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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.

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

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

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

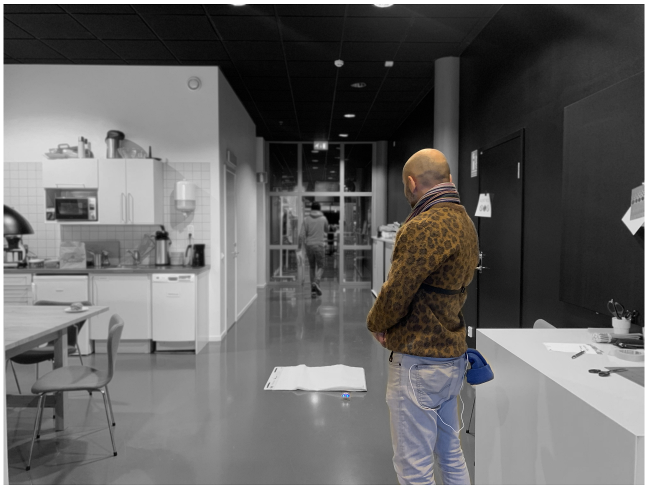


Figure 2: Example of an unplanned interaction with the prototype, only possible through sharing a RtD studio with others.

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 setup. 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."*

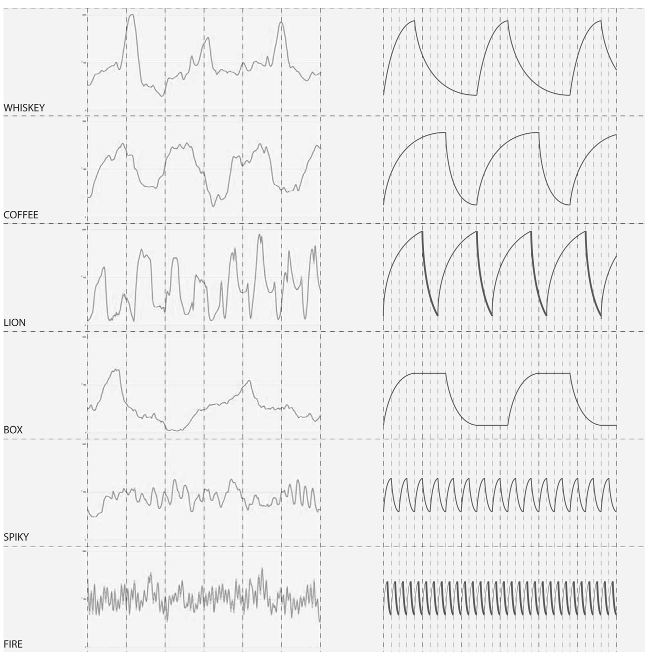


Figure 5: Breathing signals for different exercises as performed by Birgit (left), and her described "mental model" for each exercise (right). It is noteworthy that there is a disparity between her described mental models and the signal acquired.

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*

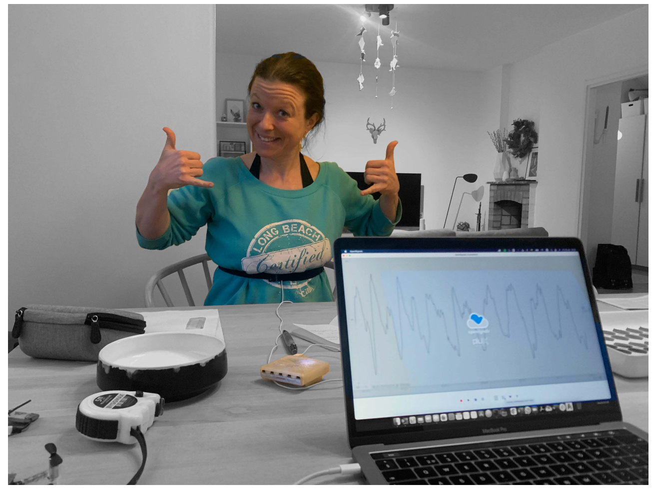


Figure 6: An image from the interview with Birgit, where we used the BITalino Breathing Sensor to gather sample signals for different breathing exercises. During this interview, Birgit also drew the mental models seen in Figure 5 for each of the exercises.

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.

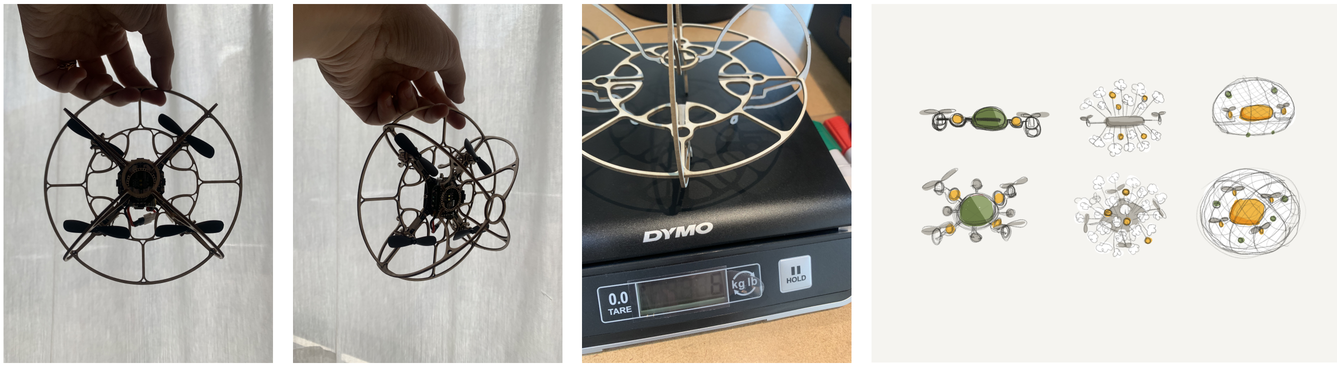
3.2.6 On Accessibility and Ethics. All three experts were asked if they had any particular considerations to accessibility and ethics in their practice. Birgit for example points out that the data she gathers now only refers to gender, age group, and occupation of the participants. Therefore she is not 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.

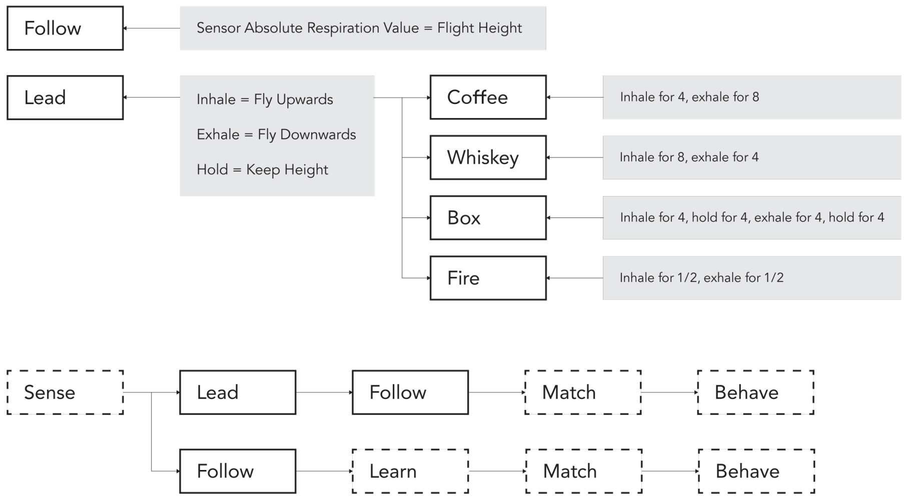


Figure 8: A diagram showing interaction modes. The dashed boxes are work in process, while the filled boxes are finished code included in the first prototype. At the time of pilot studying, the drone could follow the respiration curve acquired through the Bitalino, and lead breathing exercises.

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.

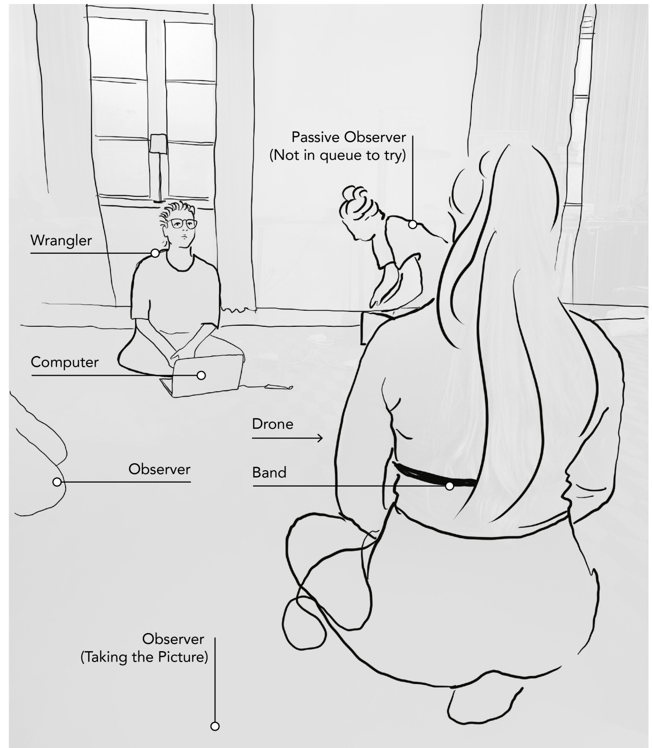


Figure 10: A sketched-over photograph of the testing environment, showing the wrangler, a participant, and a couple of observers. The drone is occluded behind the portrayed participant.

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

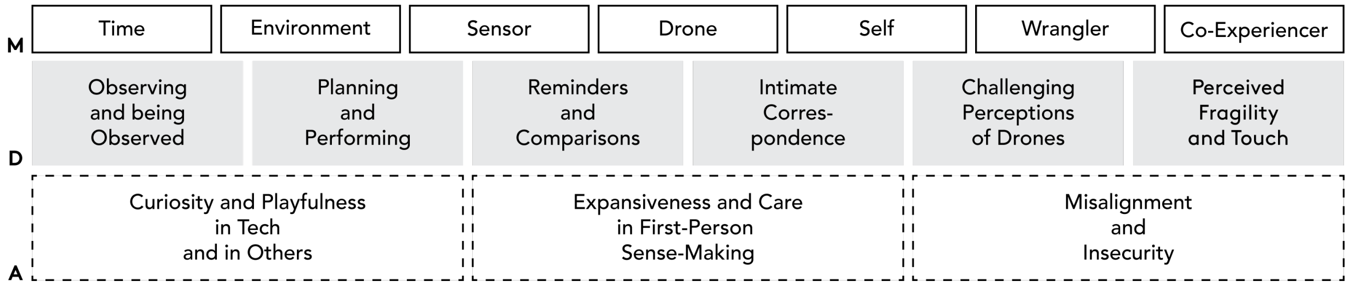


Figure 11: The Mechanics, Dynamics, and Aesthetics (MDA) extracted from the interviews through thematic analysis. Mechanics are components of the artefact which can be designed, dynamics are the run-time behaviour of the mechanics and actions taken by the users when interacting with the artefact, and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

[1] Parastoo Abtahi, David Y Zhao, Jane L E., and James A Landay. 2017. Drone Near Me: Exploring Touch-Based Human-Drone Interaction. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 1, 3 (9 2017), 34:1–34:8. https://doi.org/10.1145/3130899

[2] Ankit Agrawal, Sophia J. Abraham, Benjamin Burger, Chichi Christine, Luke Fraser, John M. Hoeksema, Sarah Hwang, Elizabeth Travnik, Shreya Kumar, Walter Scheirer, Jane Cleland-Huang, Michael Vierhauser, Ryan Bauer, and Steve Cox. 2020. The Next Generation of Human-Drone Partnerships: Co-Designing an Emergency Response System. In *Conference on Human Factors in Computing Systems - Proceedings (CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3313831.3376825

[3] Majed Al Zayer, Sam Tregillus, Jiwan Bhandari, Dave Feil-Seifer, and Eelke Folmer. 2016. Exploring the Use of a Drone to Guide Blind Runners. In *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '16)*. ACM, New York, NY, USA, 263–264. https://doi.org/10.1145/2982142.2982204

[4] Miquel Alfaras, William Primett, Muhammad Umair, Charles Windlin, Pavel Karpashevich, Niaz Chalabianloo, Dionne Bowie, Corina Sas, Pedro Sanches, Kristina Höök, Cem Ersoy, and Hugo Gamboa. 2020. Biosensing and Actuation—Platforms Coupling Body Input-Output Modalities for Affective Technologies. *Sensors* 20, 21 (10 2020), 5968. https://doi.org/10.3390/s20215968

[5] Karen Anne Cochrane, Kristina Mah, Anna Ståhl, Claudia Núñez-Pacheco, Madeline Balaam, Naseem Ahmadpour, and Lian Loke. 2022. Body Maps: A Generative Tool for Soma-based Design. In *Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction*. ACM, New York, NY, USA, 1–14. https://doi.org/10.1145/3490149.3502262

[6] Ilhan Aslan, Hadrian Burkhardt, Julian Kraus, and Elisabeth André. 2016. Hold My Heart and Breathe with Me: Tangible Somaesthetic Designs. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction (NordiCHI '16)*. ACM, New York, NY, USA, 92:1–92:6. https://doi.org/10.1145/2971485.2996727

[7] Mauro Avila Soto and Markus Funk. 2018. Look, a guidance drone! Assessing the Social Acceptability of Companion Drones for Blind Travelers in Public Spaces. In *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '18)*. ACM, New York, NY, USA, 417–419. https://doi.org/10.1145/3234695.3241019

[8] Mauro Avila Soto, Markus Funk, Matthias Hoppe, Robin Boldt, Katrin Wolf, and Niels Henze. 2017. DroneNavigator: Using Leashed and Free-Floating Quadcopters to Navigate Visually Impaired Travelers. In *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '17)*. ACM, New York, NY, USA, 300–304. https://doi.org/10.1145/3132525.3132556

[9] Jeffrey Bardzell and Shaowen Bardzell. 2013. What is "critical" about critical design?. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 3297–3306. https://doi.org/10.1145/2470654.2466451

[10] Jeffrey Bardzell, Shaowen Bardzell, and Lone Koefoed Hansen. 2015. Immodest Proposals. In *Proceedings of the 33rd Annual ACM Conference on Human Factors*

in Computing Systems. ACM, New York, NY, USA, 2093–2102. https://doi.org/10.1145/2702123.2702400
[11] Shaowen Bardzell, Jeffrey Bardzell, Jodi Forlizzi, John Zimmerman, and John Antanitis. 2012. Critical design and critical theory. In *Proceedings of the Designing Interactive Systems Conference on - DIS '12*. ACM Press, New York, New York, USA, 288. https://doi.org/10.1145/2317956.2318001
[12] Mehmet Aydın Baytaş, Damla Çay, Yuchong Zhang, Mohammad Obaid, Asım Evren Yantaç, and Morten Fjeld. 2019. The design of social drones: A review of studies on autonomous flyers in inhabited environments. In *Conference on Human Factors in Computing Systems - Proceedings*. Association for Computing Machinery, New York, New York, USA, 1–13. https://doi.org/10.1145/3290605.3300480
[13] Mehmet Aydın Baytas, Mohammad Obaid, Joseph La Delfa, Asım Evren Yantaç, and Morten Fjeld. 2019. Integrated Apparatus for Empirical Studies with Embodied Autonomous Social Drones. *1st International Workshop on Human-Drone Interaction* (2019), 9. https://hal.archives-ouvertes.fr/hal-02128387
[14] Genevieve Bell, Mark Blythe, and Phoebe Sengers. 2005. Making by making strange: Defamiliarization and the design of domestic technologies. *ACM Transactions on Computer-Human Interaction* 12, 2 (2005), 149–173. https://doi.org/10.1145/1067860.1067862/FORMAT/PDF
[15] Steve Benford, Chris Greenhalgh, Gabriella Giannachi, Brendan Walker, Joe Marshall, and Tom Rodden. 2012. Uncomfortable interactions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 2005–2014. https://doi.org/10.1145/2207676.2208347
[16] Arne Berger, Sören Totzauer, Kevin Lefeuvre, Michael Storz, Albrecht Kurze, and Andreas Bischof. 2017. Wicked, Open, Collaborative: Why Research through Design Matters for HCI Research. *I-Com* 16, 2 (8 2017), 131–142. https://doi.org/10.1515/icom-2017-0014
[17] Mark Blythe, Kristina Andersen, Rachel Clarke, and Peter Wright. 2016. Anti-Solutionist Strategies. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 4968–4978. https://doi.org/10.1145/2858036.2858482
[18] Virginia Braun and Victoria Clarke. 2022. Conceptual and design thinking for thematic analysis. *Qualitative Psychology* 9, 1 (2 2022), 3–26. https://doi.org/10.1037/qup0000196
[19] Anke M. Brock, Jessica Cauchard, Markus Funk, Jérémie Garcia, Mohamed Khamis, and Matjaž Kljun. 2019. iHDI: International Workshop on Human-Drone Interaction. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–7. https://doi.org/10.1145/3290607.3299001
[20] Anke M Brock, Julia Chatain, Michelle Park, Tommy Fang, Martin Hachet, James A Landay, and Jessica R Cauchard. 2018. FlyMap: Interacting with Maps Projected from a Drone. In *Proceedings of the 7th ACM International Symposium on Pervasive Displays (PerDis '18)*. ACM, New York, NY, USA, 13:1–13:9. https://doi.org/10.1145/3205873.3205877
[21] Jessica R. Cauchard, Jane L. E, Kevin Y. Zhai, and James A. Landay. 2015. Drone \& me: an exploration into natural human-drone interaction. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '15*. ACM Press, New York, New York, USA, 361–365. https://doi.org/10.1145/2750858.2805823
[22] Jessica R Cauchard, Alex Tamkin, Cheng Yao Wang, Luke Vink, Michelle Park, Tommy Fang, and James A Landay. 2019. Drone.io: A Gestural and Visual Interface for Human-Drone Interaction. In *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (HRI '19)*. IEEE, 153–162. https://doi.org/10.1109/HRI.2019.8673011
[23] Dylan Cawthorne and Aimee Robbins-Van Wynsberghe. 2019. From Health-Drone to FrugalDrone: Value-Sensitive Design of a Blood Sample Transportation Drone. In *2019 IEEE International Symposium on Technology and Society (ISTAS)*, Vol. 2019-Novem. IEEE, 1–7. https://doi.org/10.1109/ISTAS48451.2019.8938019
[24] Victoria Chang, Pramod Chundury, and Marshini Chetty. 2017. Spiders in the Sky: User perceptions of drones, privacy, and security. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 6765–6776. https://doi.org/10.1145/3025453.3025632
[25] Sibela Chinareva, Jack Jones, Nuha Tumia, Dan Kumpik, Palvi Shah, and Aluna Everitt. 2020. Lotus: Mediating Mindful Breathing. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–7. https://doi.org/10.1145/3334480.3382938
[26] Peter Dalsgaard. 2016. Experimental Systems in Research through Design. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 4991–4996. https://doi.org/10.1145/2858036.2858310
[27] Maria De Marsico and Alessandro Spagnoli. 2019. Using hands as an easy UAV joystick for entertainment applications. In *Proceedings of the 13th Biannual Conference of the Italian SIGCHI Chapter on Designing the next interaction - CHItaly '19 (CHItaly '19)*. ACM Press, New York, New York, USA, 1–9. https://doi.org/10.1145/3351995.3352042
[28] Joseph DelPreto and Daniela Rus. 2020. Plug-and-Play Gesture Control Using Muscle and Motion Sensors. In *Proceedings of the 2020 ACM/IEEE International Conference on Human-Robot Interaction*. ACM, New York, NY, USA, 439–448. https://doi.org/10.1145/3319502.3374823
[29] Audrey Desjardins and Cayla Key. 2020. Parallels, Tangents, and Loops: Reflections on the 'through' part of RtD. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*. ACM, New York, NY, USA, 2133–2147. https://doi.org/10.1145/3357236.3395586
[30] John Dewey. 1934. *Art as experience* (14th ed.). Capricorn Books, New York.
[31] Tinglin Duan, Parinya Punpongsanon, Daisuke Iwai, and Kosuke Sato. 2018. FlyingHand: Extending the Range of Haptic Feedback on Virtual Hand Using Drone-Based Object Recognition *(SA '18)*. Association for Computing Machinery. https://doi.org/10.1145/3283254.3283258
[32] Anthony Dunne. 1999. *Hertzian Tales. Electronic Products, Aesthetic Experience, and Critical Design.* RCA CRD Research Publications.
[33] Sara Eriksson, Kristina Höök, Richard Shusterman, Dag Svanes, Carl Unander-Scharin, and Åsa Unander-Scharin. 2020. Ethics in Movement: Shaping and Being Shaped in Human-Drone Interaction. In *Conference on Human Factors in Computing Systems - Proceedings (CHI '20)*. Association for Computing Machinery, 1–14. https://doi.org/10.1145/3313831.3376678
[34] Daniel Fallman. 2008. The interaction design research triangle of design practice, design studies, and design exploration. *Design Issues* 24, 3 (6 2008), 4–18. https://doi.org/10.1162/desi.2008.24.3.4
[35] Mathias Fleck. 2016. Usability of Lightweight Defibrillators for UAV Delivery. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16)*. ACM, New York, NY, USA, 3056–3061. https://doi.org/10.1145/2851581.2892288
[36] Jodi Forlizzi, John Zimmerman, Paul Hekkert, and Ilpo Koskinen. 2018. Let's Get Divorced: Constructing Knowledge Outcomes for Critical Design and Constructive Design Research. In *Proceedings of the 2018 ACM Conference Companion Publication on Designing Interactive Systems*. ACM, New York, NY, USA, 395–397. https://doi.org/10.1145/3197391.3197395
[37] Markus Funk. 2018. Human-drone interaction: Let's get ready for flying user interfaces! *Interactions* (2018). https://doi.org/10.1145/3194317
[38] Jérémie Garcia, Luc Chevrier, Yannick Jestin, and Anke M. Brock. 2019. HandiFly. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–6. https://doi.org/10.1145/3290607.3312957
[39] Jérémie Garcia, Luc Chevrier, Yannick Jestin, and Anke M Brock. 2019. HandiFly: Towards Interactions to Support Drone Pilots with Disabilities *(CHI EA '19)*. Association for Computing Machinery, 1–6. https://doi.org/10.1145/3290607.3312957
[40] A Garrell, Luis Garza-Elizondo, M Villamizar, F Herrero, and A Sanfeliu. 2017. Aerial social force model: A new framework to accompany people using autonomous flying robots. In *2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. IEEE, 7011–7017. https://doi.org/10.1109/IROS.2017.8206627
[41] William Gaver. 2012. What Should We Expect from Research Through Design?. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. ACM, New York, NY, USA, 937–946. https://doi.org/10.1145/2207676.2208538
[42] William Gaver, Andy Boucher, Dean Brown, David Chatting, Naho Matsuda, Liliana Ovalle, Andy Sheen, and Michail Vanis. 2022. Yo–Yo Machines. In *CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–17. https://doi.org/10.1145/3491102.3517547
[43] Barbara Grosse-Hering, Jon Mason, Dzmitry Aliakseyeu, Conny Bakker, and Pieter Desmet. 2013. Slow design for meaningful interactions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13)*. ACM, New York, NY, USA, 3431–3440. https://doi.org/10.1145/2470654.2466472
[44] Lars Hallnäs and Johan Redström. 2001. Slow Technology – Designing for Reflection. *Personal and Ubiquitous Computing* 5, 3 (8 2001), 201–212. https://doi.org/10.1007/PL00000019
[45] Jeonghye Han and Ilhan Bae. 2018. Social Proxemics of Human-Drone Interaction: Flying Altitude and Size. In *Companion of the 2018 ACM/IEEE International Conference on Human-Robot Interaction (HRI '18)*. ACM, New York, NY, USA, 376. https://doi.org/10.1145/3173386.3177527
[46] Sabrina Hauser, Doenja Oogjes, Ron Wakkary, and Peter-Paul Verbeek. 2018. An Annotated Portfolio on Doing Postphenomenology Through Research Products. In *Proceedings of the 2018 Designing Interactive Systems Conference*. ACM, New York, NY, USA, 459–471. https://doi.org/10.1145/3196709.3196745
[47] Sjoerd Hendriks, Simon Mare, Mafalda Gamboa, and Mehmet Aydin Baytaş. 2021. Azalea: Co-experience in Remote Dialog through Diminished Reality and Somaesthetic Interaction Design. In *CHI Conference on Human Factors in Computing Systems (CHI '21)*. ACM. https://doi.org/10.1145/3411764.3445052
[48] Julia M. Hildebrand. 2017. Situating Hobby Drone Practices. *Digital Culture & Society* 3, 2 (12 2017), 207–218. https://doi.org/10.14361/dcs-2017-0212
[49] Marius Hoggenmüller, Wen Ying Lee, Luke Hespanhol, Malte Jung, and Martin Tomitsch. 2021. Eliciting New Perspectives in RtD Studies through Annotated Portfolios: A Case Study of Robotic Artefacts. *DIS 2021 - Proceedings of the 2021 ACM Designing Interactive Systems Conference: Nowhere and Everywhere* (2021),

1875–1886. https://doi.org/10.1145/3461778.3462134

[50] Kristina Höök. 2018. *Designing with the Body : Somaesthetic Interaction Design.* MIT Press, Cambridge, MA, USA. 272 pages.

[51] Kristina Höök, Sara Eriksson, Marie Louise Juul Søndergaard, Marianela Ciolfi Felice, Nadia Campo Woytuk, Ozgun Kilic Afsar, Vasiliki Tsaknaki, and Anna Ståhl. 2019. Soma design and politics of the body addressing conceptual dichotomies through somatic engagement. *ACM International Conference Proceeding Series* (11 2019). https://doi.org/10.1145/3363384.3363385/FORMAT/PDF

[52] Robin Hunicke, Marc Leblanc, and Robert Zubek. 2004. MDA: A formal approach to game design and game research. In *In Proceedings of the Challenges in Games AI Workshop, Nineteenth National Conference of Artificial Intelligence.*

[53] Walther Jensen, Simon Hansen, and Hendrik Knoche. 2018. Knowing You, Seeing Me: Investigating User Preferences in Drone-Human Acknowledgement. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18).* ACM, New York, NY, USA, 365:1–365:12. https://doi.org/10.1145/3173574.3173939

[54] Kari Daniel Karjalainen, Anna Elisabeth Sofia Romell, Photchara Ratsamee, Asim Evren Yantac, Morten Fjeld, and Mohammad Obaid. 2017. Social Drone Companion for the Home Environment. In *Proceedings of the 5th International Conference on Human Agent Interaction.* ACM, New York, NY, USA, 89–96. https://doi.org/10.1145/3125739.3125774

[55] Pavel Karpashevich, Pedro Sanches, Rachael Garrett, Yoav Luft, Kelsey Cotton, Vasiliki Tsaknaki, and Kristina Höök. 2022. Touching Our Breathing through Shape-Change: Monster, Organic Other, or Twisted Mirror. *ACM Transactions on Computer-Human Interaction* 29, 3 (2022). https://doi.org/10.1145/3490498

[56] Joseph 'Jofish' Kaye, Mariah K Levitt, Jeffrey Nevins, Jessica Golden, and Vanessa Schmidt. 2005. Communicating intimacy one bit at a time. In *CHI '05 Extended Abstracts on Human Factors in Computing Systems.* ACM, New York, NY, USA, 1529–1532. https://doi.org/10.1145/1056808.1056958

[57] Robin Kellermann, Tobias Biehle, and Liliann Fischer. 2020. Drones for parcel and passenger transportation: A literature review. *Transportation Research Interdisciplinary Perspectives* 4 (3 2020), 100088. https://doi.org/10.1016/j.trip.2019.100088

[58] Md. Nafiz Hasan Khan, Carman Neustaedter, and Alissa Antle. 2019. Flight Chair: An Interactive Chair for Controlling Emergency Service Drones *(CHI EA '19).* Association for Computing Machinery, 1–5. https://doi.org/10.1145/3290607.3313031

[59] Bomyeong Kim, Hyun Young Kim, and Jinwoo Kim. 2016. Getting home safely with drone. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct.* ACM, New York, NY, USA, 117–120. https://doi.org/10.1145/2968219.2971426

[60] Pascal Knierim, Steffen Maurer, Katrin Wolf, and Markus Funk. 2018. Quadcopter-projected in-situ navigation cues for improved location awareness. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems.* ACM, 433.

[61] Sarah Komasová, Jakub Tesař, and Petr Soukup. 2020. Perception of drone related risks in Czech society. *Technology in Society* 61, April (2020). https://doi.org/10.1016/j.techsoc.2020.101252

[62] H Kong, F Biocca, T Lee, K Park, and J Rhee. 2018. Effects of Human Connection through Social Drones and Perceived Safety. *Advances in Human-Computer Interaction* 2018 (2018). https://doi.org/10.1155/2018/9280581

[63] Ilpo Koskinen, John Zimmerman, Thomas Binder, Johan Redstrom, and Stephan Wensveen. 2011. *Design research through practice: From the lab, field, and showroom.* Elsevier. https://doi.org/10.1109/tpc.2013.2274109

[64] Joseph La Delfa, Mehmet Aydin Baytaş, Emma Luke, Ben Koder, and Florian Floyd Mueller. 2020. Designing Drone Chi. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference.* ACM, New York, NY, USA, 575–586. https://doi.org/10.1145/3357236.3395589

[65] Joseph La Delfa, Mehmet Aydin Baytas, Rakesh Patibanda, Hazel Ngari, Rohit Ashok Khot, and Florian Floyd 'Floyd' Mueller. 2020. Drone Chi: Somaesthetic Human-Drone Interaction. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems.* ACM, New York, NY, USA, 1–13. https://doi.org/10.1145/3313831.3376786

[66] Joseph La Delfa, Mehmet Aydin Baytas, Olivia Wichtowski, Rohit Ashok Khot, and Florian Floyd Mueller. 2019. Are Drones Meditative?. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems (CHI EA '19).* ACM, New York, NY, USA, 1–4. https://doi.org/10.1145/3290607.3313274

[67] Jangwon Lee, Haodan Tan, David Crandall, and Selma Šabanović. 2018. Forecasting Hand Gestures for Human-Drone Interaction *(HRI '18).* Association for Computing Machinery, 167–168. https://doi.org/10.1145/3173386.3176967

[68] Sara Ljungblad. 2008. *Beyond Users: Grounding Technology in Experience.*

[69] Sara Ljungblad, Man Yemao, Mehmet Aydın Aydin Baytaş, Mafalda Gamboa, Mohammad Obaid, Morten Fjeld, Yemao Man, Mehmet Aydın Aydin Baytaş, Mafalda Gamboa, Mohammad Obaid, and Morten Fjeld. 2021. What Matters in Professional Drone Pilots' Practice? An Interview Study to Understand the Complexity of Their Work and Inform Human-Drone Interaction Research. In *CHI Conference on Human Factors in Computing Systems (CHI '21).* ACM, New York, NY, USA, 1–16. https://doi.org/10.1145/3411764.3445737

[70] Maria Luce Lupetti, Cristina Zaga, and Nazli Cila. 2021. Designerly ways of knowing in HRI: Broadening the scope of design-oriented HRI through the concept of intermediate-level knowledge. *ACM/IEEE International Conference on Human-Robot Interaction* (2021), 389–398. https://doi.org/10.1145/3434073.3444668

[71] Matt Malpass. 2016. Critical Design Practice: Theoretical Perspectives and Methods of Engagement. *Design Journal* (2016). https://doi.org/10.1080/14606925.2016.1161943

[72] Matt Malpass. 2017. *Critical Design in Context.* https://doi.org/10.5040/9781474293822

[73] Lakhan M. Mangtani, Aniket K. Khanorkar, Samrudhi N. Titarmare, Rushali S. Badhane, Swati D. Baghele, Rajani M. Pandele, and M. M. Baig. 2019. Implement Emergency Medical Facility Through Unmanned Aerial Vehical. In *Proceedings of the 3rd International Conference on I-SMAC IoT in Social, Mobile, Analytics and Cloud, I-SMAC 2019.* Institute of Electrical and Electronics Engineers Inc., 352–356. https://doi.org/10.1109/I-SMAC47947.2019.9032642

[74] Georgios Marentakis, Debanjan Borthakur, Paul Batchelor, Judith P. Andersen, and Victoria Grace. 2021. Using Breath-like Cues for Guided Breathing. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems.* ACM, New York, NY, USA, 1–7. https://doi.org/10.1145/3411763.3451796

[75] Joe Marshall, Paul Harter, Jo Longhurst, Brendan Walker, Steve Benford, George Tomlinson, Stefan Rennick Egglestone, Stuart Reeves, Patrick Brundell, Paul Tennent, and Jo Cranwell. 2011. The gas mask. In *Proceedings of the 2011 annual conference extended abstracts on Human factors in computing systems - CHI EA '11.* ACM Press, New York, New York, USA, 127. https://doi.org/10.1145/1979742.1979609

[76] Mikhail Matrosov, Olga Volkova, and Dzmitry Tsetserukou. 2016. LightAir: A Novel System for Tangible Communication with Quadcopters Using Foot Gestures and Projected Image *(SIGGRAPH '16).* Association for Computing Machinery. https://doi.org/10.1145/2929464.2932429

[77] Kensho Miyoshi, Ryo Konomura, and Koichi Hori. 2014. Above Your Hand: Direct and Natural Interaction with Aerial Robot *(SIGGRAPH '14).* Association for Computing Machinery. https://doi.org/10.1145/2614066.2614086

[78] Florian 'Floyd' Mueller and Matthew Muirhead. 2015. Jogging with a Quadcopter. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15, Vol. 2015-April).* ACM, New York, NY, USA, 2023–2032. https://doi.org/10.1145/2702123.2702472

[79] Mohammad Obaid, Wafa Johal, and Omar Mubin. 2020. Domestic Drones: Context of Use in Research Literature. In *Proceedings of the 8th International Conference on Human-Agent Interaction (HAI '20) (HAI '20).* Association for Computing Machinery. https://doi.org/10.1145/3406499.3415076

[80] Mohammad Obaid, Omar Mubin, Scott Andrew Brown, Asim Evren Yantac, Mai Otsuki, and Hideaki Kuzuoka. 2020. DroEye: Introducing a Social Eye Prototype for Drones *(HRI '20).* Association for Computing Machinery, 378–380. https://doi.org/10.1145/3371382.3378313

[81] William Odom, Richard Banks, Abigail Durrant, David Kirk, and James Pierce. 2012. Slow technology. In *Proceedings of the Designing Interactive Systems Conference on - DIS '12.* ACM Press, New York, New York, USA, 816. https://doi.org/10.1145/2317956.2318088

[82] William Odom, Minyoung Yoo, Henry Lin, Tijs Duel, Tal Amram, and Amy Yo Sue Chen. 2020. Exploring the Reflective Potentialities of Personal Data with Different Temporal Modalities: A Field Study of Olo Radio. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference.* ACM, New York, NY, USA, 283–295. https://doi.org/10.1145/3357236.3395438

[83] Pablo E Paredes, Yijun Zhou, Nur Al-Huda Hamdan, Stephanie Balters, Elizabeth Murnane, Wendy Ju, and James A Landay. 2018. Just Breathe: In-Car Interventions for Guided Slow Breathing. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 2, 1 (3 2018), 1–23. https://doi.org/10.1145/3191760

[84] Rakesh Patibanda, Florian Mueller, Matevz Leskovsek, and Jonathan Duckworth. 2017. Life tree: Understanding the design of breathing exercise games. In *CHI PLAY 2017 - Proceedings of the Annual Symposium on Computer-Human Interaction in Play.* ACM, New York, NY, USA, 19–31. https://doi.org/10.1145/3116595.3116621

[85] Corey Pittman and Joseph J LaViola. 2014. Exploring head tracked head mounted displays for first person robot teleoperation. In *Proceedings of the 19th international conference on Intelligent User Interfaces (IUI '14).* ACM, New York, NY, USA, 323–328. https://doi.org/10.1145/2557500.2557527

[86] Mirjana Prpa, Ekaterina R Stepanova, Thecla Schiphorst, Bernhard E Riecke, and Philippe Pasquier. 2020. Inhaling and Exhaling: How Technologies Can Perceptually Extend our Breath Awareness. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems.* ACM, New York, NY, USA, 1–15. https://doi.org/10.1145/3313831.3376183

[87] Maria Puig de la Bellacasa. 2011. Matters of care in technoscience: Assembling neglected things. *Social Studies of Science* 41, 1 (2 2011), 85–106. https://doi.org/10.1177/0306312710380301

[88] Maurizio Rossi and Davide Brunelli. 2017. Gas Sensing on Unmanned Vehicles: Challenges and Opportunities. In *2017 New Generation of CAS (NGCAS)*. IEEE, 117–120. https://doi.org/10.1109/NGCAS.2017.58

[89] Hager Sameh, Kulthoom Aiman, and Dilek Dustegor. 2017. A Remotely Piloted Aerial System for a Faster Processing of Traffic Collisions Towards Reducing the Resulting Road Congestion. In *2017 9th IEEE-GCC Conference and Exhibition (GCCCE)*. IEEE, 1–9. https://doi.org/10.1109/IEEEGCC.2017.8447915

[90] Parvathi Sanjana and M. Prathilothamai. 2020. Drone Design for First Aid Kit Delivery in Emergency Situation. In *2020 6th International Conference on Advanced Computing and Communication Systems, ICACCS 2020*. Institute of Electrical and Electronics Engineers Inc., 215–220. https://doi.org/10.1109/ICACCS48705.2020.9074487

[91] Thecia Schiphorst. 2005. Exhale: Breath Between Bodies. In *ACM SIGGRAPH 2005 Electronic Art and Animation Catalog (SIGGRAPH '05)*. ACM, New York, NY, USA, 62–63. https://doi.org/10.1145/1086057.1086087

[92] Thecla Schiphorst. 2009. Soft(N): Toward a Somaesthetics of Touch. In *CHI '09 Extended Abstracts on Human Factors in Computing Systems (CHI EA '09)*. ACM, New York, NY, USA, 2427–2438. https://doi.org/10.1145/1520340.1520345

[93] Thecla Schiphorst. 2011. Self-Evidence: Applying Somatic Connoisseurship to Experience Design. In *CHI '11 Extended Abstracts on Human Factors in Computing Systems (CHI EA '11)*. Association for Computing Machinery, New York, NY, USA, 145–160. https://doi.org/10.1145/1979742.1979640

[94] Stefan Schneegass, Florian Alt, Jürgen Scheible, and Albrecht Schmidt. 2014. Midair Displays: Concept and First Experiences with Free-Floating Pervasive Displays. In *Proceedings of The International Symposium on Pervasive Displays (PerDis '14)*. ACM, New York, NY, USA, 27:27–27:31. https://doi.org/10.1145/2611009.2611013

[95] Ameneh Shamekhi and Timothy Bickmore. 2018. Breathe Deep: A Breath-Sensitive Interactive Meditation Coach Ameneh. In *Proceedings of the 12th EAI International Conference on Pervasive Computing Technologies for Healthcare*. ACM, New York, NY, USA, 108–117. https://doi.org/10.1145/3240925.3240940

[96] Richard Shusterman. 2000. *Pragmatist aesthetics: Living beauty, rethinking art*. Rowman \& Littlefield Publishers.

[97] Richard Shusterman. 2012. Body and the Arts: The Need for Somaesthetics. *Diogenes* 59 (2012), 7–20. https://doi.org/10.1177/0392192112469159

[98] Richard Shusterman, Richard Schusterman, Richard Shusterman, and Richard Schusterman. 2008. *Body consciousness: A philosophy of mindfulness and somaesthetics*. Cambridge University Press.

[99] Misha Sra, Xuhai Xu, and Pattie Maes. 2018. Breathvr: Leveraging breathing as a directly controlled interface for virtual reality games. In *Conference on Human Factors in Computing Systems - Proceedings*, Vol. 2018-April. ACM, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3173914

[100] Anna Ståhl, Martin Jonsson, Johanna Mercurio, Anna Karlsson, Kristina Höök, and Eva-Carin Banka Johnson. 2016. The Soma Mat and Breathing Light. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16, May 2019)*. ACM, New York, NY, USA, 305–308. https://doi.org/10.1145/2851581.2889464

[101] Ekaterina R Stepanova, John Desnoyers-Stewart, Philippe Pasquier, and Bernhard E Riecke. 2020. JeL: Breathing together to connect with others and nature. In *DIS 2020 - Proceedings of the 2020 ACM Designing Interactive Systems Conference*. ACM, New York, NY, USA, 641–654. https://doi.org/10.1145/3357236.3395532

[102] Erik Stolterman and Mikael Wiberg. 2010. Concept-driven interaction design research. *Human-Computer Interaction* 25, 2 (2010), 95–118. https://doi.org/10.1080/07370020903586696

[103] Superflux. 2015. Drone Aviary — Superflux. https://superflux.in/index.php/work/drones/#

[104] Aaron Tabor, Reyhan Pradantyo, Book Sadprasid, Max V Birk, Erik Scheme, and Scott Bateman. 2020. Bubble Breather - A Breathing Exercise Game to Support Pneumonia Rehabilitation and Recovery. In *Extended Abstracts of the 2020 Annual Symposium on Computer-Human Interaction in Play*. ACM, New York, NY, USA, 86–90. https://doi.org/10.1145/3383668.3419921

[105] Haodan Tan, Jangwon Lee, and Gege Gao. 2018. Human-Drone Interaction. In *Proceedings of the 2018 ACM Conference Companion Publication on Designing Interactive Systems (DIS '18 Companion)*. ACM, New York, NY, USA, 183–187. https://doi.org/10.1145/3197391.3205433

[106] Paul Tennent, Joe Marshall, Vasiliki Tsaknaki, Charles Windlin, Kristina Höök, and Miquel Alfaras. 2020. Soma Design and Sensory Misalignment. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–12. https://doi.org/10.1145/3313831.3376812

[107] Yunus Terzioglu, Bilge Mutlu, and Erol Sahin. 2020. Designing social cues for collaborative robots: The role of gaze and breathing in human-robot collaboration. *ACM/IEEE International Conference on Human-Robot Interaction* (2020), 343–357. https://doi.org/10.1145/3319502.3374829

[108] Dante Tezza and Marvin Andujar. 2019. The State-of-the-Art of Human-Drone Interaction: A Survey. *IEEE Access* (2019). https://doi.org/10.1109/ACCESS.2019.2953900

[109] D Tezza, D Caprio, S Garcia, B Pinto, D Laesker, and M Andujar. 2020. Brain-controlled drone racing game: A qualitative analysis. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 12211 LNCS (2020), 350–360. https://doi.org/10.1007/978-3-030-50164-8{_}25

[110] Dante Tezza, Denis Laesker, Derek Caprio, and Marvin Andujar. 2020. Let's fly! an analysis of flying FPV drones through an online survey. In *CEUR Workshop Proceedings*.

[111] Vasiliki Tsaknaki. 2021. The Breathing Wings: An Autobiographical Soma Design Exploration of Touch Qualities through Shape-Change Materials. In *Designing Interactive Systems Conference 2021*. ACM, New York, NY, USA, 1266–1279. https://doi.org/10.1145/3461778.3462054

[112] Vasiliki Tsaknaki, Madeline Balaam, Anna Ståhl, Pedro Sanches, Charles Windlin, Pavel Karpashevich, and Kristina Höök. 2019. Teaching Soma Design. In *Proceedings of the 2019 on Designing Interactive Systems Conference - {DIS} {\textquotesingle}19*. {ACM} Press, New York, NY, USA, 1237–1249. https://doi.org/10.1145/3322276.3322327

[113] Vasiliki Tsaknaki, Kelsey Cotton, Pavel Karpashevich, and Pedro Sanches. 2021. "Feeling the Sensor Feeling you": A Soma Design Exploration on Sensing Non-habitual Breathing. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–16. https://doi.org/10.1145/3411764.3445628

[114] Robby van Delden, Danny Plass-Oude Bos, Antje Jacoba Vivian (Vivianne) de With, Koen Vogel, Randy Klaassen, Nynke Zwart, Joyce Faber, Boony Thio, and Mattienne van der Kamp. 2020. SpiroPlay, a Suite of Breathing Games for Spirometry by Kids \& Experts. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*. ACM, New York, NY, USA, 400–413. https://doi.org/10.1145/3410404.3414223

[115] Vincent van Rheden, Eric Harbour, Thomas Finkenzeller, Lisa Anneke Burr, Alexander Meschtscherjakov, and Manfred Tscheligi. 2021. Run, Beep, Breathe: Exploring the Effects on Adherence and User Experience of 5 Breathing Instruction Sounds while Running. In *Audio Mostly 2021*. ACM, New York, NY, USA, 16–23. https://doi.org/10.1145/3478384.3478412

[116] Ron Wakkary, William Odom, Sabrina Hauser, Garnet Hertz, and Henry Lin. 2016. A short guide to material speculation: Actual artifacts for critical inquiry. *Interactions* 23, 2 (2016), 44–48. https://doi.org/10.1145/2889278

[117] Michael Walker, Hooman Hedayati, Jennifer Lee, and Daniel Szafir. 2018. Communicating Robot Motion Intent with Augmented Reality. In *Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction*. ACM, New York, NY, USA, 316–324. https://doi.org/10.1145/3171221.3171253

[118] Anna Wojciechowska, Jeremy Frey, Esther Mandelblum, Yair Amichai-Hamburger, Jessica R Cauchard, Jeremy Frey, Esther Mandelblum, and Yair Amichai-Hamburger. 2019. Designing Drones: Factors and Characteristics Influencing the Perception of Flying Robots. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol* 3, 3 (2019), 19. https://doi.org/10.1145/3351269

[119] Anna Wojciechowska, Jeremy Frey, Sarit Sass, Roy Shafir, and Jessica R. Cauchard. 2019. Collocated Human-Drone Interaction: Methodology and Approach Strategy. In *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 172–181. https://doi.org/10.1109/HRI.2019.8673127

[120] Alexander Yeh, Photchara Ratsamee, Kiyoshi Kiyokawa, Yuki Uranishi, Tomohiro Mashita, Haruo Takemura, Morten Fjeld, and Mohammad Obaid. 2017. Exploring Proxemics for Human-Drone Interaction. In *Proceedings of the 5th International Conference on Human Agent Interaction (HAI '17)*. ACM, New York, NY, USA, 81–88. https://doi.org/10.1145/3125739.3125773

[121] Naoto Yoshida and Tomoko Yonezawa. 2018. Arousal and Valence in Robot's Emotional Expression of Breathing and Heartbeat. In *Proceedings of the 6th International Conference on Human-Agent Interaction*. ACM, New York, NY, USA, 330–332. https://doi.org/10.1145/3284432.3287176

[122] John Zimmerman, Jodi Forlizzi, and Shelley Evenson. 2007. Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '07*. ACM Press, New York, New York, USA, 493–502. https://doi.org/10.1145/1240624.1240704

[123] John Zimmerman, Erik Stolterman, and Jodi Forlizzi. 2010. An analysis and critique of Research through Design: towards a formalization of a research approach. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems - DIS '10*. ACM Press, New York, New York, USA, 310. https://doi.org/10.1145/1858171.1858228