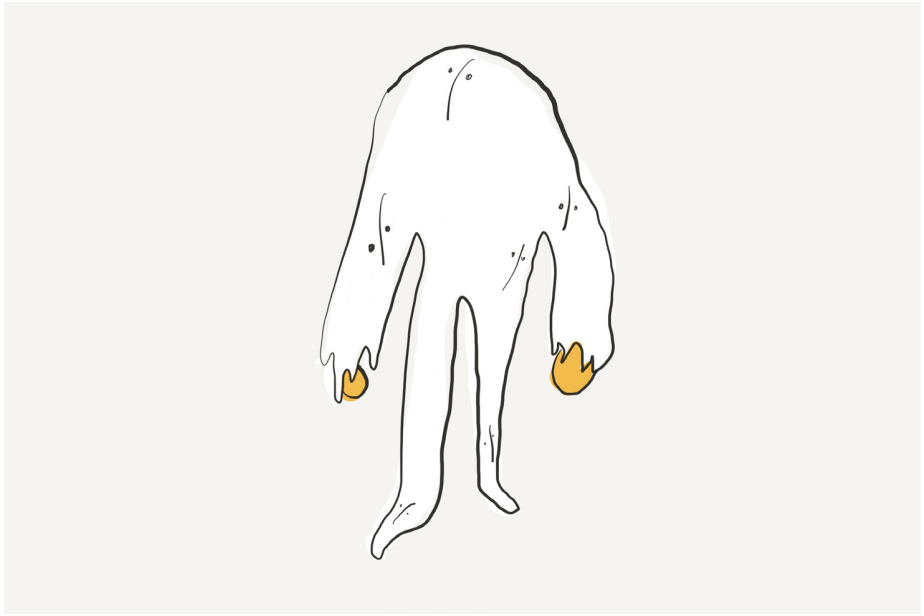


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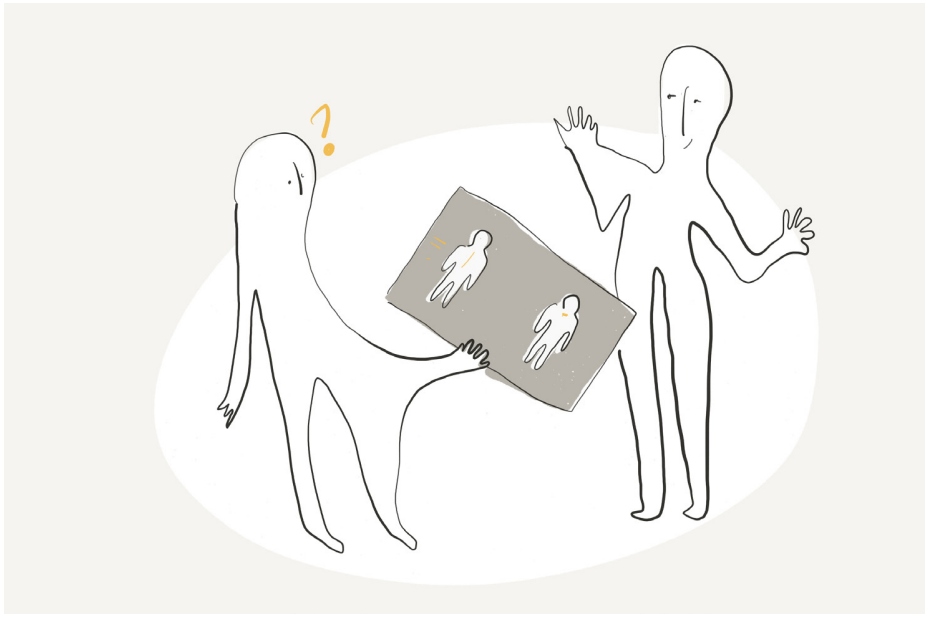
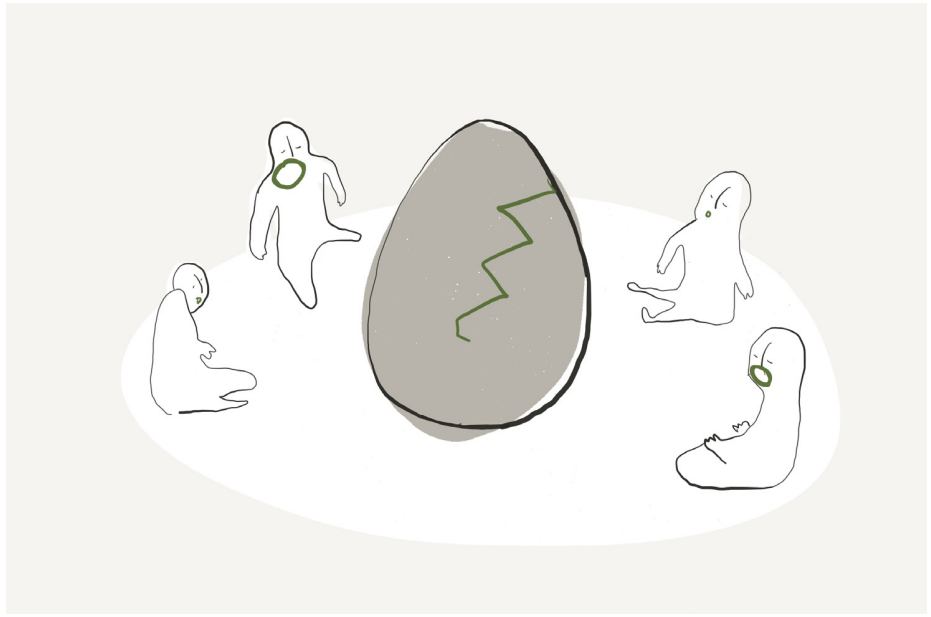


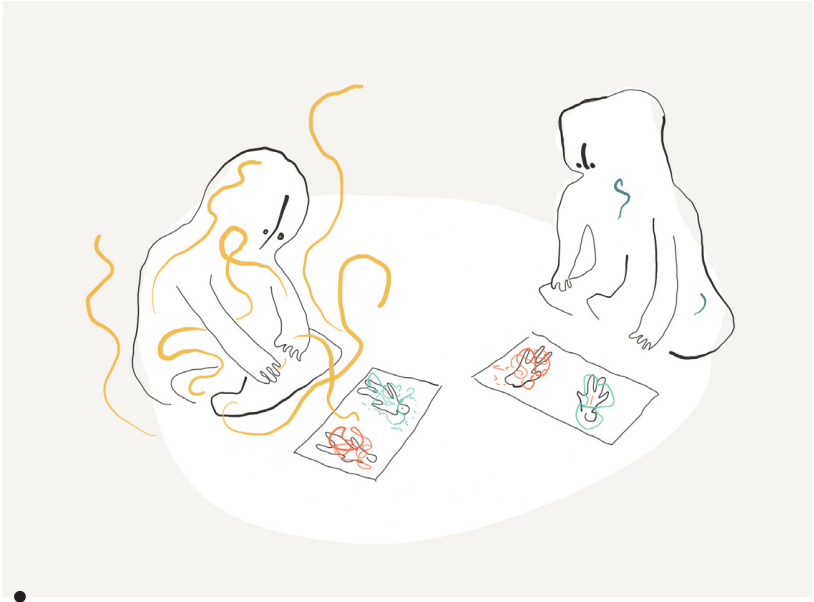


what Ings would call enstasis, “an induced interior state of self hood where one dwells in the creative potential of what is not yet formed” [10].

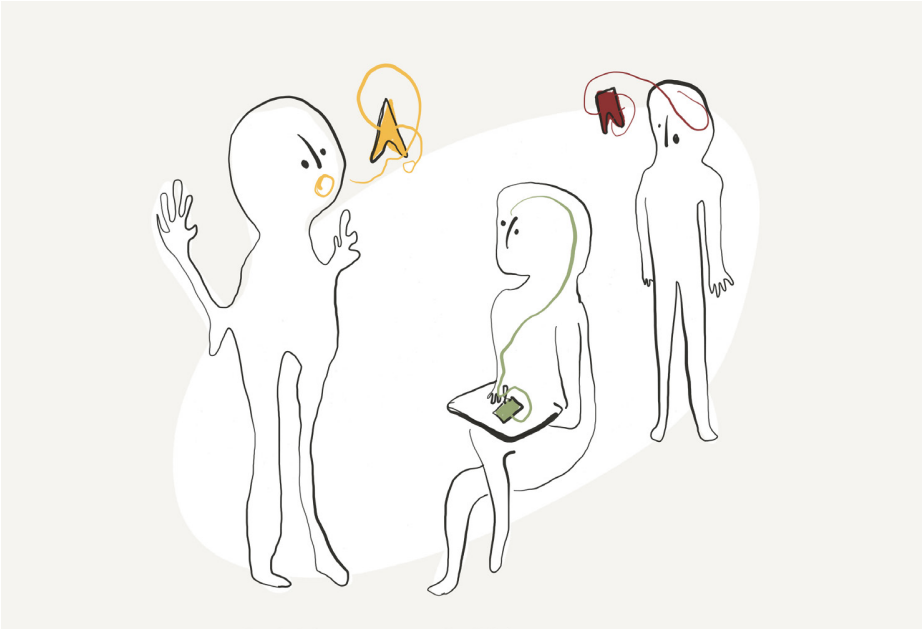
Over My Shoulder

Towards the end of the workshop, I started illustrating our final group discussions. While watching me sketch, other participants picked up interest in my interpretation of the knowledge, creating a chain reaction. I saw their body shifting over my shoulder to get a better view of my drawings. Did my sketching just influence thinking as if I was talking over the speaker? What would happen if everyone in the room would be sketching? Would the sketches infect one another, like a viral disease?

This effect reminded me of the body maps we had often used: a sketching method used to evaluate an experience by filling in two outlines of a human body before and after the experience [1]. The point is to elicit a reflection on the felt experience. Often, when filling my own, I would glance over to my neighbour participant, at times feeling inadequate in my own approach.



BODY MAPS



RESOLUTION

The sketches produced during this week varied in detail. By the end of the workshop, the conversations with myself were hardly expressed in text or words – even when writing this pictorial, I am uncertain of what has exactly changed through these experiences in design epistemology. But my understanding of design knowledge has somehow shifted. I know this, because the anxiety was not there anymore after the sketches came to be. The knot was still present, but defined, under control, frozen. I had found the new space, where time had slowed down.

I have learnt I am sketch-bound, and designerly activities will cause a type of embodied obstruction which can only be resolved by picking up the tools again. This was the time the work of Kirsh [11] became real to me: I was literally thinking with *things*, and I depended on that kinaesthetic engagement. Although this insight

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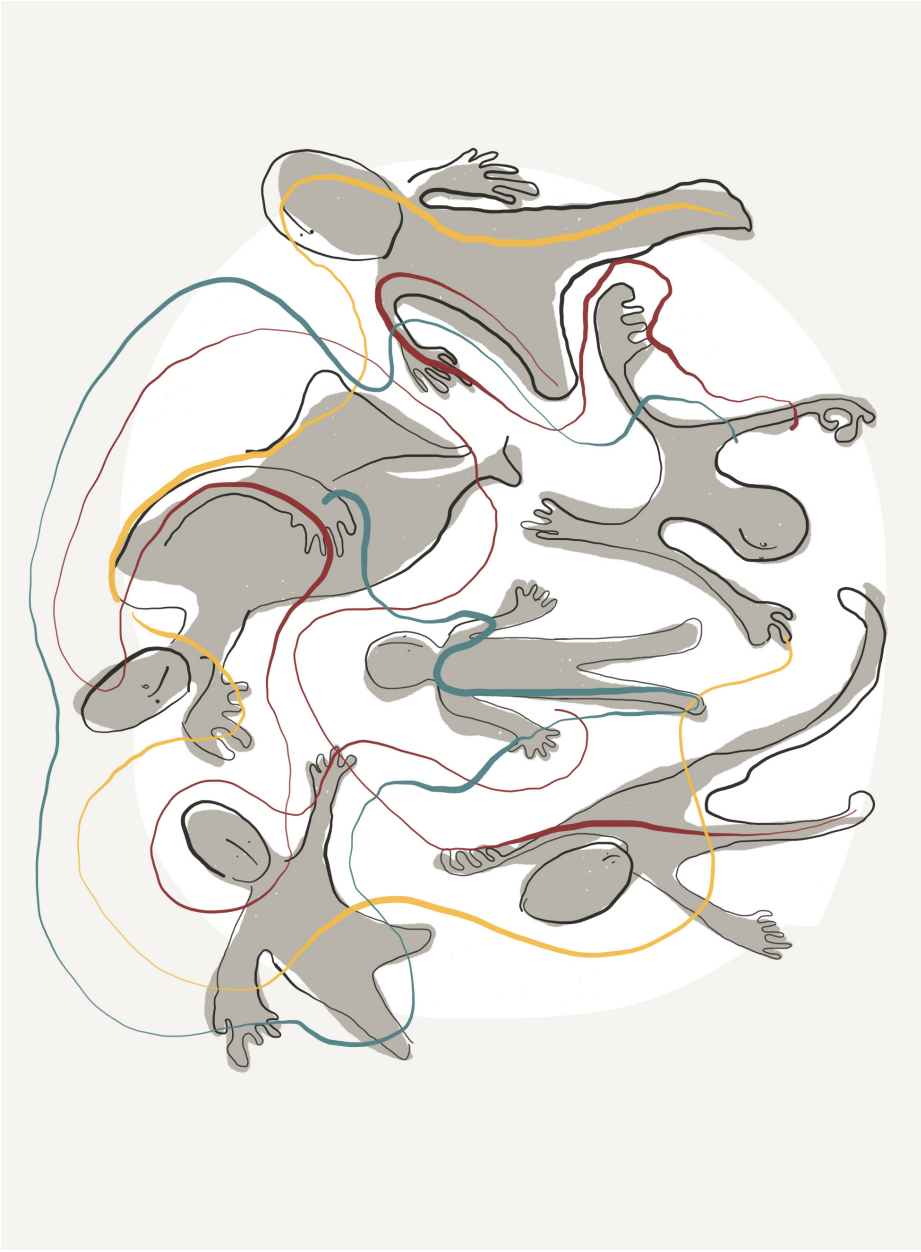
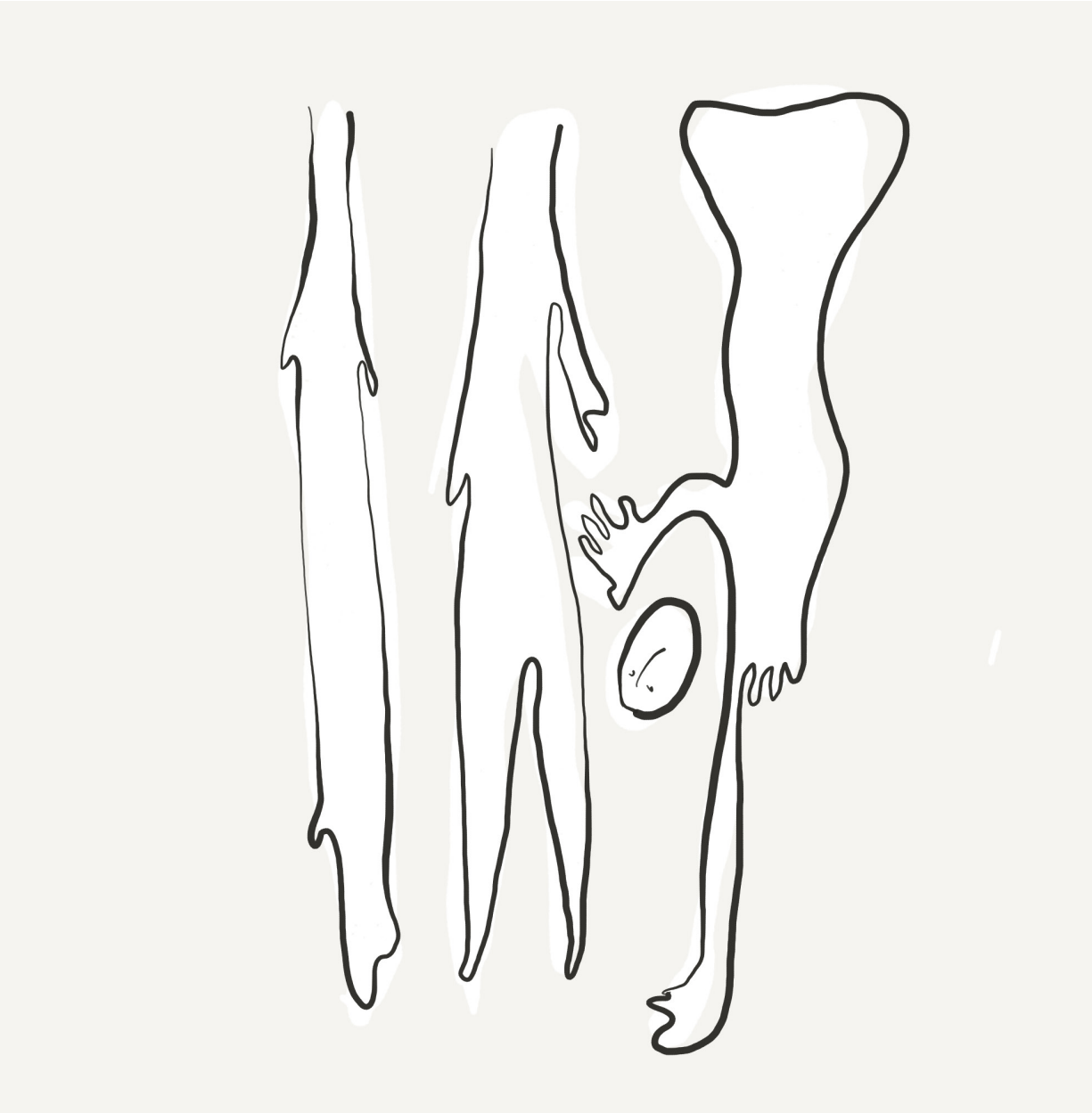




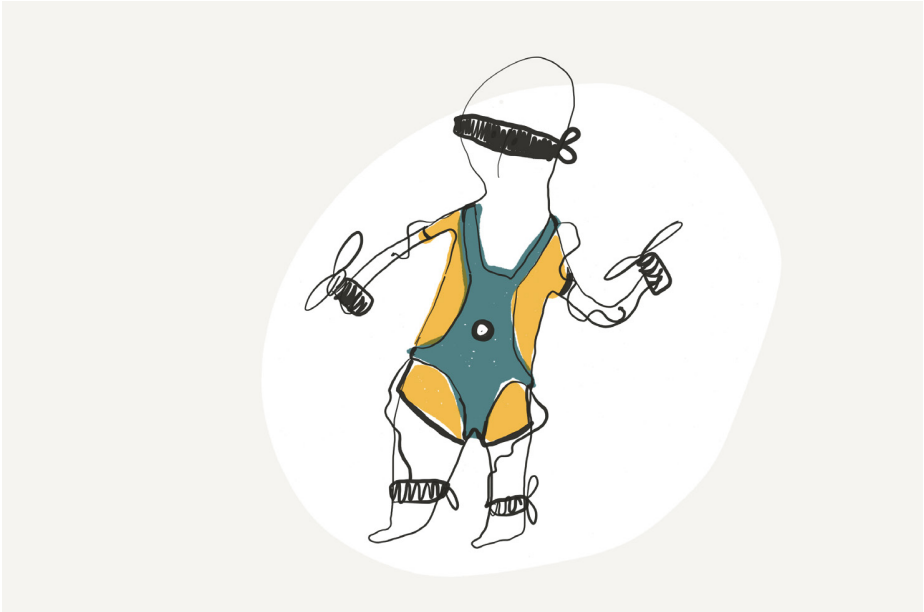
is still not untangled, I have now explored the shape of the entanglement through sketching. As posed by Goldschmidt, "[Experienced designers] produce the sketch in order to have a dialogue with it, and the sketch's backtalk is the reward they get for bringing it into being" [7]. But the dialogue here is not only a tool for reasoning [6], but also therapy, a necessity. The embodied relief I felt when finally sketching had not even been there at night, when I processed my thoughts before falling asleep. If anything, thinking alone made the obstruction worse.

One interesting detail is that the Deweyian experience was reconstructed, but it expressed itself as a conflict between expectations and outcomes: I had found the pauses that unified the experience: "[When we have *an* experience], There are pauses, places of rest, but they punctuate and define the quality of movement. They sum up what has been undergone and prevent its dissipation and idle evaporation." [3]. The experience of the workshop had started before the first day and ended after the last, and acknowledging this transition happened via the sketches, and not through words.

WORKSHOP FOR THE INDIVIDUAL

As the workshop closed, I absorbed how much I had learnt from others. But this knot of knowledge, which for me could only be resolved through sketching, had no space to exist. I needed my own time for drawing, and I had kept myself from it. I wonder at times, if each of the participants had a similar feeling but with whichever is their favourite activity for conversations with themselves. Each time I spoke, the knot grew, and had further and further threads hanging loose.

Each sketch helped identify one of these threads: but they are my threads to pick up again. Could others also formulate their threads in their own ways? How can we facilitate a pluralistic first-person process of documenting and sense-making? Koulidou et al. [12] for example, propose a method of Dialogical Sketching as an aid to investigate the sense of self in co-design.

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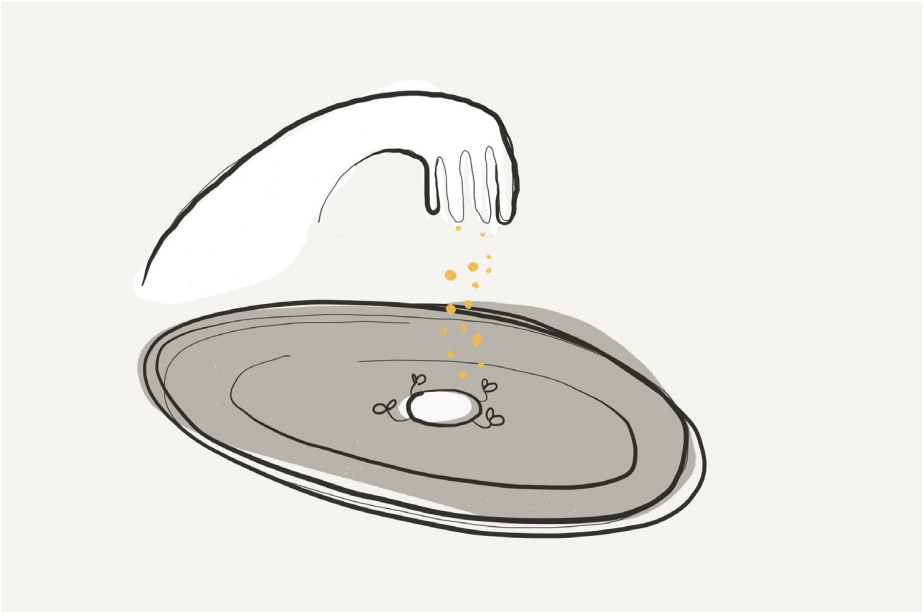

I advocate for including yourself when attending workshops, prioritising conversations through and with oneself. Take a look at the schedule, at the venue: is there a time and space for your own thoughts? Is there a pause, a place of rest? This requires the possibility to take the time and space to find one's own way of discovering the right communication venue. For me, it seems to be sketching. For others, perhaps other artistic and creative practices in dire need of acceptance in research [16]. And while sketching may not be the universal tool, it is one that affords reflection, and should be encouraged beyond a means for documentation or dialogue with others – but also as a conversation with the self.

Insight into own work

Inside my unpacked bag were a set of drones - one of my design materials. After almost a year of living with drones, my perception of what defines the technology was shaped by each small experience I had with them. This means, within myself, there was a design material baggage. I was eager to share this with others, this somewhat intimate first-person relationship with the design and reserch material.

During the first days, there were other participants who also had baggage, and I was curious about their relationship. When looking back now, I wish I had given even more space to engage with others through the design material – by actually doing, sketching, building together. Yurman exemplifies this beautifully with other researchers through the fluid medium of watercolour [18]. At the workshop, we talked and enacted dreams, but I left my own drones behind. In this process, I caught glimpses of the baggage in others as they demonstrated their designs to me: how they handled their designs, how they packed them, how they touched them, their body language when recounting stories. I imagined research and design paths for myself and my drones: a type of future enquiry [17], but a personal one.

I did not take out my sketching material during the workshop to develop any of these imagined worlds. Why not? Perhaps it felt like the wrong method at that time, because it was mine, and nobody else's. As a friend said, my workflow felt smothered, I struggled not because the material was hard to grasp or... weird as it often was referred to, but because I could not tackle it from my own perspective. The offering was like cold hard stone, it did not give way to my touch? Could I be failing at being talked into a research perspective just because the water was too cold?

CONCLUSION

During the first day of the workshop I was convinced I would be documenting my experience through sketching as a way of reporting back from it. I had planned on embedding myself deeply into the material of the workshop, letting it lead my process, being open to new perspectives. Maybe I should have still kept my most familiar design tool. But I thought there was no time, no opportunity, I was too engaged in the moment, to eager to participate. I did not sketch because I felt as if nothing could be communicated, as I could make no sense of the knowledge I was acquiring – but I had missed the point. I needed sketching as a conversation with myself. Perhaps I should consider which conversations I am supporting in workshops, with my students, with research participants. Not only between themselves, but with themselves. Am I affording space for it?

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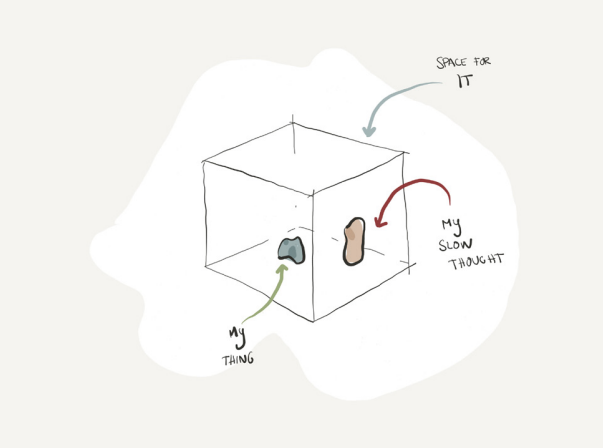
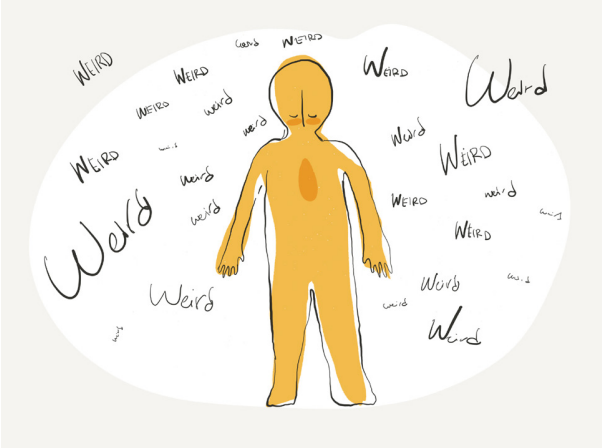
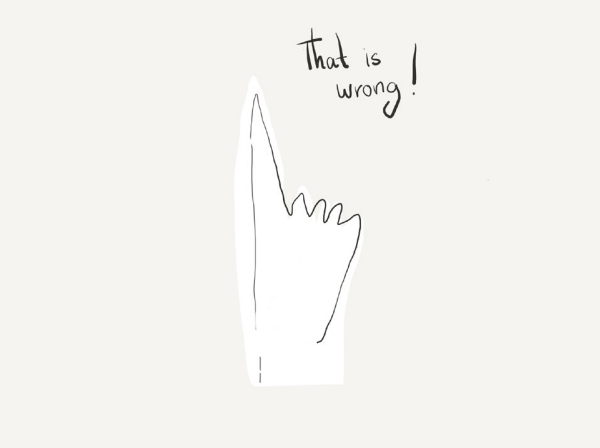
I thank the organisers of the soma design workshop and all the participants. I am grateful I was able to be involved in their design work. Most of all, I am grateful they gave me the freedom to express my discomfort in an open manner, and kindly supported my epistemological struggles. It was an incredible workshop! Thank you!







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Paper III

Wisp: Drones as Companions for Breathing

M.Gamboa, M.Aydın Baytaş, S.Hendriks, S.Ljungblad

TEI'23, February 2023

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Abstract

The spectrum of applications for social drones is broadening as they become an increasingly accessible technology. In order to expand on the immensely rich but poorly researched field of Human-Drone Interaction (HDI), we present a minimal, explorative, and antisolutionist design.We describe the first steps of a Research through Design (RtD) project focused on the concept-driven exploration of an unlikely pairing: drones and breathing. We present Wisp, a micro-drone probe controlled by a user's breath. Informed by experts on breathing, drawing inspiration from soma design, Wisp is described as platform for the development of defamiliarising views towards intimate somatic interactions between humans and drones. In this paper we describe the initial studies in a RtD development process, including expert interviews, prototyping, and informal evaluations. We contribute to the field of HDI with a design composite framework combining soma design and slow technology for exploratory somatic slow interactions between humans and drones.

Wisp: Drones as Companions for Breathing

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Figure 1: Wisp works by replicating the breathing motion of its user, introducing breathing exercises, and exhibiting behaviour when the exercises are complete.

ABSTRACT

The spectrum of applications for social drones is broadening as they become an increasingly accessible technology. In order to expand on the immensely rich but poorly researched field of Human-Drone Interaction (HDI), we present a minimal, explorative, and anti-solutionist design. We describe the first steps of a Research through Design (RtD) project focused on the concept-driven exploration of an unlikely pairing: drones and breathing. We present *Wisp*, a micro-drone probe controlled by a user's breath. Informed by experts on breathing, drawing inspiration from soma design, Wisp is described as platform for the development of defamiliarising views towards intimate somatic interactions between humans and drones. In this paper we describe the initial studies in a RtD development process, including expert interviews, prototyping, and informal evaluations. We contribute to the field of HDI with a design composite framework combining soma design and slow technology for exploratory somatic slow interactions between humans and drones.

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CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models**; **Interaction design**.

KEYWORDS

research through design, human-drone interaction, breathing, soma design, slow design, concept-driven design

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1 INTRODUCTION

Drones (also referred to with other denominations such as UAVs, quadcopters, flying robot interfaces) are gaining interest in society as they become more widely available commercially [37]. It is likely that their presence in social environments will become increasingly prevalent, which justifies the research interest in understanding and designing drones as social agents [12]. With our work, we seek to question what relationships and perceptions can be formed between humans and drones aiming to understand bodily and sensory experiences of drones. We aim at defamiliarising drones as currently perceived and experienced through science fiction, as military tools,

as a hobby, or other utilitarian applications in society. We propose an exploratory design framework supporting sense-making and discussions on relationships and slow bodily experiences with small intimate flying robots. Through our research, we investigate the possibilities for drones as a design material, and contribute with *an experience* [30] as support to sense-making and reflection. We seek to explore the design space of Human-Drone-Interaction (HDI) through a critical framing, as a provocative, defamiliarising, and non-utilitarian approach in order to support novel interpretations of what a social drone is.

In this paper, we present Wisp, a micro-drone developed in a Research through Design (RtD) and concept-driven [102] manner. It is designed as a probe to support exploratory sense-making between users and bystanders in a showroom context [36, 63]. Wisp can be described as an experimental system [26], where the unlikely pairing of drones and breathing as a control modality is established for exploratory reasons [34]. Breathing was chosen as a quintessential and embodied manner of control, exhibiting characteristics different from more granular and directed natural interfaces such as gestures, speech, eye-gaze, or other body movements. Breathing is the first vital sign of life outside the womb, and it supports us throughout our life. Unlike a heartbeat, breathing can either be unconscious or purposely controlled, and it is an essential part of many of our social interactions such as speaking, talking, or laughing. Breathing techniques are widespread and known to support many practices, from music to sports, meditation and even as a mode of interaction in assistive devices (e.g.: Sip and Puff interfaces). Due to previous work on non-habitual breathing and sensors [113] and a clear connection between slowness, reflection, and the body, our approach is informed and inspired by a combination of soma design [50, 92, 93, 97] and slow technology [43, 44, 81, 82]. Through this design probe and case study, we explore a platform for sense-making within human-drone interaction outside of an application context, opening up for free interpretation and inquiry of a personal interaction with drones – and essentially defamiliarising perceptions of drones [14]. Wisp is controlled by its user's breathing, captured through a sensor placed on their body. The project is presented in its initial stages of research, encompassing the first phases of the process including interviews with 3 breathing experts, first explorations with the technology, construction and sketching of a design probe, and a short evaluative study with 5 users in a relaxed environment, and gathered through unstructured interviews. We present the results of this first iteration and indicate future work and directions for this platform in the form of a design framework.

2 BACKGROUND AND THEORY

In this section, we present background on drones and their place in society. We also provide an overview of soma design and its relevance to HDI. This is followed other examples of RtD engagements, which lays the methodological foundations to the case study presented in the paper.

2.1 Perception of Drones, Applications, and Interaction Modalities

In this section, we describe drones investigated as a flourishing design material within HCI research. Drones are gradually becoming integrated into the fabric of society – they exist both as professional tools [69], and as a hobby [48, 108]. Social drones are described as interacting with people, inhabiting social space, or being physically close to people [12]. Research on drones has explored and proposed different types of applications, such as leading paths, delivering, and guiding in public and semi-public spaces (e.g. [7, 20, 22, 40, 57, 59, 60, 62, 76, 94, 105]). Furthermore, drones are being researched as strong agents in emergency situations (e.g. [2, 23, 35, 58, 73, 88–90]).

It is therefore vital to research what perceptions we construct on drones and their use. Komasová et al. [61] researched how in Czech society, users and non-users of drones perceive drones differently according to their familiarity with the technology, but shows that familiar users do not necessarily perceive the risks as any lower. Chang et al. [24] focuses on informing policy by researching perceptions about drones, privacy, and security. Ljungblad [68], informed by professional drone pilots, reflects on how it is necessary to put a strong emphasis on understanding safety in drone use, but also on the complicated relationship between pilots and bystanders. The great majority of the research dedicated to drones is centred on technical issues developing their capabilities for safe flight in different environments. In this paper however, we focus on the design aspects of human-drone interaction (HDI) as an expanding sub-field within interaction design and human-robot interaction [19, 37, 110, 117]. Previous design research has explored a number of different social applications for drones, but in the context of this paper, we focus on the notion of "companion drones" through an embodied and intimate interaction. These can be defined as drones that exist in close proximity to their users, and play roles of a more personal nature. Karjalainen et al. [54] identified some of these possible denominations such as "butler", "assistant", "toy", "pet", and others. Research has also suggested that drones could become useful for guidance for people with visual impairment, or used for leisure by people with cognitive and motoric disabilities [3, 8, 38, 39], which offers a very relevant set of difficulties to be surpassed in terms of control and perception of drones in the environment. Obaid et al. [79] also point out, for example, that children are an understudied user group. It is essential to consider that as drones embed themselves into the fabric of society, there will be more and more bystanders forced to enter in contact with them. These bystanders will most definitely include people from traditionally understudied fringes, such as those mentioned above.

There are relevant gaps in research, not only in modes of control and interaction, but also in understanding how drones are perceived. There are intricacies in the interactions between drone and human which are worth considering. Comparisons have been drawn to animal behaviour [21] and how the design of drones could be based on it. Kim et al. [59] note on how users have an inclination to appreciate teaching interactions to drones rather than expecting full autonomy. Wojciechowska et al. [118] present a study focused on the design aspects of the drones, reiterating some of the preferences for animal-like appearance but also the necessity

to design propeller guards. The panoply of possible modalities of interaction and applications reveal a design space which includes a wide variety of experiences of drones in a social environment and in deep engagement with the body. Interactions with drone can either be dependent on another device or on direct manipulation. While a great body of research uses headsets, controllers, or mobile phones (e.g. Pittman and LaViola [85] dedicate research to comparing a game controller to a head mounted display), there seems to be a prevalent interest in understanding more "natural interfaces". Embodied modalities span from using hand/foot gestures (e.g. [1, 27, 31, 67, 76, 77]), to body movements (e.g. [33, 65, 78]), and proxemics (e.g. [45, 53, 80, 119, 120]). Some remarkable exceptions can be found, where brain-control [109] and muscle and motion sensors [28] are used to control drones. Most notably for our work, La Delfa et al. [65] combine micro-drones with soma design and Tai Chi, creating close connections between users and drones [64–66] through coordinated gesture control. To the best of our knowledge, the combination of drones and breathing is unexplored and thus novel type of embodied and sensory based interaction. We frame the combination of breathing and drones as relevant in the two following subsections.

2.2 Soma Design and Breathing

Soma Design is a design programme [50] grounded in a phenomenological approach to research. It builds on the philosophy of somaesthetics [96, 98], which puts emphasis on the felt dimension and subjective understanding. Within soma design, designers and users alike are encouraged to develop their sense of aesthetic appreciation towards living better lives. Movements, feelings, and entangled connections between the soma [1] and the world are at the root of the research topic. This process requires training, being exposed to appreciation and imagination through the senses, and considers the pluralism of bodies [51]. When teaching soma design, the type of exercises vary from slow to fast, and rely on having particular experiences one may aim for [112]. Whenever reflecting upon somatic experiences, consciously breathing is a common grounding activity. Even before performing body maps [5], it is common to give some time to breathe through the experiences in the soma. Unsurprisingly, many of the design artefacts produced under soma design are connected to breathing (e.g. [6, 55, 91, 100, 111, 113]). There are many other examples of breathing awareness as a means of interaction with other interactive platforms [86], with widely varying intentions, from wellness (e.g. [25, 74, 83, 95, 101, 115]) to discomfort (e.g. [15, 75]), games (e.g. [84, 99, 104, 114]), and even as a function of robots (e.g. [107, 121]).

To create a novel experience of drone control, leading towards a negotiation between orchestration and misalignment [106], we combined a breathing sensor with a small drone to support a somatic play of lead and follow between the human and the drone. With our artefact we seek to create new appreciation for the design materials and the body through the robotic agent's mimicry of the breathing motions through the biosensor, in an orchestrated biosensor to actuator relationship [4]. We intend to approximate any body to a drone, discarding the need for a precise controller or other external devices. La Delfa et al. [65] recruits the same theoretical framing and intentions when designing Drone Chi – another design aimed at creating intimate connections between humans and drones through hand movements. In our project, we leap beyond gestures towards inclusiveness and defamiliarisation of movement thorough the use of breathing as a control mode. All living somas breathe, and hence anybody can be the pilot of our artefact. The universal accessibility of breathing was a primary motivation for this choice of interaction mode.

2.3 Design Research Approach

Nestled in the multifaceted characteristics of drones described above, we adopt a critical design stance in order to question underlying assumptions on human-drone interaction [9, 11, 32, 71, 72]. To leap beyond the most commonly seen interactions in research, we suggest an approach grounded on an anti-solutionist attitude [17], where the aim is not to solve problems, but to create space for reflection. Therefore, instead of tackling existing issues within HDI, we seek to explore the design space through concept-driven research [102]. This can also be described as the development of counterfactual artefacts, where the objective is to create designs which, albeit make little sense in our everyday world, can be used as tools for critical inquiry [116]. Our work is a Research through Design project [10, 16, 29, 41, 46, 63, 122, 123], which is becoming increasingly accepted and studied within human-robot interaction [49, 70]. For example, Superflux has developed drones as probes for discussions of surveillance [103].

In our particular case, however, we are seeking to discuss the qualities of a slow and intimate and somatic connection to the drone as a means to non-habitual new experiences. In that sense, we chose an approach similar to Kaye's study of intimate low bandwidth minimal devices as communication tools for long distance relationships [56]. Similarly, Gaver et al.'s Interaction Research Studio introduced small DIY devices for minimal interactions [42], and Hendriks et al. [47] enclose a familiar technology (a mobile phone) to diminish the types of interactions allowed in a phone conversation. While Wisp is not directly mediating a conversation between two humans, it is used as support for discussions through minimal interaction (direct mapping between breathing and flight) and sense-making. Through the minimal coupling of breathing mimicry and a drone's flight, participants are invited to engage in a conversation on drones on the somatic interactions departing from their own subjective first-person experience, freed from considerations to functionality or application.

3 CASE STUDY: WISP

In the following subsections we describe the process of development of Wisp [2] until its current status. Given the exploratory RtD approach, many of the steps have no immediate results, while others are clearly manifested into the design. We chose to report on both to properly represent the tacit but yet rich messiness of a RtD process. The nature of this project is exploratory – this intention was made the primary emphasis of the project from a very early stage. Grounded in RtD and slow technology, we tackled the design task by acknowledging each of the separate parts of the design

[1] Within somaesthetics, the division of body and mind is rejected, and instead our whole being is described as the unified soma.

[2] Wisp, as something frail, incomplete, a fragment, but also a will-o'-the-wisp.

Figure 2: Example of an unplanned interaction with the prototype, only possible through sharing a RtD studio with others.

process as malleable material, available for us to further define the designed artefact. Therefore, the framing of the design space changed throughout the timeline of the project. The initial prompt assumed was the combination of a hitherto not observed technological pairing: breathing sensors and micro-drones. This combination became the driving concept, to be tackled and observed from many perspectives. The reasoning behind this particular choice, is twofold:

(1) to reach out to a wide audience of users, including children and people with varying levels of accessibility needs; introducing drones to their lives in innovative, exploratory, playful, and critical ways;
(2) to explore how minimal human-computer interactions can create value in ground-laying terms and through basic somatic inputs such as breathing; and how critical design can support discussion, redefinition, and understanding of the intimate somatic interactions with drones;

3.1 Technological Explorations and Feasibility Studies

The feasibility studies started by identifying the appropriate technology to be explored. Whatever was picked, however, was assumed as a design material with its inherent constraints and possibilities.

Crazyflie: Crazyflie is a versatile and open source platform for build, programming, and expanding small drones [3]. For this project, and similarly to the work presented by Baytas et al. [13], we explored different positioning technologies paired with the crazyflie. We started by testing the development with a location independent combination of a flow deck and multi-range deck; while in parallel studying the possibility of using a motion capture (MoCap) system by Qualisys [4] combined with physical markers mounted on

[3]https://www.bitcraze.io
[4]https://www.qualisys.com/

Figure 3: A still image of the Crazyflie drone in a Qualisys MoCaP environment for the earlier tests. The drone can be seen in the foreground.

the drone, or an active marker deck (see Figure 3). Both of these systems have advantages and disadvantages which are relevant to the design of the interaction: while the the more static MoCap solution allowed us great precision and a controlled environment for interacting, the flow deck made it possible to use and test the drone anywhere without a lengthy and complicated technical set-up. We decided to move forward with the more flexible solution which gave us a drone-centred design space to work with. Wisp became therefore a robot which perceived its environment in a vague manner without being aware of the user or of its precise location in space.

Tello: Paralelly, we considered using an off-the-shelf DJI Tello drone which can be programmed. While this solution would have been possible, and meant we had a drone with a very stable flight to work with, the possibilities for designing a custom experience became limited. Light design and shell customisation are two important factors in our research process, opening up for more diverse options when developing different designs of a companion drone. Furthermore, the Tello drone is substantially bigger and noisier than the Crazyflie.

Breathing Sensor: In order to capture the breathing biosignal, we looked into different low-cost and easy to implement solutions which would still give us enough fidelity for the user to feel in control of the drone through their breath. We chose to use a BITalino [5], *"an affordable and open-source biosignals platform that allows anyone from students up to professional developers to create projects and applications using physiological sensors"* with a piezoelectric respiration sensor mounted on an elastic belt which is worn around the thorax or abdomen (see Figure 4). The priority was given to a non-intrusive solution rather than a sensor that would give a better signal precision. This sensor in particular measures the displacement variations in volume when inhaling and exhaling.

3.2 Expert Interviews

Semi-structured expert interviews were conducted with 3 specialists (see Table 1). The intention was to gather an understanding of how breathing is used in different practices, from meditation,

[5]https://bitalino.com/

Name	Location	Profession	Description
Birgit Penzenstadler	Sweden	Researcher and Teacher	Researches all angles of sustainability: social, individual, and environmental. Within individual sustainability, she practices as a yoga teacher. Embodied mindfulness and breath work is a primary tool for her practice.
Rita Pinhal	Portugal	Child Psychologist	Works as a child psychologist and holds workshops on breathing for children together with a partner.
Kelsey Cotton	Sweden	Professional Singer and Researcher	Works as a research assistant at a university, and is well versed in breathing exercises for singing. A very relevant part of her research is based on exploring sensors and breathing as a mode of interaction. She is a classically trained singer working with contemporary and experimental music.

Table 1: List of interviewed experts.

Figure 4: A detail of the Bitalino breathing band during set-up.

mindfulness, yoga, singing, or even psychotherapy. In these interviews, we aimed at finding a general understanding of breathing practices and tricks to lead into respiratory awareness. We wanted to be informed by specialists on how to not encourage harmful or unethical practices, and find inspiration for design in the narratives they tell of their own practice – their small tricks and reflections. The topics covered included questions on their practice and explored the role of breathing and breathing awareness, technology, accessibility, and ethics. Furthermore, we were particularly curious about considering children as practitioners, as they are taking their first steps in learning about their own body. The interviews were semi-structured by topic, but we allowed the experts to lead the conversation. However, we had a set of topics we were seeking to explore and kept as a guide to the interview. Below we offer a summarised analysis of the interviews sorted under each of these pre-defined topics.

3.2.1 Breathing as Introductory Practice. All three specialists mentioned how breathing is a practice useful as an introduction to embodied knowledge. Birgit in particular points out how *"by doing research on these topics I try to open and make the area of breathing practice more accessible to people who would not consider them otherwise because of certain pre-judgement of anything with the smell of a spiritual practice."* In her view, it is not easy to convince everyone that spirituality is not the absence of science. Therefore, she uses breathing as an introductory practice: *"Breathing practice gives us simple access to the fundamental basics of being a human – connected to survival. Makes us realise how easily we can decide the state of being that we want to stay in by adapting our breath to a certain pattern. (...) So breathing practice has the lowest barrier because you need to breathe anyway so you might as well use it. It is the easiest way to get acquainted with yourself, becoming more aware of things ongoing in your body and mind."* Rita, who works primarily with children, also agrees with viewing breathing as a clearly introductory practice. She notes that in her mindfulness practice *"breathing is fundamental. We can later add other activities, but the base is always breathing."*

3.2.2 Breathing and Embodiment. Connected to grounding and viewing breathing as the first activity for understanding, appreciating and getting to know one's own body, Kelsey mentions that in her own music practice she uses *'breathing as a means to support my sound on a basic level, but I also [use it] as a barometer to see how connected I am with my body. If something is not going quite right I can always trace it back to something not well in my body and it's really grounded in breathing."* Interestingly, she even brings up how she uses her own body and touch for internalising rhythm: *"I use the metronome and listen to the rhythm and then tap it on my body. So if I am trying to really internalise a rhythm, I will clap and use my feet and I will try to hit on my collarbone to really internalise it into the core of my body."* Rita also resonates on the same connection, while establishing a body-mind duality: *"Breathing is the base – as we usually say in our practice. Our body is in the present, it has nowhere to go. It is our mind that is the question, it is always either in the past or in the future. (...) What we consider is that breathing is our big anchor. Because while breathing, since the body has nowhere else to be than in the present, it is through our body that we can connect to earth."* The relationship she establishes between the body and the present, and being present in the moment rather than dispersing into the past or future is quite valuable for understanding and designing for somatic experiences.

3.2.3 Exploratory Nature of Breathing. While breathing is described as basic, an anchor, ground-laying, it also seems to create reactions. Birgit for example mentions how she got *"feedback where somebody said that [a breathing exercise] made me uncomfortable – yep it can be uncomfortable when you are comforted with what is going on with yourself. Not everyone will like it."* Kelsey has worked with people on different occasions, through workshops or sessions. She recounted

how difficult it is to manage the negative sides that arise from the breathing experiences: *"There is one thing in particular with one of the people I worked with; one of the people said that after one of the sessions [their voice] felt really raw, and I kept thinking back how could I have stopped it, well if I had stopped then I am interfering with their experience: 'no that is a bad thing to feel you do not want to feel that', and then that would interfere with the experience of how my body works, how do those sounds feel to make. I am on the fence [regarding] if I would go back, if I would have said 'don't do it like that, that will hurt you'. That assigns a value. I do not want people to hurt themselves but then it is also, how far to go with that: to interfere with what they are doing as their experience is unfolding."* Rita mentions conflict as an essential part of practice. She mentions they use a quite fragile ball to represent breathing and it can sometimes break, but that is no reason not to use it in the practice: *"Our intention is also to model and make use of all experiences, even the less positive ones, so that we can talk about conflict resolution. (...) We should not remove possible experiences – the children should be in contact with discomfort to get to know each other, talk about what they like and train their assertiveness. And when working in groups this is central."*

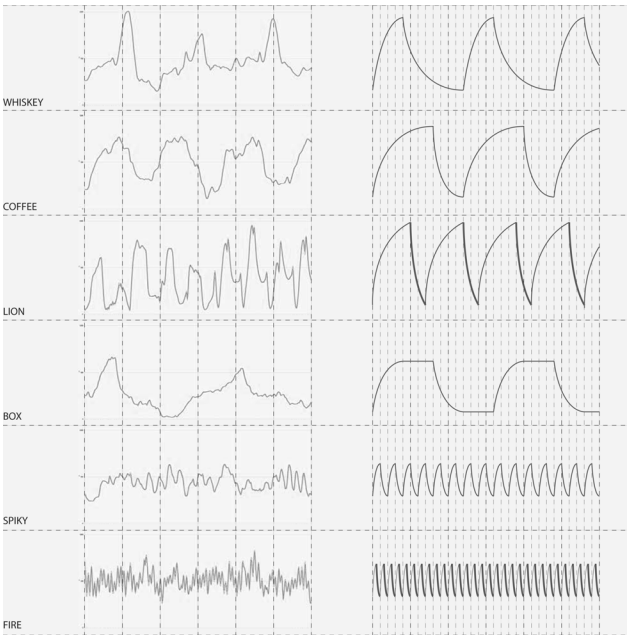


Figure 5: Breathing signals for different exercises as performed by Birgit (left), and her described "mental model" for each exercise (right). It is noteworthy that there is a disparity between her described mental models and the signal acquired.

3.2.4 On Context, Use of Tech and Sensors. The environment around breathing practice is quite important. Consideration to all the senses is a factor in the practice. An organic material sense seems to appeal to all the experts but Birgit in particular mentioned: *"I like working with scents, essential oils – to the best of my knowledge we have not done it yet through technology, but people are working on it. Scents are incredible for memories, we can't describe stuff but we smell it and they have a lot of power unconsciously."* This brings some conflicts towards using technology and sensors connected to the practice, clearly stating that they avoid it because it is so prevalent otherwise: *"While I work with technology I actually try to keep it out of some blocks of time because I feel it is so much everywhere – so it is hard to disconnect."* (Birgit) and *"No, not during class, we make sure not to use technology. (...) It is a personal choice, nowadays technologies are everywhere and we have to offer a space for the children to be in relationship with themselves and nothing else."* (Rita). Kelsey remarks on the environment of her practice, nothing how it strongly influences the connection to her body: *"The studio I have now is kinda depressing actually, it is underground, large, with a lot of random junk in there, so not a very welcoming space, the acoustics are strange, the sound is really dry, [the air] does not move well. So if I am not careful I have to push harder [with my singing], which makes me disconnect from my body, so I need to use my breath to ground again."* (Kelsey). All three experts, when prompted on the potential usefulness of technology to their practice, show some positivity and imagination, but always paired with reservations: *"I have my general reservations – if I see a good purpose I would [use technology], but otherwise I would rather lean away from it. (...)I would say that wherever it can support the practice — let us say if somebody has trouble focusing for example then maybe a visual cue would be supportive, and having that compared with guidance. Maybe if we record mine [signals] and try to match – maybe that is an example scenario that could be helpful, could be therapeutic or could be for learning."* (Birgit), *"With something like the [breathing sensor] belts, placement is really important, and also the accuracy [of its readings] – if they have a lot of drift. With the pillows, because they are great and interesting, [but] I would feel very uncomfortable asking someone to be inside that unit, I would not want anyone to feel encased in that."* (Kelsey) and *"It depends, we could use a breathing sensor but we*

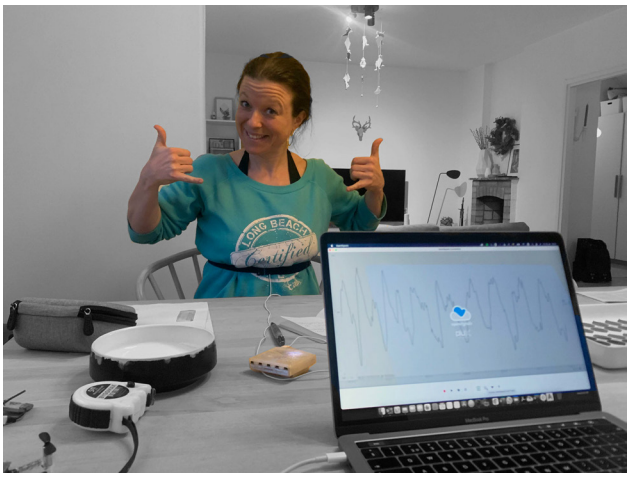


Figure 6: An image from the interview with Birgit, where we used the BITalino Breathing Sensor to gather sample signals for different breathing exercises. During this interview, Birgit also drew the mental models seen in Figure 5 for each of the exercises.

would have to explain what it is for. If it is necessary for the children to be very still it could also be a difficulty, until the closing exercises we can not expect them to be still." (Rita)

For example, the use of video seems to be quite prevalent but also described as disruptive at times: *"As much as I love it, I find videoing things quite disruptive. Whenever we are doing them [workshops] at work we video because I really like to go back and look, but [in the moment] it feels like you are being observed, but when I am practising, my music is on my computer, so I feel like I am staring into something. I am just seeing the little blue light and I am being watched and it breaks the experience of just sitting and practising, you become very performative in the moment where there is a camera there, that can hinder, disrupt."*(Kelsey)

3.2.5 On Other Interactive Modalities. While the use of digital technology, screens, and sensors posed some reticence, all three experts had examples and could relate to other modalities of interaction. Birgit pointed out: *"I like haptic things – anything that we can do with kinesthetics I find personally interesting – because I spend too much time interacting with a screen and I would rather interact with other materials. (...) In general as society we tend to interact with the same few devices a lot of the time, so there is little variety, so we if we can stimulate our senses in different ways it triggers new neural pathways which is always good. It just makes for different experiences. (...) Currently technology feels like it is being designed for permanent interaction and constant interruption whereas where I would like to use more experiences with a single focus."* Both Kelsey and Rita use tangible non-interactive artefacts such as straws, balls, papers, and others to support their practice. Kelsey, for example, uses a straw to sing through, aiding and mediating an adjustment to her breathing that is perhaps not grounded enough. Rita uses straws and small light pom-poms that the children can try to move together with their breath. To explain diaphragmatic breathing, she also uses a small paper boat or a stuffed animal. They instruct the child to lie down and pretend their belly is the sea, and to breathe slowly so the boat does not fall off. They use these techniques to mediate perceptions of the body to be able to reconnect after the exercise.

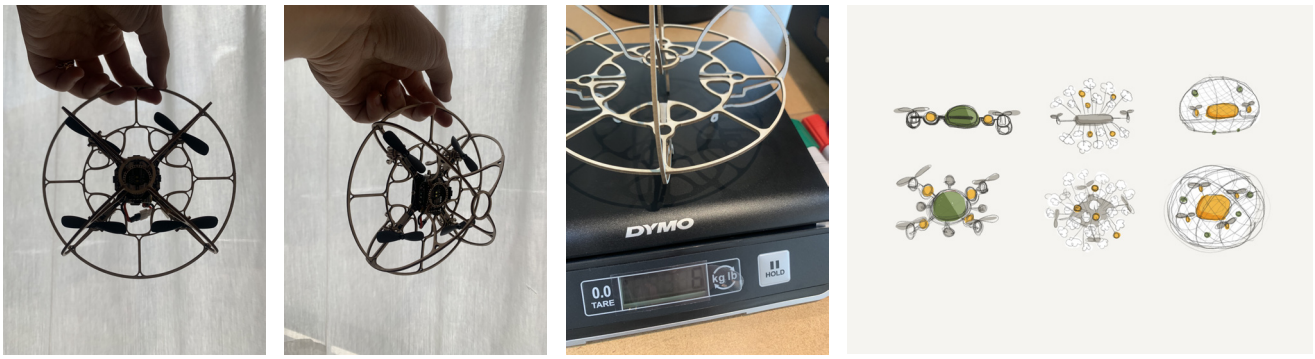
3.2.6 On Accessibility and Ethics. All three experts were asked if they had any particular considerations to accessibility and ethics in their practice. Birgit for example points out that the data she gathers now only refers to gender, age group, and occupation of the participants. Therefore she is not aware of any participants with disabilities, but thought it would be something important to consider. She is however aware of some previous conditions and counterindications such as Post-traumatic stress disorder (PTSD): *"I cannot allow people with severe PTSD to participate because if an emotional release is triggered I am not there to hold space for them and to be there for them. That is a limitation of doing this online. It depends on the level of facilitation."* Kelsey on the other hand reflects on ethical questions around discomfort and how to facilitate workshops. She points out that *"there are some big ethical questions in what kind of comfort and discomfort that you can reasonably ask from people participating. Touching their body is also sensitive, and how much control [and agency] they can have. If I was to use the [inflatable] pillows for example then I need to make sure that someone else is controlling on the screen, then I need someone to help me, which feels a little clumsy."* Rita points out the value of a diverse crowd: *"Well, I think the only thing I can say, being a difficulty too, is that diversity is the beauty of the practice. Inside a group you can respect the idiosyncrasies of each child, and that is as much of challenging as beautiful when you manage to combine it. For example, we had a child with autism, and at first it was difficult to support their integration, so that the parents could feel comfortable to leave the child with us. But in the end all went well, we did not experience many difficulties, as long as you respect the individual characteristics of each child, which applies to all. You shape the practice to each individual, and what they can do."* Approaches to breathing may be informed by a desire to conform to a certain aesthetic, which can impact the way one breathes. Kelsey mentions how the way we breathe is shaped by perceptions of the self: *"I am sure there is a point, I think it happens pre-puberty, when we get self conscious, then we want to look a certain way so we start breathing a certain way which contradicts so we maintain an aesthetic look. You want to look slimmer or slender, follow[ing] the body ideal and breathing into your belly disrupts that image."*

3.3 Design Implications from Expert Interviews

The expert interviews informed the design and intention of the developed prototype: it was clear to us that Wisp should allow for a free interpretation of breathing practice without necessarily leading into a particular experience (e.g. relaxation, mindfulness, activation, joy). The experts reported on many different facets of breathing, but confirmed that the argument of breathing as a grounding activity of high ambiguity. Therefore, we decided to keep the experience as ambiguous and open-ended in order to support a reflective personal somatic experience based on perceptions of the self. Therefore simplicity and single focus were kept as a value, while we aimed for the drone to allow for a close physical connection with the user's body.

3.4 Material Explorations and Casing Design

Designing a casing for the prototype was a priority: not only would it contribute to the identity of the prototype, but it would also help make the drone safer. It was also necessary to design a cage that would transport and dissipate the light of the LEDs to make them more easily perceived by the user. However, this task was quite difficult to achieve. First of all, the payload allowed on the small drone is minimal, and secondly, the shape of the shell contributes massively to the noise generated and stability of flight. Furthermore, as the choice was made to focus on a prototype with a self-contained positioning system, it was near impossible to design a cage that would not conflict with the multi-ranger. La Delfa et al. has successfully designed a shell for a drone using an external motion capture system through 3D printing, and those explorations were inspirational to our own approach [64]. We developed and struggled with a casing produced in cardboard, and later on in plastic. The intention was to support a clockwork aesthetic which would protect the propellers, both when colliding with obstacles but most importantly when approaching users. This shell took time to assemble, as it was composed of 12 separate parts. Every time the drone would collide with an object, some adjusting of the casing was necessary, but each of the 12 places if broken could be easily and cheaply replaced. The process of caring for the casing is an



(a) Front view of a working case in laser-cut paper.

(b) Side view of a working case, weighing 4 gram.

(c) One of the first versions of the casing, weighing 6 gram.

(d) Sketches for the protective casement. The materiality of these casements is an important part of the RtD project.

Figure 7: A collection of images of the first casing designed for Wisp, and some sketches of possible future developments.

intentional part of the design, where the slowness of assembly is considered part of the experience, affording for a pause in between breathing sessions.

After some reflection, the first prototype was instead developed as a "naked" drone. This design decision went hand-in-hand with the ambiguity desired by the experts in their interviews. We realised that postponing the design of the casing was a decision that opened for free interpretation of the material, and even potentially allow for a more open-ended quality to the prototype. It was our intention to allow the users to feel free to manipulate the drone and perceive it as an intentionally unfinished probe, rather than a more stabilised result. Further development of the casing was postponed to after the first tests, letting the research through design process dictate the direction to be followed.

3.5 The First Prototype

The first prototype for testing and exploration was done combining a Crazyflie micro-drone with a multi-ranger deck, a flow deck, and a LED-ring deck (Figure 9). This drone was then paired via bluetooth to a laptop. To sense signal from a user, a Bitalino respiration band was also connected to the same laptop through bluetooth. Python code was developed to do the following: (a) mimic the signal gathered by the breathing sensor in flight, directly mapping the sensor values to drone flight height and (b) command the drone to fly the pattern of four breathing exercises. These flight actions are illustrated in figure 8. The code mapping the sensor data to flight height could be adjusted for baseline height, which allowed for different postures and positions of the drone (e.g. the user could sit down and still have the drone flying at eye height, or the drone could fly at different heights in different sessions). The code developed for the exercises allowed for some flexibility in defining the time of each inhalation and exhalation cycle, as well as minimum and maximum height of flight. The LED ring supported a mapping of the light to the height values, progressing from purple to blue. However, this feature was not further developed as the drone had severe difficulties flying in a dark environment without the external motion capture system, and therefore the light was very difficult to perceive in broad daylight. A number of safety features were implemented: (a) the drone was designed to avoid all obstacles approaching from any side and (b) by placing the palm of a hand on top of the drone, it would emergency-land.

4 PILOT STUDY

In this section we describe the process of the pilot studies, the context, and participants, as well as the method of data gathering, analysis, and the results.

4.1 Context and Participants

The prototype was tested during a *Soma Design* course held for PhD students. In this course, the participants were allowed to interact with a DJI Tello drone, as well as with some high fidelity prototypes developed by La Delfa et al. [65]. Furthermore, they participated in daily activities engaging the soma in different ways, from singing to Feldenkrais. It is therefore important to consider that the participants in the pilot study were strongly influenced by a context of soma design, being also homogeneously interested in research, and capable of very articulate responses to the prototype. Although their research backgrounds are different, all the participants were able to contribute with their own understanding of the design space. The pilot tests were conducted over two days in a very relaxed environment, without filming to prevent the performative factor mentioned by the experts (Figure 10 shows an illustrated photograph of the context and Figure 9 the prototype used). There was no standard procedure, and the participants were allowed to engage with the prototype without any briefing. The only information given was on how to wear the respiration sensor, how the drone could be pushed away simply by being approached, and landed by placing a hand over it. This lack of briefing resulted in very different interactions, with more or less participants present at the same time. Participants decided how long they would interact, when to leave the room, and even how to position their bodies. The mode tested was the "Follow" mode, where the drone replicated in flight height the values captured by the respiration sensor.

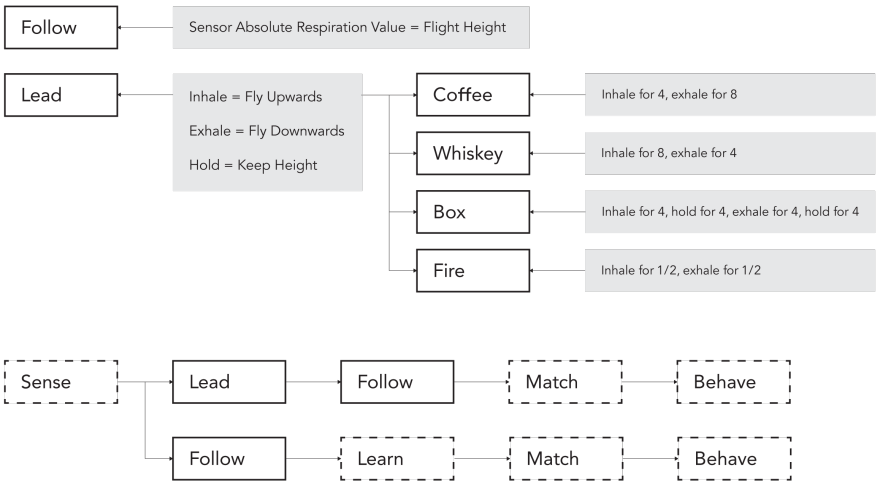


Figure 8: A diagram showing interaction modes. The dashed boxes are work in process, while the filled boxes are finished code included in the first prototype. At the time of pilot studying, the drone could follow the respiration curve acquired through the Bitalino, and lead breathing exercises.

4.2 Interview and Analysis Method

The interviews were conducted online with 5 PhD students, some weeks after the event. In line with the slow technology approach, we wanted to give the participants time to be able to reflect back on the experience rather than feeling pressured to immediately articulate any feelings. We probed into the memory created by interacting with the prototype, and what reasoning and thoughts were formulated in a slower manner. The unstructured retrospective interviews took about one hour each. The interviews were recorded and transcribed. After transcription, the data was analysed through inductive and reflexive thematic analysis [18] by two researchers, with the aim of extracting possible directions for further developments of Wisp - or other exploratory somatic interactions between humans and drones. First, we individually coded the interviews, and then together agreed affinities between the codes and named the themes. During this process, we recognised the MDA framework would be useful for sorting the themes. Presented by Hunicke et al. [52], the MDA framework is habitually used for the analysis and development of games, and structures artefacts into three dimensions: Mechanics, Dynamics, and Aesthetics. Mechanics are components of the artefact which can be designed, dynamics are the run-time behaviour of the mechanics and actions taken by the users when interacting with the artefact, and aesthetics are the emotional responses in the user [52]. Figure 11 shows the identified mechanics, dynamics, and aesthetics stemming from the interviews. More details and quotes from the interviews are outside the scope of this paper. Here, we present the abstracted knowledge that led to the development of the design framework presented in the discussion.

4.3 Results from the Pilot Study

Below, we present the results of the pilot study organised by the MDA framework.

4.3.1 Mechanics. The participants clearly identified mechanics in their interviews, which we sorted into categories. Some of these were manipulated individually in the design of the probe and of the study, while others (such as the self) are not easily designed for. These mechanics can be altered resulting in dramatically different experiences, but they are inequitably non exhaustive part of the showroom context. The categories mentioned by the participants were: **Time** (of the day, of the drone flight, of the waiting in queue, observing others, of the battery lifespan, of their turn, of the take-off and landing), **Environment** (light, space, colours, placement of the drone, sounds, informality, friendliness, intimacy, comfort), **Sensor** (tightness, sturdiness, ease of use, comfort), **Drone** (sound, lights, cuteness, safety, fidelity, battery, propellers, symmetry, closeness, predictability), **Self** (previous perceptions of drones, mood, relationships to own body, perspiration, breathing expertise, individual context), **Wrangler** (presence of, relationship with, interest in, technical know-how), and **Co-Experiencer** (who they are, how far they are, how many they are, what they know)

4.3.2 Dynamics. The participants mentioned many actions that they took in direct response to the mechanics above. They noted on the dynamics of the system and how it was designed such as the time to take off, the patterns of lights, and also the visual presentation of the prototype. We collected these impressions into the following categories:

Observing and Being Observed: Participants actively stayed in the room when others tried the prototype. Their observations were centred on the body and reactions of others, and on turn-taking. Only one of the participants left the room when someone else was interacting because *"wanted to give space to the other person."*

Planning and Performing: Stemming from the social context, and while observing, participants planned their own interactions

Figure 9: A photograph of the first prototype box showing two Crazyflie drones, a Bitalino respiration sensor, other accessories, and spare parts.

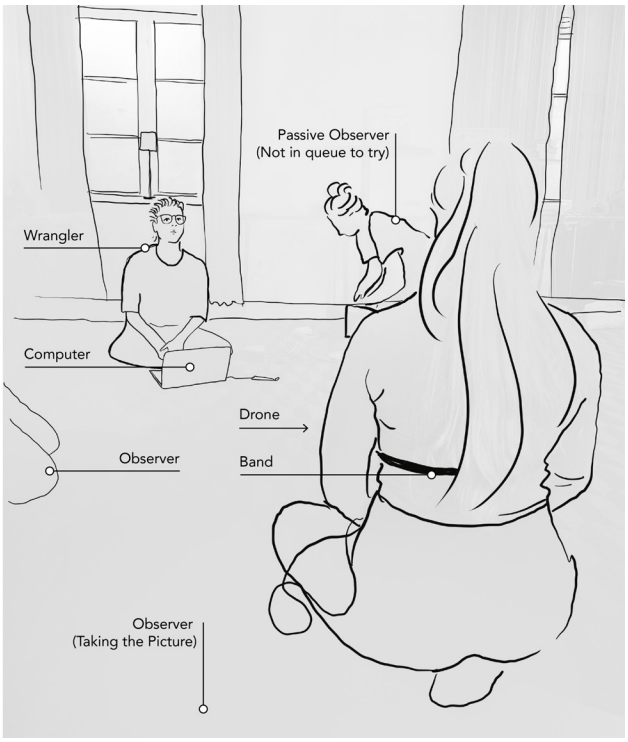


Figure 10: A sketched-over photograph of the testing environment, showing the wrangler, a participant, and a couple of observers. The drone is occluded behind the portrayed participant.

or reflected back on their experience. Their reasoning was centred on their own body, and even after trying the drone, they had further plans for other interactions. A participant, when about to try the drone for the second time reported: *"I had intent after having observed a few people, maybe one more person interacting with your drone. I wanted to try something in particular, I wanted to see how the drone would react to very erratic breathing."* A participant that only observed and did not get the chance to try it noted: *"So I wanted to get a feeling for it. What would the drone do for me? Would it go up? If I breathed in, would it go down if I breathed in? And then because someone else has had switched the direction... I was like, 'okay, I got to do it'. If he can do it, I can do it. So I wanted to also try and do that. And yeah, I also wanted to see if I took quick yoga breaths: What it will do, just like, bounce around? Yeah, just try different types of breathing."*

Reminders and Comparisons: The participants made independent comparisons and established metaphors and analogies between this experience and others. The unpredictability of wisp was often picked upon as a sign of agency: *"We've got something that fails, or something that does random stuff is a lot more organic and a lot more living natural than something that does precise, very controlled actions."* or *"Oh, it's a layer of like otherness. It's a social layer. Just like interacting with a cat or a wild animal that you don't really know how they're going to react. And they're not pre-programmed"*. A participant experienced the mirroring of the breath as powering: *"I'm pushing this up with my breath, because it's resting on air in a way. So I had this weird connection of: I have to push it up while breathing. So in a way, it felt like I was powering the lifting of the drone. Not just instructing it, like, you know, as information."* Most participants however felt that the relationship was unequal and that they had mostly control over the drone: *"But when I interacted with drone, it felt like I had the power, like I had the agency to control that particular technology. So it suddenly felt that I was the elephant and the drone was a small and tiny bird."*

Intimate Correspondence: The connections established were primarily between the active participant, the drone, the sensor, and the wrangler: *"Sitting there. I'm looking at you, I'm looking to the drone and this kind of back and forth, I was very focused in this moment on the floor with you and the drone."* Participants were intimately engaged with the experience: *"(...) even though it was a facilitated, it was still a one to one in my mind, socially, I had an interaction with a drone"*. Some of these were expressed through care: *"And after a while, I begin to form a certain amount of attachment, especially the things that I take care of. So it felt like I was taking care of the drone without and not allowing it to break."* These connections

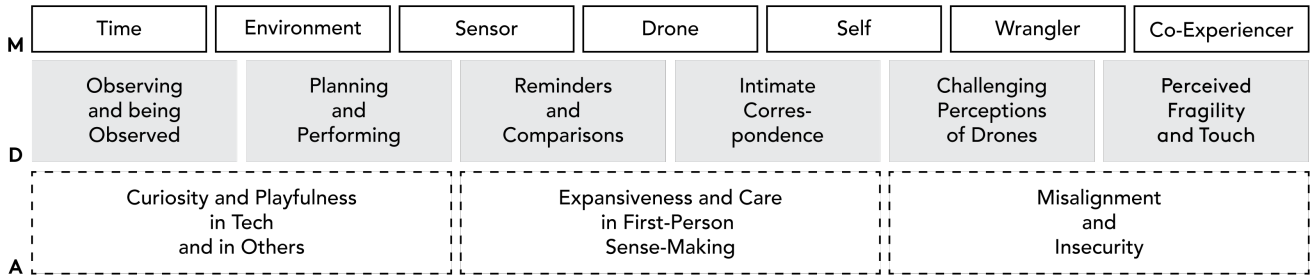


Figure 11: The Mechanics, Dynamics, and Aesthetics (MDA) extracted from the interviews through thematic analysis. Mechanics are components of the artefact which can be designed, dynamics are the run-time behaviour of the mechanics and actions taken by the users when interacting with the artefact, and aesthetics are the emotional responses in the user.

were clearly grounded in the breathing practice: *"I think I was so excited that it moves according to how I breathe Yeah, but I think the the breathing part was so memorable. Because I really also slow down the breathing, in interaction with the drone. I also wanted to feel that it, or that I can see the difference I feel around my ribcage. Because, of course, I felt the tension which I think was another feedback that I got other from the visual part (...) I'm also more aware of my ribcage actually expanding and contracting."*

Challenging Perceptions of Drones: All the participants previous perceptions of drones. While some related to war-like and entertainment media perceptions: *"The idea that I have for the drones was coming from Hollywood movies, you know. So yeah, I have this very particular notion of the drone, being manipulated from any other place in the earth and just pressing a button and then the drone will just throw a bomb, and that will be all. But I've never watched a movie where the drone could do anything else than that."* Others saw them as tools: *" I've never tried first person new drones.(...) I think drones have an interesting way of extending our capabilities that are worth exploring."* But engaging with Wisp and other small drones consistently challenged their perception: *"Probably because they seem a lot more relatable now that there's smaller. And now that's more easily available. And it's more hackable or Tinker-able"*, *"I would actually like a pet drone at some point, to just (...) follow me around (...) I'd never thought about a drone as anything other than a flying thing."*, *"They're not cold and calculating machines that don't break down, they're quite human in nature in the sense that they go wrong quite a lot."*

Perceived Fragility and Touch: The fragility of the drone was mentioned by all participants. Most also discussed touch as a dimension, either through the sensor: *"(...)this invisible bond or invisible connection. That almost seems like magic, but of course there is no physical touch to the drone, but then still, the touch of the band."* While the intention to touch the drone itself was present, participants expressed that they were uncertain where they could touch it: *"I wouldn't even know where to touch it or not to mess with any of the things because maybe there's a sensitive thing on the outside that has to be there. I think not knowing makes me also not wanting to actually touch it."* and *"I would have love to touch it. Like in the centre, just touch it, the wings. (...) So maybe the materials or the texture somehow also didn't allow me to touch you as much as I would like to."* The fragility was however seen as relevant: *"I think the fragility of the drone was an important characteristic, felt like I was responsible for the drone, as opposed to an sturdy endurance thing that I would I would be inclined to view as a tool."*

4.3.3 Aesthetics. Ultimately, the aesthetics created during the experience varied greatly between participants. However, we could group them into three categories of relationships which relate clearly to the showroom-like context of the experiment. The aesthetics have an entangled quality which represents a complicated relationship stemming from such a minimal interaction. The three categories are:

Curiosity and Playfulness in Tech and in Others: The social context of observation and being observed clearly led to an enhanced dynamic of planning and performing different daring interactions. The presence of the unlikely connection between drones and breathing, and the small presence of the micro-drone was conducive to feelings of playfulness and curiosity both in how others interacted: *"I was very curious. I was I wanted to know if the drone would respond in the same way that it responded to another person."* and in the technology itself: *"I did want to touch the drone, I had this curiosity of actually disarming the drone for seen what it has inside of its mechanical body."*

Expansiveness and Care in First-Person Sense-Making: The dimension of touch and intimacy contributed to challenged perceptions of drones which expanded the participant's own feelings towards drones. Often, care was mentioned as a part of the process, with great consideration towards the fragile technology but also the personal investment of the

Misalignment and Insecurity: Participants were insecure in their experience and checked often with the wrangler. They were afraid of doing something wrong. They felt a certain misalignment between the breathing motion and the motion of the drone, as well as some discomfort in the fitting of the sensor.

5 DISCUSSION

This project focuses on minimal, exploratory, and anti-solutionist interactions with drones. The overall aim of Wisp is to materialise a defamiliarising formulation of drones, by using breathing as an intimate control mode. It represents the first steps in a RtD process,

Soma Design Manifesto / Slow Technology Guidelines	Design Presence of Form (F)	Design Presence of Material (M)
We design for better lives - not for dying	...safely engaging with drones...	...and using organic materials.
We design to move the passions in others and ourselves	...through ritualistic setups...	...and touchable forms and textures.
We are movement, through and through.	...in social layers...	...flying in expansive space.
We design with ourselves - through empathy and compassion.	...in ambiguous exchanges...	...and occasional misalignments.
We design slowly.	...observing and caring for others...	...and incorporate fragility.
We cultivate our aesthetic appreciation.	...through intimate contact...	...and minimal interactions.
We disrupt the habitual & engage with the familiar.	...through expansive experiences...	...curious shapes.

Table 2: Composite framework for exploratory somatic slow interactions between humans and drones.

grounded in soma design, and approaching breathing as ground-laying interaction from several different perspectives. With the help of a small selection of breathing experts, participants, observers, bystanders, and researchers; we have learned how breathing is not only an essential function to survive, but an intricate and multifaceted somatic modality. The preliminary study conducted suggested that such minimal interactions, even if in the form of one cohesive experience rather than repeated experiences, can lead to reflection and sense-making. Exploring breathing as minimal interaction with drones, extends previous somatic engagements between humans and drones such as through brain-control [109], muscle and motion sensors [28] and bodily interaction through tai chi [64]. The reflections given by the participants combined with the insights from the experts suggests that further work is needed on designing the actual belt housing the sensor. The participants barely touched the drone itself, and therefore much of the somatic reflections came through the contact with the belt. Overall, intimate somatic connections with drones have ample space for development, approximating to interactions such as described by Kelsey when she taps the rhythm of the metronome on her body, or when Rita places small paper boats on the children's bellies.

We intend to make Wisp into an open probe, sturdily constructed for the showroom and with a simple enough set-up so that it can be exhibited anywhere and experienced by anyone, including commonly marginalised participants. The accessibility of the prototype is paramount, and one of the grounding reasons for choosing breathing as the interactive modality. Our work extends beyond first-person orchestration of biosignals [4], towards the inclusion of bystanders in an open or semi-open social environment. In the words of one of the participants as they watched another participant interact: *"Like watching someone else try it. (...) Did you make it go up or down? Like, intentionally? Was that the right way? And then we had this discussion of should it go up or down, depending on breathing, of course. And so I was kind of excited to see them, react to the experience, see them do this handshake thing, really kind of figure out how it how it should work. And then afterwards, hearing 'oh, but did you do that intentionally?'(...) I think that's always fun."*

The intricate dimensions of care [87] (in this case, for the drone, for the other participants, for the researcher) are tightly connected to somaesthetic appreciation, and were neglected at first in our theoretical grounding. But it became clear through the evaluation that the showroom is a place of care: for the drone, for our own perceptions, and for the engagement of others. This care was described in many ways; but it was particularly visible in the interactions between participants as mediated by the probe. For example, in a user-centred perspective, one may consider that optimising battery life and minimising queues to interact with the drone should be the main objective of future work. However, when listening closely, the choices made to either leave the room, observe the other, or even finish an interaction to allow time for someone else to try are respectful and ethical actions contradicting the individualistic experience usually supported by HDI. Another clear example comes in the form of the rituals necessary to set-up and maintain the drones. One may want to remove the repetitive tasks, but the care-taking of the drones in their current form is part of their characteristics.

5.1 Composite Framework

The preliminary design presented in this paper is an instantiation of the combination of two theoretical frameworks. We have found it particularly useful to contribute to the field of HCI through a re-arrangement of existing theory. In this manner, we propose a composite framework as a possible lens for the creation and evaluation of novel experiences. In order to guarantee our theoretical grounding was kept in the framing of the results from the RtD process and the pilot study, we devised a table as a method to create design statements for the next iteration of Wisp. Appended to this paper we offer the composite as an empty template that can be printed out by other designers.

To summarise our results so far and condense intentions for the next iteration of the prototype, we combine the directions for Wisp as a composite of the soma design manifesto [50] and the two slow technology guidelines [44], where "the design should give time for reflection through its slow form-presence (F) and invite us to reflect through its clear, distinct and simple material-expression (M)". The use of this composite requires some familiarity with the underlying theories. Table 2 shows this composite already filled in and as applied in our project: an analysis document for exploratory somatic slow interactions between humans and drones. We leave up to the TEI community to try this composite as a novel approach to be applied to other artefacts.

The composite framework is envisioned as a reference sheet during the design process, as a theoretical compass, and an anchor for the next design decisions. Similar to a design vision or mission statement, this composite can be used throughout the RtD process. The statements resulting from the framework are conversation-starters, and are helpful in the argumentation for the concepts surrounding a design project. For example in our formulation of Wisp into the framework, we have the following resulting statement: *We design to move the passion in others and ourselves through ritualistic setups and touchable forms and textures.* This statement is the frame to our next iteration, where Wisp will be introduced to users in a manner that engages the participant through allowing them to be the ones to perform the ritualistic care of the drone (e.g.: cleaning the propellers, replacing them, charging the batteries) and creating a more interesting touch surface of the drone to be felt when performing set-up.

5.2 Limitations

The study of Wisp is at very early stages, and the participants in the pilot rather few and lacking diversity. In that context, the results are preliminary, but should be seen instead as a provocation to discussion, and a thorough report of what an early stage artefact can look like. Our theoretical approach is particularly valuable here, but the design work is still lacking many steps. The artefact itself is not yet safe enough to be tested at a wider scale, and the interactions need further testing. In terms of analysis methodology, the use of the MDA framework has had an impact in the presentation of our results, where a more inductive approach would have been beneficial. We found that the use of MDA analysis tool was however particularly fruitful to surface these types of aesthetic qualities of interaction. We found this approach more operative from a design perspective: when planning for the next iteration, we have started by skewing some of the mechanics or planning for different dynamics than the ones we identified. We saw, for example, that the participants did not move their somas as extensively as expected. We plan therefore to manipulate the sensor (mechanic) so it can be calibrated through movement (dynamic – even if this calibration is not technically necessary), to give a more prevalent and comfortable role to the self rather than the wrangler.

6 CONCLUSIONS

As Human-Drone Interaction (HDI) grows academically and commercially, fringe approaches to the research of drones in society will multiply. In this paper, we have taken steps towards the expansion of the design space through the initial development of an exploratory probe (Wisp) supporting a defamiliarising minimal interaction between a human and a micro-drone through breathing. Supported by RtD, we focused on describing the conceptual grounding for such a minimal interaction, and reported on the various steps in the development of the probe. To inform our design approach, we conducted a set of interviews with breathing experts. These supported creating metaphors and guidance towards the design of an even simpler and ambiguous drone. Grounded on an informal pilot study, we combined the results in a composite framework of soma design and slow technology, advancing somatic slow interactions with drones. Drones are a promising design material, with engaging qualities which may result in deeply innovative aesthetics. The next steps for Wisp lie in shaping and questioning the imagination of what social drones may mean to us in the future, and making the probe accessible as a showroom piece.

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Paper IV

Conversational Composites: A Method for Tangible Illustration Layering

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Abstract

The conversational nature of sketches is a widespread topic of research. Understanding drawing as a cognitive activity is commonly accepted, and many of the most extensively used methods within Human-Computer Interaction recruit sketching as a technique for ideation, explanation, documentation, and conversation. To further develop the use of this illustration process as a tool of knowledge production, we suggest a novel sketching method. We present Conversational Composites: a flexible method grounded in the material and tangible qualities of sketching in different forms and media, creating physical and digital layers of conversation between participants. We present and reflect on the proposed method through an applied case of a conversation between a PhD student and her supervisor, and offer suggestions on how it may be adapted and appropriated by other researchers in the HCI community.

Conversational Composites:
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ABSTRACT
The conversational nature of sketches is a widespread topic of research. Understanding drawing as a cognitive activity is commonly accepted, and many of the most extensively used methods within Human-Computer Interaction recruit sketching as a technique for ideation, explanation, documentation, and conversation. To further develop the use of this illustration process as a tool of knowledge production, we suggest a novel sketching method. We present *Conversational Composites*: a flexible method grounded in the material and tangible qualities of sketching in different forms and media, creating physical and digital layers of conversation between participants. We present and reflect on the proposed method through an applied case of a conversation between a PhD student and her supervisor, and offer suggestions on how it may be adapted and appropriated by other researchers in the HCI community.

Authors Keywords
illustration; sketching; design methods; drones

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CSS Concepts
• Human-centered computing~Human computer interaction (HCI)

INTRODUCTION

The nature of drawing – in this case sketching and illustration – is dependent on the tangible characteristics of the material used. The media defines the possible vocabulary and determines the spectrum of afforded drawing conversations. For example, drawing on a white board with a pen is entirely different from drawing on paper with brush and ink. In this pictorial, we present a method developed to take advantage of the tangible facet of sketching to guide and support illustrated dialogues between participants in a project. Our method is reminiscent of *exquisite corpse*, a technique invented by surrealists, where a sequence of images is collectively constructed. In exquisite corpse, each participant draws a fragment of a composition, and proceeds to fold the piece of paper so the next participant can continue without being able to see the earlier fragments. In the same spirit, we developed a method to support conversations through transparency, where each participant is allowed to see and build upon earlier fragments by using layers of different drawing media.

While verbal and written communication is key in most human exchanges, we offer a method that complements group or pair discussions by scaffolding the expression of ideas, opportunities, and concerns in a format that requires interpretation and purposefully incorporates subjectivity rather than clarity. Sketching is already a widely used technique within Human-Computer Interaction for design work [2, 4].

Still, there is a need for design research methods to be open to alternative and accessible forms of interrogation and future enquiry, engaging in the complexity of design practice [18], and including personal experiences [23]. In this pictorial, we contribute to the HCI and TEI community through a method that relies heavily on the tangible facets of drawing as a generative and collaborative technique.

BACKGROUND

The 'sketch' can encompass many forms, domains and purposes, from a small piece of comedy or a piece of programming code, to a technical diagram, or, as we present in this conversation, an image using artistic media, specifically watercolour paint, which with its fluid nature allows free-form expression, and serendipitous discovery in examination of a particular piece of technology.

Sketching in Technological Enquiry

Sketching within computer science and specifically, within Human Computer Interaction provides a lo-fidelity, accessible (in terms of availability) and low cost method of designing both applications and tangible devices, surfaces and spaces, but also the interactions for them [14, 20]. It offers more than a few sentences of textual description, and can scaffold conversations by allowing individuals to realise their ideas in a multi-modal way. Sketching also allows us to work with real people, who may not have 'expert knowledge' but can use sketching to make visible the interactions from their imaginations, as part of an iterative, collaborative, design process [11].

Although primarily existing within the 2D space, paper sketches allow us glimpses of shapes and ergonomics, and complex, 3D objects can be realised, and in some form, prototyped via this method to future-proof initial designs by working through the complexities of a build in this visual, shareable space.

Sketching as Dialogue

Sketching is a rich form of visual communication, with roots as far back as preliterate civilisation. Whereas this kind of imagery can be realised for consumption alone – often a one way process – it also invites response, and these responses can take many forms, such as interrogation and iteration, continuation or reaction in other media. The 'loose' nature of sketching has often been explained as a metaphor for invitation [22], where an image remains unfinished or purposefully ambiguous.

FIGURE 1

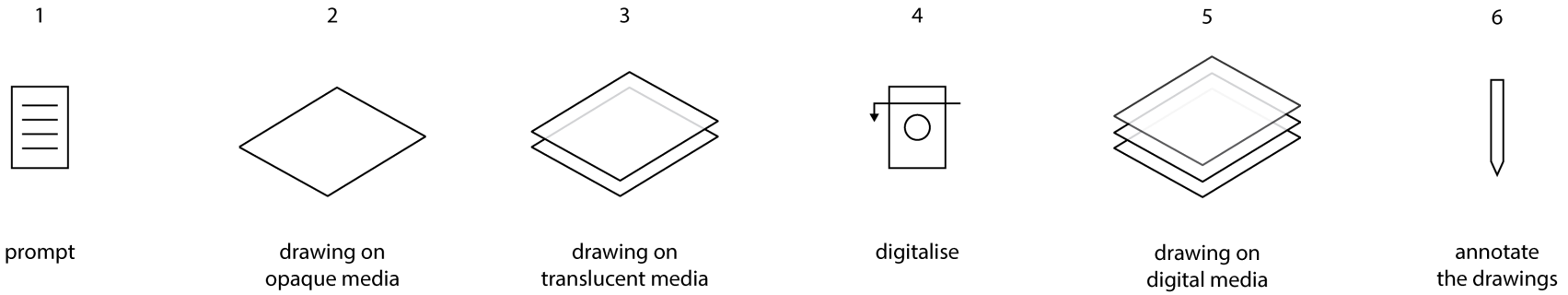

FIGURE 2

In this way, sketching can also become a form of dialogue [10], a conversation between researchers [15] or artists [19] and designers [8, 12]. These dialogues can create unexpected and inspiring imagery [g], and whilst grounded in a research question or starting point, can also inform us in varied and unexpected ways. As an example, Koulidou et al. [13] explore themes of displacement and lived experiences via a dialogical sketching process, a multi-layered approach where original drawings are used as a basis for deeper enquiry. Others have used sketching as a subjective process, a conversation within themselves [7] but equally also available to read and respond to as research articles.

Developing the Method

The method of conversation presented in this pictorial was created as a submission to a conference's workshop [22]. The workshop's aim included developing "visual dialogues resulting from the merging of drawings created by different people" [22]. This idea is grounded on Yurman's Drawing Conversations [21], a method where watercolour is used in its ambiguous capacity to create collaborative visual conversations between participants "drawing in partnership", creating evolutions between drawings. The method is about playful reinterpretation of artefacts leading to speculative designs. To fit the call for papers, we imagined a method which would allow us to find research interests in an unfamiliar conversation using drawing. Grounded on Fluid Speculations [21], we decided to create a sequence of layers that would allow us, through contrasting artistic characteristics, to build on each other's ideas, making it possible to identify each layer as a separate part, yet view them as a cumulative and meaningful sum. Hence, we decided we needed to depart from a specific prompt, and through drawing arrive at a renewed understanding of our research problem or artefact. Figure 2 shows the abstract steps of the method as envisioned.

This *Conversational Composites* method differs from existing uses of the exquisite corpse in HCI (e.g. as a direct homage, but utilising a different technique or domain such as textual enquiry [3], developing 3D interfaces [17]; or exploring interactions through video [5]) – we use it in the original sketch-based and visual form. We also apply the concept of layering rather than folding over and hiding the previous image, to allow for reinterpretation and ambiguity [9] rather than abstract novelty. In this way, the continued reinterpretation focuses on the chosen topic but allows for creativity, which in turn affords insight and ideation. In this way we also differ from Yurman's approach [21] as there is one starting point, rather than two objects of interest. The starting points also differ as unlike Yurman's method, our prompt is not necessarily object- or artefact-oriented. In our method, the process is centred in the building of narratives with less speculation and more emphasis on re-interpretation. Koulidou et al. [13] also makes use of building upon images, yet their work is not hidden, the conversations and image making are open and detailed in their execution, 'shrinking down' each image to draw around, rather than creating layers of the same size.

None of the techniques we use are new, but their blending creates a new design space, which could be applied to other topics, and even re-imagined in different materials. We build upon the work of others to view design and research issues through a new tangible lens – layered narrative prototyping.

CONVERSATIONAL COMPOSITES

Conversational composites relies on a sequential exchange of sketches and drawings between participants. Unlike other sketching methods, we rely on the tangible construction and possible deconstruction

of the composite, incorporating traceability of each participant's interpretations and perspectives. The notion of a composite material is central to the definition of our method: the produced artefacts should have distinct layers with their particular identity, while still contributing to the whole. The method can be applied from one participant to as many as the layers accommodate. As described in Figure 5, a prompt is a necessary starting point for a conversational composite. We suggest as potential prompts:

- **Research questions**
- **Requirements**
- **Stories**
- **Photos of events**
- **User quotes**
- **Diary entries**
- **Design artefacts**
- **Design guidelines**
- **Manifestos**

After picking an appropriate prompt for conversation, the layers of the composite must be defined. This method can be applied from one participant to as many as the layers accommodate. For each layer it is important to rely on the tangible and material characteristics of the chosen media and technique. For example, when using translucent paper, watercolour is likely not a suitable technique. We suggest the following sequence of layers as represented in Figure 4:

(1) opaque media with fluid technique

(2) translucent media with line drawing

(3) digital media with pen on screen

FIGURE 3

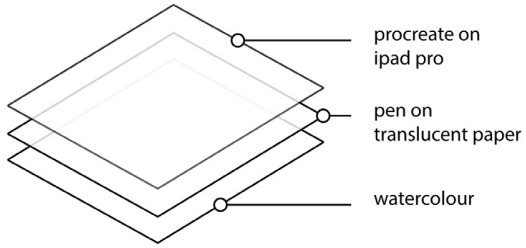

FIGURE 4

The method relies on each layer being created, and exchanged with the next participant. Each step should thus build on the previous content, and take advantage of the media and technique of the current layer. Lastly, the participants should annotate each of the layers they were responsible for, and grounded in their reflections, discuss new insights to feed into the starting prompts.

We suggest that the participants read each other's annotations, and thereafter discuss and describe the composite as a whole, for example by noticing what changes between layers, what parts of each image were built upon, redrawn, ignored, or left untouched. The method also gives the opportunity to dissect the composite by considering each layer on its own, and even reshuffling the order of the layers in search for new meanings.

We imagine *conversational composites* as a method that supports interdisciplinary collaboration, aiding in flattening hierarchies, and allowing for design and research discussions to take place in alternative forms to trigger novel and deepened understanding of the research. The ambiguity afforded, and the equal balance in the influence of each participant, makes for a rich conversation which can be generative at levels beyond speech or text. The last step of this method guarantees the composite is analysed and discussed, being re-interpreted in a conversation. The composite can then be seen as whole, and an analysis of which of the elements are visible through the layers, and which are allowed to fade is an important part of the process.

Applied Method

Below, we present a description of the method as applied by two of the authors: a PhD student (Mafalda) and her Supervisor (Sara). In our case, we used as prompts a set of micro-stories gathered through an online questionnaire (note the blue pieces of paper on Figure 1). Our research interest lies with drones, and we recruited respondents through an online social media group. The group is dedicated to hobby drone piloting. The questionnaire was of a very simple nature, prompting them to report on any accident, or special incident, they may have experienced with their drones, without providing any particular limits on the length of the text. We then used their narratives as the starting point for a conversation in drawings between us: two researchers working in the same Research through Design project on Social Drones. Our process was as follows: we read all the stories and picked three each. Then, we interpreted the chosen stories in watercolour (A1-F1). The choice of watercolour as the starting layer was inspired by Yurman [21], but also because the ambiguous quality of the liquid was a desirable characteristic to start a conversation. After this, we exchanged drawings and built on the watercolour with a layer of transparent paper and black pen (A2-F2). We then scanned the combination of watercolour and pen. Finally, the original painter had a chance to add a digital layer to the composite using an iPad pro and Procreate (A3-F3). Finally, we annotated each of the drawings, and discussed new insights on our research goals. Throughout this process, we exchanged no words, but had expectations on what the other would draw. In the following pages, we show each of the 6 prompts, drawings, and annotations generated.

In our application of the method we found that:

• We intentionally left space for each other in the drawing. For example, an empty hand was intended to be filled.

• Drawings are ambiguous. Misinterpretation was easily pinpointed in the discussions, but affected the next drawing in the process. For example, one drawing was accidentally turned upside down in the second layer, which was reversed in the third layer. Since the initial text story was shared, the interpretation still made sense.

• Each media afforded different types of representation in every layer: watercolour would set the overall scenery, and pen and digital sketching would be used for details.

• The layering allowed us to bring back elements and intentions from earlier drawings as perspectives of time, events, background, and foreground shifted.

• It was a fun, playful, and relaxing way to engage with research data.

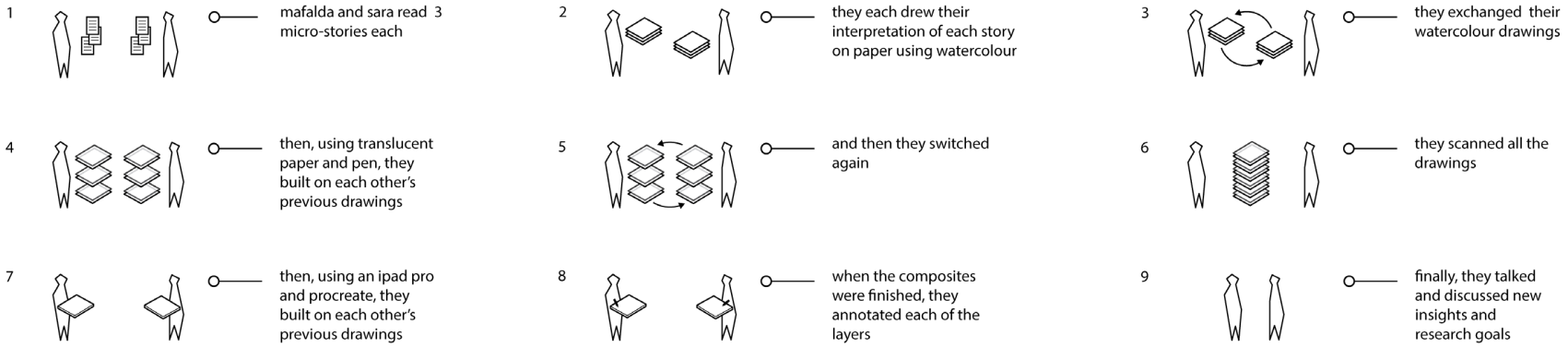

FIGURE 5

"It flew away. I used the app litchi and had created a route it would follow, but it never came back. It turned out that I did not think that the stated height is in relation to the starting point and when the ground rose, it came closer and closer to the ground and finally stopped in front of a large spruce and did not know where it would go. There it hovered until the batteries ran out. A resident in the area found it after 1 1/2 years and when I checked the film on the memory card it was clear what had happened."

A1 / Mafalda: I wanted to illustrate the woods and the found small drone, and wanted to leave space for the passage of time to be made clearer as a layer in the next drawings. In the corner, I added a device being held in the hands of a user.

A2 / Sara: I wanted to create a reaction among the trees to show that the drone without its pilot is a strange phenomena in the woods. I sketched a new tree as an individual with eyes, and a drone that appears stuck in front of it. I wanted the tree to look confused and have a slightly sad look. The idea was to make this scene with the looking tree foreground, a living creature that is affected by the lost drone.

A3 / Mafalda: I was surprised to see that the image in the corner and the the actual woods were not part of this new layer. The new drawing built very little on the initial one, but brought into the story the big spruce. This reminded me of the agency of different materials in nature. The big spruce I had first ignored had a somewhat surprised expression, but I imagined that if all these drones kept colliding with it, as time passed, it would be harder and harder to know where the forest ends and the drone cemitery begins. The one human that found the drone fades further and further into the background.

"Unpleasant experiences where large metal objects under the ground or in the form of a large crane affected the drone's compass so it gave of itself and could not be steered. Should almost be on the drone map so more people will be aware of this. There are items near bridges and at metal ports under the ground that always cause major problems."

B1 / Mafalda: I drew a bridge in black with large areas of metal around it and under it. I made this drawing rather abstract on purpose and imagined the next step would be to consider the map and how there are hidden worlds beyond the visible to consider when piloting drones.

B2 / Sara: I interpreted the sketch as an abstract expression of magnetic fields. I overlaid them with a drone, flying in a small circle to show that it is affected by the magnetic fields.

B3 / Mafalda: Sara had turned my drawing upside down! She did not perceive the black as a bridge, and drew what looked to me as a lost drone. In this digital layer, I hid all the previous traces of the metal as a layer under the earth, only marked by crosses on a map. But the world under it is upside down now. Which one is the real one, does it matter for the drone? The drone itself does not know what a bridge means.

"I'm on my 5th drone. I have crashed three drones and that is of course due to the way I use the drone. My drone is a camera dolly and the best movie clip is when you drive backwards and sideways. Unfortunately, you do not see in the direction of travel either. I usually film my grandson, who engages in kite surfing and kite foiling, 2-3 m above the water is usually the best and safest, but sometimes you end up below 1 m and then there is a crisis."

C1 / Sara: I painted a diver coming up from the water with an empty hand in the air. I intended Mafalda to continue the story of how a drone got lost in the water and potentially add a drone in the divers hand.

C2 / Mafalda: I thought this drawing of the diver was beautiful and it seemed very clear to me Sara was leaving an open hand for me to fill with a drone. However, as I did that, the paper moved and I saw how the transparent layer could be used as a dual-meaning layer, of the drone in the hand and at the same time the drone in the air getting tangled in the threads of the kite. I left the drawing without much detail and expected Sara would build on this travelling of the drone in the air and the drone under water as simultaneous states. What if the drone could dive, like a bird catching fish?

C3 / Sara: I made the drone appear like it just got out of the water entangled with green seaweed. I also make the arm and the hand of the diver more prominent in the picture, so that this becomes the primary focal point. I had an idea of adding some fish in the water, but decided not to. I added some color to the windsurfing sail to make it appear livelier.

"One fine spring day I was going out with my newly bought drone. Just as I am about to take off and fly away with the drone, I see a large eagle just above me circulating around me. Almost like it was waiting to put its claws on. Do you think it was a ride after that shock? Nope!"

D1 / Sara: I painted an eagle that is circling over a drone on the ground. I leave some space for Mafalda to add a person. I imagind adding a person that looks scared and is squatting next to the drone, maybe protecting their head?

D2 / Mafalda: The superhuman capacity of the drone brought the human closer to nature. But nature won this fight, so I tried to expand the story and show a sequence of the human seeing through the drone, almost touching the eagle. And after this exciting experience, a drone gathering dust on a shelf.

D3 / Sara: I was not sure what to draw first. I make the eagle more prominent. Then I draw a box to illustrate that the drone will be put back in its box. Somehow I did not see the face that Mafalda had drawn first. Then I saw it, and focus on making it more prominent.

"Meant to lift from a table on a small bridge. Had run the same sequence last autumn but now it was winter and wanted the same bit in winter but did not want footprints in the snow so flew into the place. When I took off I hit a branch and the drone bounced around in a birch... the propellers broke partly but managed to steer it down with difficulty and crashed on the small bridge and not in the water. Everything is on film."

E1 / Mafalda: The passage of time, the two seasons told in this story felt like a beautiful poem. The pilot wanted to catch the same space in two different conditions, just as we wanted to draw multiple layers. I drew the bridge and the river in an anonymous landscape, with traces of winter and of falling autumn leaves in the corner.

E2 / Sara: I interpreted the painting to have a bridge that is far away. I was not sure what the brown drops are. I sketched a large tree on the side with a branch that a drone is stuck on. There was some snow on the tree. I also sketched some footprints and snow. Avoiding footprints in the story was a potential reason for the drone mishap, so I figured that their existence in the painting is an important part of the story.

E3 / Mafalda: As I got this drawing back, I saw the drone now in a much closer frame. In the digital layer I brought back the mixture of autumn and winter, and pondered on how the drone was unchanged. Its skin the same between the seasons, its metal body not a part of the organic elements of nature, a stark contrast. Even the footsteps of the human would have been a natural part of this landscape.

"A family became interested when I flew my drone before. At about the same place a few months later, an angry man came and said that he would shoot down the drone if I flew over his house."

F1 / Sara: I painted a farmer standing in front of his house. Initially the arms were crossed, but open arms worked better to signal that the farmer says "stop!" I deliberately left space for Mafalda to continue the story.

F2 / Mafalda: This story reminded me of a game I played last year called "Untitled Goose Game". The idea of the man against the drone was already put in a humorous tone, but I imagined the man would create a sign to send to all drones and place it outside his house, just as one would warn about a guardian dog. The design of this signage would be an interesting topic of research. I speculated on the roles of other creatures in this scenario, and their interplay in negotiating the privacy of space.

F3 / Sara: Overall, I was not sure what to add in the picture, more than making the existing objects more vivid through colour. I made the "no drones" sign colorful and prominent with red paint. I added color to the dog, the rifle and to the farmer. I also added an angry expression on his face.

DISCUSSION

The use of the method opened up for discussions on new research directions. We were surprised to experience how refreshing the silent discussions were, and how they supported a visual understanding of the importance we gave to each topic or agent represented. For example, Mafalda, the PhD Student, found that there was a greater emphasis on the more-than-human elements of human-drone interaction. In her view, this revealed a need to revise the research questions and ponder if the considered stakeholders were too limited – were the trees and birds included? Or, the underwater creatures when a drone collapsed in the sea? From Sara's perspective, who had been painting watercolour in her spare time for many years, this was an enjoyable, intuitive, and playful approach to research, and to jointly reflect on user data. Bringing user stories to life by taking turns in interpreting them and continuing on each other's drawings was a new experience – different from other methods of qualitative data analysis we had previously used such as thematic analysis or coding. We considered how the method could support preserving the privacy of the users while depicting ethically questionable situations (such as dangerous or illegal actions).

We have yet try the technique with another prompt (e.g. research questions, design guidelines, manifestos), but we see a promising aspect in the layering of media and the conversation the space of the paper affords. The method is relatively flexible but relying heavily on the physical media – this may mean that a remote application of the method is limited. An advantage of the set-up is that it could be adapted to available tools, prompts, and number of participants. We suggest as future work the development of a collection of possible steps with examples, and departing from the applied use of this collection, evaluate the method with different participants. While previous research has focused on using drawing as mediation in many forms, we focus instead on a sequential conversation in layers where each spoken sentence is an integral part of the final result, and simultaneously, where each step is easily archived due to the tangible nature of the method. *Conversational Composite*s are prepared to take advantage of a panoply of different prompts, from research questions to ethnographic data.

We recognise as a great advantage that the composites are tangible, each layer inviting for a specific type of artistic expression: Figure 6 offers a list of media compatible with the method. The interplay between transparency and opacity is an added value. Opposed to techniques such as presented by Yurman [21], the collaboration our method proposes results in an artefact that is necessarily collaborative – a hybrid of every participant's individual expressions. These types of artefacts produced during the design process are valuable to the research community as the "hidden treasures" [1] now being more widely shown in publication formats such as pictorials. Temporality is also an important material factor: some layers may take longer to settle. In our case, for example, we had to wait for the watercolour layer to dry before adding the next and played with a hair dryer to this end (see Figure 3). This is a characteristic that makes the method particularly compatible with HCI theories where slowness is contemplated (e.g. Slow Technology [16]).

Every method comes, of course, with its drawbacks. We found that not every composite was generative, and that it was difficult to write and facilitate the interpretation of the annotations, as their goal was not always clear. A particularity of this method is that the ambiguous nature of images may shift what is central in the original data towards the margins and vice-versa. We found it conversely more helpful to use the composites as imagery for interdisciplinary input during the workshop, where others could probe our drawings with questions of their own. The method is open for development at the hands of other HCI researchers, and we would invite the conversation to be ongoing. We pinpoint the need to reflect more systematically on the emerging perspectives supported by the method, but also on leaping from the abstraction of drawings towards more specific research directions. We count on the TEI community to be a helping hand in this development.

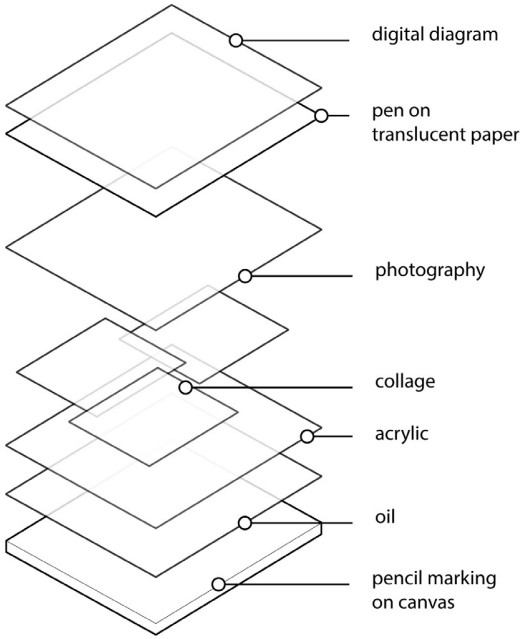

FIGURE 6

CONCLUSION

Drawing – in particular sketching and illustration – is an instrument with growing interest in the HCI community. As the research field develops, the need for methods that accommodate subjective and nuanced conversations is increasing. This pictorial, we present a new method for conversation relying on the tangible characteristics of drawing media – *Conversational Composites*. We introduce the method through an example application between a PhD student and her supervisor, and discuss how it can be further developed and adapted by other researchers. The method builds on the potential of combined drawings as a nuanced space with alternative values for tackling and exploring research data in a tangible way.

ACKNOWLEDGMENTS

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