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INTERFACING

An exploration of sensory experiences

Faculty of Information Technology and Communication Sciences
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ABSTRACT

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STATEMENT To minimise discord between bodies and devices, emerging technologies require methodologies that offer responsive sensory experiences to people who are not directly involved in the making of these technologies.

PURPOSE To explore sensory experiences, along with shape and rhythm, to study the interaction of body, material, and environment.

ABSTRACT

Interfacing is the way our senses respond to beings, material and devices. From here, interfaces become more than smartphones or pixels on a screen. This research work identifies interdependencies between bodies and material. Through sculpting or shaping, clay for instance, digital devices or virtual environments can be modelled, while also offering bodily ways to make what could be. Interfaces then become interactive, body responsive, story sharing and co-making materials. To make body responsive devices, more people with varied experiences need to be involved in making our technologies. Body-material affordances can be established by acknowledging and responding to experiences of the body, e.g. sensory experiences and expressions of body knowledge. These interfaces would then afford responsive movements to suit diverse groups of people coming from varied lived experiences.

Body-centred interaction is made possible by means of non-digital interaction. Through the primacy of sensory experiences, interfaces can then avoid high-precision repetitive interactions, while affording more general movements when using software and devices. The first of the three microstudies in this work, establishes an awareness of environment, followed by participation in an environment with non-digital devices, and finalised by a response to these experiences. One form of participation was to sculpt or shape an interface out of clay; here participants, with their body, responded to material and contributed to the immediate environment. Shaping is a body-material responsive process where the participant decides when their interface, or device, is ready, i.e. complete. Following this, a microstudy was conducted that involved an activity known as stone balancing. Here, gaze tracking revealed the end of an interaction as a duration, not an instance: as hands released the stones, and gaze lingered. The third and final microstudy was another stone balancing experience, this time in the dark with glow-in-the-dark stones and without the gaze tracker. The dark environment afforded a low-sensory environment and general movement. Overall, this work on sensory experiences and general movement establishes meaning and importance to the interdependent bodily process of interfacing.

KEYWORDS interface, body, movement, rhythm, shape, interaction, HTI, small data

TIIVISTELMÄ

Janna Lumiruusu: Rajapinta-vuorovaikutteisuus
M.Sc. Gradu -tutkielma
73 sivua, 4 viite- ja 5 liitesivua
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VÄITE Uusissa teknologioissa tarvitaan metodologioita minimoimaan ristiriitoja kehojen ja laitteiden välillä, tarjoamalla muuntautuvia aistikokemuksia niille eivät ole suoraan osallisena näiden teknologioiden luomissa.

TARKOITUS Tutkia aistikokemuksia, muotoa ja rytmiä sekä tutkia kehon, materiaalin ja ympäristön vuorovaikutusta.

TIIVISTELMÄ

Tämän tutkimukseen päämäärä on selvittää miten kehot ja esineet toimivat yhteistyössä. Rajapinta-vuorovaikutteisuus (englanniksi: interfacing) on tapa jolla aistimme reagoivat olentoihin, materiaaliin ja laitteisiin. Tästä näkökulmasta rajapinnat ovat enemmän kuin pelkkiä älypuhelimia tai pikseleitä näytöllä. Oman kokemukseni mukaan digitaalisten laitteiden tekeminen muotoilemalla, esimerkiksi savesta muovaten, antaa mahdollisuuden tutkia millaisia laitteiden tai virtuaalisten ympäristöjen muotoilumahdollisuuksia on olemassa. Näin rajapinnoista tulee interaktiivisia, kehotietoisia, tarinoita jakavia ja yhdessä luomisen mahdollistavia. Erilaisia kokemuksia ja taustoja omaavia ihmisiä tulisi osallistaa teknologioiden tekemisprosessiin, jotta voitaisiin luoda kehollisesti herkkiä laitteita. Keho-materiaalin käyttömahdollisuuksia voidaan luoda tunnustamalla kehon kokemusten tärkeys ja vastaamalla niihin, mukaan lukien aistikokemuksiin ja kehotietoisuuden ilmauksiin. Tällöin rajapinnoissa mahdollistuvat responsiiviset monimuotoisille ihmisryhmille, joilla on suuri kirjo erilaisia elettyjä kokemuksia.

Tutkimuksessani kehollinen osallistuminen tehdään mahdolliseksi ei-digitaalisten aktiviteettien kautta. Ensisijaisuus annetaan aistikokemuksille, jolloin käyttöliittymissä mahdollistuu suurpiirteisten liikkeiden tekeminen pikkutarkkojen liikkeiden sijaan ohjelmistoja ja laitteita käytettäessä. Ensimmäinen tämän työn kolmesta osatutkimuksesta perustaa tietoisuuden ympäristöstä, mitä seuraa osallistuminen ei-digitaalisten laitteiden ympäristössä ja lopuksi vastine näille kokemuksille. Yksi osallistumisen tapa oli muovata käyttöliittymä savesta, jolloin osallistujat vastasivat kehollaan materiaaliin ja siten osallistuivat lähiympäristönsä luomiseen. Muovaaminen on keho-materiaalin suhteen herkkä prosessi, missä osallistuja päättää, milloin hänen käyttöliittymänsä, tai laitteensa, on valmis ja täydellinen. Tämän jälkeen tehtiin mikrotutkimus, jossa oli mukana kivien tasapainottaminen. Tässä tutkimuksessa katseenseuranta paljasti interaktion lopun jatkuvaksi, ei vain kerran tapahtuvaksi. Kun kädet päästivät irti kivistä, katse jäi viipyilemään. Kolmas ja viimeinen mikrotutkimus oli toinen kivien tasapainotustutkimus, jossa käytettiin pimeässä hohtavia kiviä, mutta ei katseenseurantaa. Pimeä ympäristö mahdollisti matalaärsykkeisen ympäristön ja yleiset liikkeet. Kaiken kaikkiaan tämä aistikokemuksiin ja yleisiin liikkeisiin liittyvä työ luo perustaa toisistaan riippuvaisten, rajapinta-vuorovaikutteisusta määrittävien kehon prosessien merkitykselle ja tärkeydelle.

AVAINSANAT rajapinta, vuorovaikutus, käyttöliittymä, keho, liike, rytmi, HTI, small data, pieni data

Interfacing

Rhythm makes shape
Sensation shapes motion
A feeling for the stone
Upon stone
Turbulence to branching
‘til equilibrium
$\Delta\nabla$

CONTENTS

Appreciation

Dear Reader, thank you for selecting this work to read. I very much appreciate you time and effort to explore this work. It has been a long journey to map out this research work of human-technology interaction through sensory experiences, and some of the writing may not be as cohesive or complete as expected. Therefore, I am grateful for your attention and interaction with this material, whether digitally or on paper. If you choose to scan through this work. I recommend especially the microstudies as there are some visualisations and photos to study. Thank you again and I hope this work moves your own research, exploration and discovery.

First, I would like to express gratitude to my supervisor Päivi Majaranta. Päivi has been an encouraging and reassuring presence throughout this process of exploration and inquiry. Our conversations on both human- and planet-centred design moved the research processes towards sustainable and maintainable work. Our process was organic and, much like the theme of this paper, co-evolving. While the process felt uncertain, Päivi valued and appreciated the direction of the work.

I acknowledge and thank, Markku Turunen, who has provided courses with wide scope for exploration and discovery in the field of HTI. In the HTI Project course, he encouraged unconventional and crafting approaches to making technology. There I made the projection tent, in co-ideation with Tejal Mate and Ismo Rakkolainen, which I utilised in the responsive bodies study “What shape are you?”. He also ran the Information Visualisation course, here I became familiarised with digital tools to visualise the findings. Markku also offered valuable comments and insights on the earlier iterations of this paper, specifically regarding the processes and methodologies that this work offers.

I am also appreciative of Jaakko Hakulinen, HTI course advisor, who encouraged me to continue my programming studies, and providing thoughtful feedback on my coursework. Through Jaakko’s mentorship, I had a lot of space to explore a wide range of studies, interests and topics within and beyond the scope of Human-Technology Interaction. And while I did not apply any digital programming to this work directly, being aware of current programming techniques and processes guided my explorations into stones and working with stones. As computer programming is the art of finding out what stones would say if we could speak with them.

I appreciate and acknowledge Tarja Rautianen-Keskustalo’s thoughtful influences in this work through our discussions on culture, bodily introspections and multimodality. Her attendance to wayfinding experiences offered sensory and rhythmic landscapes to consider, research and apply. Additionally, I am also appreciative for her course, co-lectured with Meri Kytö, for their cultural and sound-based perspective on modalities and

more diverse experiences of space, experience and timing, which introduced meaningful alternative positions and directions.
I am very grateful for Zahra Aemaebasir's generosity, capacity for emotional understanding, and endless curiosity which ignites her incredible ability to ask meaningful, thoughtful and insightful questions. Zahra's professional experience as a librarian has been invaluable when I needed clarification on format and structure. Lastly, her enthusiasm, interest and appreciation for this research, has provided me with valuable momentum to finalise this work. Anu-Marja Laitinen, Anu Passoja, Satu Dalnell, and Juho Rissanen contributed to the Suomi version of the abstract, I am especially thankful for the work they did to ensure that the meaning and intent translates. Additionally, Olli Koskinen, for the 3D virtual modelling of Breath and Atmosphere, as I could not have achieved such work on my own in Autodesk. Oleg Spakov and Päivi Majaranta for assisting me with some of the gaze technologies available at TAUCHI, namely the Dikablis and Tobii devices. Also, Jussi Rantala and Roope Raisamo who provided biomechanical perspectives and processes of sensory receptors. Also, Kirsi-Marja Tuominen for our initial discussions regarding my enrolment, as well as her support and advice throughout my studies.
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In extension, I would also like to express my gratitude to the following people for reminding me of who I am, and where home is, Earth: Robin Wall Kimmerer (Potawatomi); Joseph M. Marshall (Sicangu Lakota); Joanne Shenandoah (Wolf Clan, Oneida Nation); Karlie Alinta Noon (Gamilaraay); Luke Pearson (Gamilaroi); Candace Brunette-Debassige (Cree); Mini Aodla Freeman and Taqralik Partridge (Inuit); and all the people of the Cook Inlet Tribal Council (citci.org), namely the President and CEO Gloria O'Neill — their game Never Alone helped me find the perseverance to continue. Through their spoken or written words, they have shared through rhythm and tone the feeling of belonging to place. Though we have never shared the same immediate space, they have told me of their experiences. They have made themselves known to me and shared their core values which informed this work. In a world full of colonising industrial attitudes, disrespecting the land and local communities, I am truly grateful for their expressions and reminders of what it means to belong to place.
Before and during the course of these studies into Human-Technology Interaction, I have made a point to seek out those with *girls'* names, and along with it all the societal

demands, assumptions, and expectations of being the one responsible to do the emotional labour of care and nurture. While these attributes are admirable and must be sustained, they need to be a shared responsibility by everybody throughout community. To make visible their experiences, I wanted to learn about their work, the work which comes from those who are often obscured, especially in STEM fields (Science, Technology, Engineering and Mathematics). Moreover, it has been important to make their first names visible, names that are usually removed, obscured and hidden in traditional academic literary value systems.

First names are also often referred to as birth names, names given near or after birth. In hospitals, the rhythm of birthing is regulated by clocks and metric measurements, and not of the momentum of waves, as in the way animals give birth, as stones are gradually moved up from the earth, as mushrooms emerge into the air from the forest floor, or as waves ebb and flow in large bodies of water. In the academe, the process of ideating, or birthing ideas, is also regulated by deadlines, ticking clock and following the academic or financial calendar. In this sphere of intellectual professionalism, only surnames, or family names, are visible. While birth names are omitted from reference lists, hidden behind a single initial, or left hanging, secondary to the surname, after a comma. There is no family, without birth. Here, in this work, the whole name is visible, with primacy of birth names. The order of references responds to this birthing process we all have been through.

In response to the waves of birthing, as an expression of rhythm and movement, I would like to thank Carrie Noland, Sady Doyle, L. Onerva, Eeva-Liisa Manner and Susan Griffin for showing me the application of flow, wording and heart in their poetry and writing. And those in other fields who have demonstrated the power of imagination and emotional thinking in academia and science: Courtenay Raia-Grean, Janna Levin, Helen Czerski, Daina Taimina, and Margaret Wertheim. And to acknowledge all those who came long before in the fields of science, music and history: Hypatia, Sophie Germain, Sofya Kovalevskaya, Emmy Noether, Clara Schumann, Ada Lovelace, Vera Rubin, Zaha Hadid and Maryam Mirzakhani. May they always be remembered in the cosmic soup of knowledge. Because without them, where would we be.

1. Introduction

I have long felt that there is a disconnect between our technologies and our bodies, and the aim of this work is to explore sensory experiences, along with shape and rhythm, to study the interaction of body, material, and environment. This work required involving those who might not be included in the making of their technologies; therefore, an outreach process was required to find interested participants who use everyday technologies, e.g. mobile phones, smartphones or tablets. In the field of Human-Technology Interaction (HTI) and Human-Computer Interaction (HCI), there is an understanding and appreciation of the importance of emotions, senses, and experiences. Through evaluation systems that gauge cultural responsivity, movement, enjoyability and interactivity, interfaces can be made through co-making processes by responding to our bodily experiences. The research questions explored in this work are:

- **How can body-material experiences be involved in the co-making processes of our technologies?**
- **How can we involve those around us who might otherwise be excluded?**
- **How are sensory experiences articulated in human-technology interaction?**

In this work, interfacing is expressed as a body sensory experience (*suomeksi: aistikokemus*) that is expressed through an interdependent and responsive process. This relational interaction of body and material can be expressed as body-material movements and rhythms, resulting in the shape of an interface. It is our technology that shapes us, as much as we shape our technology (Fotini Markopoulou-Kalamara, 2016). "We can develop designs that help us live better lives, by creating experiences and systems that shape us in the ways we want to be shaped" (Kristina Höök, 2018). The choices we make as individuals are not independent of, but rather interdependent with our community in our environment (Robin Wall Kimmerer, 2014). The products we co-make are both the outcome and representation of the people we are. In the process of making products and component choices, we reveal who we are and what we value.
The body guides the shaping of form through movement. Body movement is learnt through experience: entrainment, interaction and internalisation. Entrainment is the process of "experiencing any rhythm" requiring "both perceptual attunement and a synchronisation of attention" (Brigid Costello, 2018, p. 7). Interaction itself involves "the rhythm of action and response" (Brigid Costello, 2018, p. 1). While internalisation is the process of materialising interactions, for example, "The rhythmic traditions of the musical culture we are born into give us an internalised ruleset." (Brigid Costello, 2018, p. 13). Through the process of entrainment and interactions we internalise rhythms, and

thus, movements resulting in the ubiquity of culture. By applying responsive and bodily methodologies, we can co-make interfaces in response to each other, material and place. This is a very different practice from symbolic logic and "geometric figuring" (Margaret Wertheim, 1997, p. 52). Here "soma design is a qualitatively different process from those involving symbolic processing" (Kristina Höök, 2018).

"Neuroscience now appreciates that the brain is in a body and the body is in the world" (Patrice Duquette, 2017). Our interfaces are in the world, we interact with and respond to them every day. We are in an interdependent relationship with our devices and machines, we shape them as much as they shape us. How we feel in relation to them, or in response to them, also matters. Internal body sensations come from a multitude of interoceptive mechanisms, such as organ function and hormone production. Thus, if our interaction with them is disruptive to related body rhythms, such as breathing and heartbeat, we could be shaping ourselves in ways that are harmful. Moreover, high-precision repetitive movements on high precision interfaces have been long known to cause repetitive strain injuries, such as carpal tunnel and eye strain.

Much like learning to drive and navigate in a car, we learn to drive and navigate with a computer. This can be done by attending to general movements, smooth responses and seamless transitions to promote an internal sensory equilibrium, i.e. homeostasis. Interfaces with responsive interactions that promote movement can lead us to sustained interactions with technology. Consequently, in a working environment with less frustrating technologies, we may also reduce some of the strains on our relationships and the demands we place on the planet and living environments. We can further do this also by valuing our existing devices, learning about the materials to make the technology, and the work involved, and being aware of the pathways it took to bring about our technologies.

Part of the process to co-make such interfaces is regularly participating in general movements by means of regular interaction with open terrestrial landscapes, such as forests, lakes, deserts, and meadows. Alternatively, participating in activities that afford low-precision movements, while not forcing high-precision movements, such as land-art, sculpting, crafting, sketching, cleaning, gardening, and painting. Moving through open terrestrial landscapes, i.e. spaces that are integrated, synchronous, and complex, we too begin to calibrate to these environments, e.g. a decrease in heartrate (Bum-Jin Park et al., 2009; Yuki Ideno et al., 2017). Our experiences then shape the interfaces we make. Therefore, the "paradigm based on an invisible observer conducting unbiased, objective, repeatable, verifiable experiments" (Susan Kozel, 2008, p. 10) is problematic in co-making interfaces for ourselves and each other. The process of observation must be integrated and emotionally responsive to the participants, interfaces and environment.

In the in-forest (as opposed to in-room) study of Anna Ståhl et al. (2017), the interaction design sketching process was described as: “sketching is not seen as a step in a linear process where sketches are gradually refined into functioning products, but rather as part of an improvisational and explorative way of engaging with ways of expressing the workings of a system”. Therefore, instead of a reductive method of functional refinement, this work is a collaborative exploration of expressing body knowledge through interfacing and interaction. Thus, the process involved gently holding the idea of bodily experiences and expressing body knowledge through experiences throughout the interdependent practices of co-making and co-doing. This is similar to the in-forest design processes: "During each walk we brought an array of possible representational challenges in the back of our minds rather than a specific problem to solve, which formed our way of looking at and exploring objects and elements in the forest." (Anna Ståhl et al., 2017).

Kristina Höök (2018) challenges designers to identify interdependencies between bodies and elements: “for designers to fulfil this responsibility, for them to create designs and systems that create harmony between the soma and the object, a new design program is needed. This program would help designers cultivate somaesthetics sensibilities, so they can better and more deliberately shape the space of movements invited by technologies, increasing the possibilities of pleasure, somaesthetic experiences, and more meaningful interactions with our lifeworld”. Sustainable interactions through general everyday movement needs to be responsive and interdependent. Here, emotionally detached observational methods are not responsive to experiences nor environments. They lack somatic and sensory awareness and responsiveness to co-make with people in our everyday environment and communities. Without care, attention and response, we cannot make what we love to interface with every day.

The following sub-section is my own motivation for doing this work and why exploring sensory experiences needs to be integrated into interface and device making processes, for example, over mathematical or computational paradigms. After Motivation, are Literature and then Background, which will discuss related earlier work on the body, sensory experiences, technology and interaction. The literature section introduces articles and books relevant to this work. Then the background contains sub-sections on affect, materiality, rhythm and modalities. The next sections are methodologies, microstudies, discussion, and summary, with references and appendix at the end. Appreciation (which precedes the Introduction) included those in my local community who have been involved in this work as well as poets, game developers, authors, artists, academics, and scholars who have influenced this work. Motivation outlined the purpose and statement, then continued to discuss why this process through sensory experiences is necessary to make responsive interfaces. This goes on to the three microstudies that

explore and study the relationship of body, material and environment. Finally, the section discussing *completeness*, follow by a broader discussion and in the end with a summary. References, along with Supplementary reading and media, can be found after the summary, followed by the appendix, containing the tasks, surveys and results from the microstudies.

1.1 Motivation

Sensory experience matter more than three-dimensional (3D) divisions of space. The primacy of sensory body knowledge needs to be given a visible and meaningful position throughout the co-working process of making interfaces, e.g. computers, digital accessories, and other peripherals and devices. These 3D mathematical constructions of space and shape, can create barriers that generate resistance in movement-based interactions and sensory experiences. Meanwhile bodily expressions of space can work through them without artificial constructions of space, for instance, through sensory experiences with techniques such as improvisation, sculpting and ideation. Formal mathematics and physics through symbolic logic are useful tools, but even computers require translations into code in order to implement them. By establishing processes where bodily sensations can be responded to through interface making, e.g. sculpting, arranging and drawing, we can make forms that respond to our senses, and not only to discrete cognitive expressions of symbolic logic, arithmetic and text.
The bodily experiences within our constructed domesticated cities all around the world have narrowed our views and dimmed the night sky with light pollution. We no longer have regular exposure to open skies with limitless views. Our restricted daily experiences in cities has reduced our sensory knowledge to narrow paths, interrupted skylines, loud traffic and construction noises, and constantly surrounded by unfamiliar people — desensitising us to our bodily experience. To build our cities, the land is levelled. Buildings are not made in response to place, but to the demands of quantifiably discrete three-dimensional space, typically applied in virtual engines, 3D modelling applications, and architectural modelling software. Cities are based on square grid formations, removed from the original topology of the terrestrial landscape, making intersections of 90° angles. Our everyday experiences are limited by and filled with the *right angle*.

> *"There are 360 degrees, why stick to one?"*
>
> Zaha Hadid, 2003

This standard "square", or *right*, thinking is also evident in the rectangular forms of our phones, tablets and laptops, the orthogonal structures of pixels, coordinate grids and the circuit-boards within. Most design, architecture and construction are based on square

shapes and 90° angles, conforming to the hard thinking afforded by hard materials. Like Zaha Hadid, I too need to explore other methods to shape interfaces: interfaces that are synchronous with our sensory experiences and movements.

I've experienced the progression of computing and digital technology in my own everyday experiences since the early 80s. As a very early adopter, since probably around the age of six, my bodily development was in response to the development of computer technology. Due to the immobilising nature of these digital interfaces, I have developed a physiology afforded by computing devices and the culture that developed them. I have regularly had to treat ailments related to computer use. And feel it is a problem that our daily working instruments and equipment do not afford sustainable responsive movement, bodily expression and healthy breathing rhythms and body position.

Through my lived experience, I have felt an implicit and ubiquitous social pressure to see clearly and read a lot, while other ways of knowing and sharing information remain wanting. Therefore, in this work, I wanted to create a space where it was not necessary to need "perfect vision" and a space where body knowledge was valued and body movement was an expectation. Because unlike my lens-wearing colleagues and classmates, I do not have a visual aid to help me cope in this academic sphere existence of predominantly reading and writing. I do have, however, access to text-to-speech readers which only works on most pdfs and now webpages. Personally, I learn best from mixed mediums and engaging a mix of senses. Otherwise the body is neglected, just a thing to carry the brain around, and only the senses of sight, sound and a little touch on the keyboard provide stimulus. And all the rest of the body is ignored, and existences of emotion, taste and smell have no place, not to mention the more subtle internal senses of vestibular, proprioception and interoception.

I consider myself to be culturally integrated into the digital computing age through my regular daily computer and digital use of desktop computers, laptops, mobiles, smartphones, and tablets. And now I have also attained some familiarity with some VR headsets and controllers, and some exposure to dedicated interactive technologies such as gaze trackers, fog screens, motion trackers, 360° cameras, and large touchscreen devices. However, even with all this digital experience I recognise the immobility embedded in these devices through high-precision and repetitive movement often requiring fine motor skills and very precise hand-eye coordination. Often due to the very small buttons and even smaller font size. Thus, lacking in general broad-spectrum movements and visual interaction.

Moreover, when using a computer or laptop with a keyboard, I hardly use my upper body, only my hands and fingers, while breathing is shallow. I also find it difficult to breathe when I use a smartphone or small touch device, and my arm quickly becomes tired, feeling heavy, as I keep holding my phone up to head level. VR devices are a bit different,

but that depends on the type and rhythms of the interaction. VR interactions often require more movement, as long as they are used with controllers. The upper body then engages in more varied activity, but I experience fatigue in my neck and lower back, and find breathing laborious and strained. However, large touchscreens, fog screens and mid-air gestures with depth and motion tracking sensors, such as Intel RealSense, Leap Motion, or Microsoft Kinect, have the potential for greater range of movement than the traditional keyboard and mouse.

To make these movement-based technologies sustainably produced, more widespread and culturally accepted locally, there needs to be an expectation that technology should not hinder our innate bodily movement and autonomic breathing rhythms. Our working technologies, postures and environments should not immobilise us. Therefore, from here we can explore working environments that support, expect and promote adaptive and responsive movement. Tasks that involve plants, stones and working directly with open terrestrial landscapes offer these movements because these environments are always working in immediate local responsive relationships and in partnership with the land, Earth and cyclical systems of our solar system and cosmos. There is no barrier or wall between body, sensation and experience.

2. Literature

Co-evolving with our technology depends very much on the movements we make and life-habits we form. It is in the way we breathe, move and feel in relation to our technologies, materials and environment. The affordances of technologies can be explored through movement, while also attending to breathing rhythms and other internal sensory experiences. Awareness of what is inhibiting movement is also investigated through interactions of body, material and environment.
For example, in I-Mei Lin and Erik Peper's preliminary study on: psychophysiological patterns during cell phone text messaging (2009), they found that many of the participants were unaware of their immobilised position while using their device. "To perform fine motor movements necessary to manipulate the controls of the devices, participants automatically and unconsciously stabilise their trunks, tighten their necks and shoulders and breathe shallowly as well as thrust their heads forward in order to read the small screen." (I-Mei Lin and Erik Peper, 2009). Additionally, "The increase in repetitive stress injuries like eye strain and carpal tunnel syndrome also point out that over time, the repetition of high-precision movement can be unhealthy" (Christine W. Park and John Alderman, 2018).
The daily use of such small myopic devices severely limits our vision, motion and mobility, by only affording ridged poses and limited positions. "I was holding my breath when I performed any actions that required precise timing." (Brigid M. Costello, 2018, p. 42). We need space to breathe, in turn, to feel and think. Breathing is also what forms the rhythm, and hence the shape of our devices. It is also what shapes us. The way we breathe comes from our muscles, the muscles we use to breathe and move also move our body fluids and help to excrete waste material from tissues via the lymphatic system through to the circulatory system, i.e. the blood stream and capillaries. But if our technology mainly affords us shallow breathing while being stationary or sedentary, then what is it doing to our bodies and the bodily ways we experience the world we inhabit.
The relationship between rhythm and shape is influenced by entrainment, interaction, implementation, modality and environment. Entrainment is the integration of a movement or posture of the body: the human body. It is in what we learn to do as well as the way in which we learn to do. Through osmosis we absorb culture and body knowledge. "'No one taught me,' she [Sarah] says. 'I just watched.'" (The Library of Ice by Nancy Campbell, 2018). To internalise is to breathe in experience, to be present in the moment and internalise an event as it is happening; this is also known as embodiment: an experience that is internalised and expressed in the body. It is not about being instructed on what or how to do something with one's own body. From Roxana Ng's course a "Health, Illness and Knowledge of the Body" she recalls: "'Are experiences always stored

in the body?' My answer was 'I think so.' Since that time, I have learned a lot about embodiment and embodied learning. Now my answer would be 'Absolutely,' even when we have no active memory of the experience or event." (Roxana Ng, 2018, p. 47). An integrated and localised interface comes from the experience of making, or co-making. It does not become from being told or instructed on how to draw a shape, but rather, the feeling and experience of the shape and the way we interact with the shapes. This is how we get-to-know a shape, or interface, and to discover what it means on one's own terms. From a statement made by dance artist, Nalina Wait: "...watching someone move can communicate the weight, timing and rhythm of a movement and allow you to absorb that rhythmic knowledge into your own body." (Brigid M. Costello, 2018, p. 37).

The environment, here, synonymous with space, the space where experience, design, implementation and multimodal internalisation happens. Implementation is the outcome of design, the result, what we have made when it is ready for our intended use. Without the body, lived experiences and kinesthetic knowledge, implementations of technology become detached and made for no-body. "...computers and virtual technologies of all kinds engineer a duality between human and computer, material and immaterial, analogue and digital, organic and inorganic, and body and mind, with the body side of things coming out the worse for wear." (Susan Kozel, 2008, p. XVII). Moreover, lived experiences are often "dismissed as suspicious because of the belief that it is discursive and subject to infinite interpretations" (Sheila Batacharya, 2018). However, all we have is our bodies and through respect for diverse lived experiences, we can then make technology better suited to more kinds of bodies.

The body-to-computer modalities are gaze, body motion, gesture, speech and touch. The prioritising of the body in human-computer interaction draws focus on the capabilities of the body, rather than the limitations of the computer. And we can then proceed to transform experience into interaction through entrainment and internalisation. Experiences are synchronised and fused into the body from exteroceptive senses (sight, hearing, taste, smell and touch) as well as other senses, namely, thermoception, vestibular, proprioception and interoception, to make memories through processes of internalisation, stored in the body for later use, they do not need to be memorised, they are saved in emotion and body motion, feelings triggered by similar future moments (Sarah N. Garfinkel et al., 2016). And over time, our reactions change as we learn from each new experience, adapting to the change. This synchronicity of modality and sense is how experience is internalised.

The ever-changing nature of our bodies, made known through interoceptive awareness of internal and sensory processes, thus making each experience feel (a bit) different, this internal motion is amplified when the surroundings, i.e. environment, are static and controlled. Putting an ever-changing body in the same environment, the same

temperature, the same tools, and the same furniture, one becomes increasingly aware of one's own internal sensory processes. We notice our own changes in unchanging static environments, like office buildings and controlled laboratories.

Our cities, digital devices, books, and furniture follow straight lines and right angles, rarely traversing landscape topologies. The only time urban development does, is when it is forced to do so by rivers and lakes, and large hills or mountains. Otherwise, the land is flattened to the 2D plane of *x* and *y* coordinates. Streets are orthogonal, buildings are square upon square upon square blocks, and our homes becomes scaled down models of our cities, square rooms full of square or rectangular shelves, beds, books, drawers, and so forth. As we navigate our bodies through these straight and flat interiors and cityscapes, lacking vast open views, our own internal sensory experiences become limited, narrow and myopic.

Human bodies are adaptive to their environments and move in response to the structures or obstacles around them. Already several studies have proven that spending time in cities increases blood pressure, while spending time in forests reduces it (Bum-Jin Park et al., 2009; Yuki Ideno et al., 2017). People enjoy spending time in the outdoors and natural environments (Kirsi Mäkinen and Liisa Tyrväinen, 2008). There are numerous differences between cities and forests, for example, sound and form. The sounds in our built-up living environments are often mechanical, such as engine sounds or construction noises, as well as musical instruments. While organically grown environments, such as forests or meadows, include bird songs, rustling of leaves, or waves lapping on the beach or rocks. The fundamental difference of these sounds is in the way they are made. Automated mechanical sounds are made from the regular impact of manufactured materials that move air. While organic sounds are made from responsive systems by means of vorticity, or turbulence, of air and water from or with living matter: trees, people, animals, weather, and bodies of water.

The difference in forms of our cities is also great, cities are more crystalline, like the formation of fluorite or quartz crystals, while the forest is dendritic, fluid, like capillary networks. Moving through the forest requires more fluid motion and sensory awareness; however, while in the city we are, constrained to moving in straight lines, right angles, and constantly avoiding other people. The outlook or view is also different, in cities buildings obstruct or linearly direct our view through three-dimensional spatial perspectives, while forests might be full of trees, there is always a way through; and cliffs and beaches offer far away, distant views out to the horizon. Then the stars, on a clear night, unpolluted by city lights, offer such an expansive view beyond imagining.

We are highly complex biological organisms, and while we may share some minerals with crystals, we are not stationary beings made immobile by gravity on the surface of this planet. We are emotional and mobile, requiring motion, breathing space, a way through

and an expansive view. We come from open terrestrial landscapes like forests, jungles, mountains, valleys, deserts and plains.
This research work has led me to investigate the works of Kristina Höök's "Designing with the Body" (2018); Brigid M. Costello's "Rhythm, Play and Interaction Design" (2018); Christine W. Park & John Alderman "Designing Across Senses" (2018); Susan Kozel's "Closer: Performance, Technologies, Phenomenology" (2008); Roxana Ng's paper "Decolonising Teaching and Learning Through Embodied Learning: Towards an Integrated Approach" (2018); and Mary Evans' "Gender and Social Theory" (2003). These works have a respect for the body, nature, as well as lived experiences. They demystify the body and provide meaningful contributions to bodily practices in technology, learning and culture. Furthermore, it has been worth investigating the long history of technology, particularly in Europe, whose effects still echo today through the global dominant governance. Moreover, Western Europe's 1000+ years of European led colonialisation has also been a dominant force in the development of technology still today. Margaret Wertheim, in her very accessible book: Pythagoras' Trousers (1997), exposes the practices of exclusivity that still exists in the fields of mathematics and physics. These two areas of study, still shrouded in inaccessible cultures through standardised testing, are unwelcoming to those who do not do mathematics through symbolic abstractions and who instead might prefer more bodily and sensory-responsive ways of exploring space and form. Thus, these testing systems, exclude body- or sensory-centered learners from technical degrees of engineering, computer science, and architecture: the fields that build our cities and technologies.
However, there are other ways to build and make, and other ways to learn mathematics, physics and the skills needed to make technology. Based on Papert's work (1980), Kristina Höök (2018) pointed out that "this merging of mind and body proves true for even the most abstract subjects, such as mathematics, which turns out to be firmly grounded in our spatial, bodily ways of being in the world". Bodily methodologies, such as explorations into somaesthetics (Kristina Höök, 2018) show how products and technologies can be made from bodily experiences, not in spite of. The interaction of our bodies with devices is now very much part of our everyday. "The everyday, much-repeated gesture to open your smartphone, for example, must be meaningful and pleasurable" (Kristina Höök, 2018). At the same time, we need to acknowledge that "repetitive daily usage is one of the most challenging types of interaction to design" (Christine W. Park and John Alderman, 2018).

3. Background

3.1 Affect

It is problematic that during the early peak technological development of the 70-90s, it has mainly been specific performances of predominantly male bodies who have designed, architected and defined what our technology should feel like. For example, how the buttons should feel like to press and how the screens or devices should feel like to touch and hold. Beliefs about body, posture and movement established paradigms, metaphors and design motivations to make devices feel and look as they have done since then. The computer, for the most part, has not changed. And has immobilised its users while affording increasingly high-precision repetitive movements.

The look, feel and touch of computing devices today, have not changed that much. Therefore, our interactions with them have not change that much either, since the 80s. We still have something to type on and something to call. While we have a mouse, it has mainly been designed for right hand use, where the left-hand has been an afterthought. Digital drawing pens and tablets came very late in the game, and are not as widely adopted as the mouse or touchpad. Only in the last decade or so, touchscreen technology has afforded new pathways to movement and interaction with devices. However, this has been predominantly limited to smartphones.

The small touchscreens reduce our hand-eye interaction to a very small area, about 13-20cm square. And holding up our phones or tablets to eye height is difficult to sustain. Typically, using such devices, requires the head to be tilted down and arms and hands are strained while holding up the device. Making the device not suitable for ongoing continuous use, but for infrequent updates and brief interactions.

Additionally, traditional manufacturing and engineering for mass production has dictated the affordances of devices through what is achievable on large scale production. These limitations have established hierarchies and linear processes in the development of our technologies. It is critical to be aware of these limitations, paradigms and metaphors that support these linear methodologies. Moreover, these methods are often driven by expressions of aggression to move production forward, for example, in the form of movements and postures often found in military-derived hierarchies. These hierarchies do not represent the broad and diverse range of feeling, movement and expression that bodies are capable of, but it is the affect of dominance, aggression and rigid multi-tiered hierarchy that designs linear, rigid and hard forms. Alternatively, artists and designers may seek out paths of least resistance to counter the resistance of dominant hierarchies; however, through avoidance they meet contrasting or reflective outcomes, which in turn validate the rigid processes of mass production.

Affect moves design, and the outcomes of our devices and technologies. The affect that is responded to, or is valued, and is regularly performed, is what establishes the devices we hold in our hands today. In order to express more sustainable adaptive affects, we need to participate in the expression of sustainable adaptive affect by responding to sustainable adaptive environments. Such environments are open terrestrial landscapes: lakes, forests, woods, jungles, deserts, rivers, meadows and fields. We need to respond to and interact with the land from where the material of our technologies originates in order to establish other affects, and ways of being and knowing.

3.2 Materiality

By the stone's firm, resistive nature to flesh (i.e. skin, muscle, membrane and organ), it does not immediately change to my bodily form, instead the body responds to the shape of the stone, interacting with the stone through sensory pathways. Stone is the ore of mineral and the material of much of our technology. The surface smoothed by the rotation of the earth and swirls of water; or jagged and sharp from hitting against another stone. Stone is also a material whose form is often cut and moulded in squares and rectangles in service to the hierarchical structures of industry, construction, and architecture. It is shaped to meet the demands of linear expressions of efficiency and effectiveness — void of contours and sloping gradients.

From stones to computing has had multiple pathways, such as the abacus, pianos and player pianos, looms, typewriters, clocks, and automatons. Another pathway is games. Games develop the strategies, systems and logics for the structures and relationships within communities and cultures, resulting in their respective technologies. Like our square cities, printed circuit boards (PCBs) they are built in relation to and representative of the internalised structures which produce them, for example, Chess or Checkers. Played on a board with eight by eight squares, much like our 32- or 64-bit processors in that still run computers today.

Alternatively, we can look at other ancient games, for instance, in the case of the Viking warrior (Charlotte Hedenstierna-Jonson, 2017), she was buried with her set of carved antler game pieces. The game pieces, indicating the warrior's "knowledge of tactics and strategy" (2017), serve not only tactic sensation but strategic purpose as well, that is to strategise battle plans. Playing with pieces moves our hands. Our hands move with our eyes, or gaze paths, arranging pieces to attain a desired solution.

Figure 1. Female Viking warrior's carved antler game pieces from Birka, Sweden (Historiska, 2001, CC by 2.5).

The interaction or sensory responses with material changes depending on the properties of the material. For example, in the case of Elisa and Elvin's paper, they study user experiences with a soft lamp. "By using the lamp in a playful and open-ended way, the user can explore a variety of ways in which to use the artefact." (Elisa Giaccardi and Elvin Karana, 2015). Without playfulness and an open-ended exploration, we limit the potential of use. The body's interactive response in relation to material is interdependent: "...materials, people and practices come into relation with each other both 'in the moment' ... and 'over time'...". In contrast to the theoretical, imagined or virtual material which "never gets dirty, never ages and never breaks". It is in the experience of and interaction with the real material that we learn what we can do with it. Furthermore, we also learn how our own body moves with material, or how we move in response to material.

By seeking out perspectives and feelings regarding the experiences of stone and other materials we can explore these sensory based understandings of material. The methods employed to explore these material narratives and experiences were interaction with non-digital interfaces and stone balancing, and here digital refers to the discrete electronic computation of audio and visual interfaces. Stone balancing is an activity where stones are balanced atop each other or are arranged on a surface in a way that feels

balanced, or anywhere in-between. No tools nor previous training are required to balance or arrange the stones. The participant interacts with the stones, or interfaces, on their terms in relation to their sensory experience.

The current day notions of space and form in mathematical and physics have been develop through predominantly male-centered or male-only monastic institutions (Margaret Wertheim, 1997). The materials of these formulations of space and form have been and are still today, paper, wood, stone and metal. Fields such as design, architecture, and engineering still mainly develop their models from discrete mathematical structures and arrangements of space, namely the two- or three-dimensions of space, utilising directions of x, y and z. From here explanations of physics, mathematics, and the corresponding frameworks have been devised through those flat (2D) or cubic (3D) structures, with some thought of fractional dimensions as seen in in the formation of fractals like snowflakes. These monastic traditions which built structures, not for residential housing of diverse communities, but for an exclusive cloistered male-only institution.

However, in today's world with so much diversity of thought, belief and expression, the understanding and practices of mathematics reach far beyond the limits of Cartesian or Euclidean geometry. Ultimately, mathematics is a practice of the imagination. A way to imagine and generate images in the mind's eye (in Finnish: *mielikuva*). And this process of imagining can also be achieved through material sensory experiences, as we touch material and environments. Here is where our actual bodily interactions with space and material are sensory, not discrete nor computational; moreover, they are not computed through the coordinate framework of x, y and z. They are responsive of our sensory system, our senses, in direct relation to our immediate environment. Material and environment prompt responses by way of receptors throughout our body.

Interactions, with material, are sensory, and everybody experiences these interactions in relation to their sensorial ability and sensory awareness. The stone is a material, appreciated, worked with, or interacted with by all. One of the earliest forms of stonework is stone napping, a non-exclusive practice. Since we began cutting and hunting our food, everyone has needed blades and knives for gathering and preparing food. Food has always been a shared space for all our technologies. While this study does not relate directly with food, food is one of the materials we all interact with daily.

Some sources of daily general movement are the material interaction involved in gardening, cooking and supermarket shopping. These activities are performed by many people around the world every day. The material activity of gardening (or small scale local or urban farming) offers movement affordances that are adaptive and responsive to immediate environmental events. Even cooking and supermarket shopping is often responsive to our immediate mood or availability of produce. These materials and

movements have been our everyday interactions that our bodies have been adapting to for millennia.

3.3 Rhythm

Rhythm is the recurrence of movement. It plays out in our everyday life in many ways: cyclical seasonal or calendar events, moving through our urban areas or cities, moving through our homes or workplaces, and rhythms in speech and music. Our relationships with our colleagues, friends and families also have rhythms, for example, through the patterns of encounters and the cycles of feelings we experience in these encounters, resulting in a sense of familiarity.

Interactions with technology also have rhythms. For instance, the tapping of keys, the drag and click of the mouse, or slides on a touchpad; also, the slides, pinches and taps on touchscreens, and the synchronous (or asynchronous) breathing rhythms during the interaction. As recurring movement is a rhythm, there are numerous rhythms of motion we express during our human-technology interactions.

Brigid Costello's book "Rhythm, Play and Interaction Design" (2018) goes into depth on the relationships between users and interactions with technologies. She highlights our everyday interactions: walking, gestures, speech, breathing and thinking. Kristina Höök (2018) during a horseback riding study, sought to translate the rhythms of horseback riding into design situations. She then goes on to introduce Elsa Kosmack Vaara's (2017) work where she "explored rhythm as an organising principle in the temporal gestalt of an interaction" in her doctoral dissertation (Kristina Höök, 2018). The way time and rhythm are experienced and internalised during interaction can inform how the rhythmic affordances of an interface.

As indicated in I-Mei Lin and Erik Peper (2009) paper on the immobilised state of mobile use, computer use also has similar affordances of suppressed or impeded breathing. Computers, typically used with keyboard and mouse (or touchpad), affords stationary, or fixed, positions, namely, sitting or standing. Thus, not affording whole-body movement. However, Kristina Höök's aim to reuse "some of the qualities that make horseback riding so engaging" in interaction design may offer rhythmic experiences that afford, or even promote, mobility and movement-based interaction. "Moving our whole bodies feeds back into our experience" (Kristina Höök, 2018). Therefore, rhythmic interactions could have affordances that internalise breathing rhythms through movement.

If breathing plays a key role in human-computer interactions, then what is its role in our emotional and mental wellbeing? The correlation, or perhaps causation, of restricted breathing and poor circulation, becomes apparent. Mental health and depression seem to be a critical issue in this age of computing, smartphones and ubiquitous technology, as

belief in numbers, data and the "rational" supersede other ways of knowing. Bodies carry much knowledge, knowledge and sense that is not found in numbers, but neither is it found in the "supernatural" nor emotionally detached rationality. Body knowledge is the accumulation of events experienced by the body, such knowledge is internalised through experiences and entrainment.

"We all sense that life is faster in the big city than in the small town and that it has ubiquitously accelerated during our lifetimes as cities and their economies grew." (Geoffrey West, 2017). People living in larger cities walk at a faster tempo than those in rural areas (Geoffrey West, 2017), and different cultures express gestures and speech not just differently, but at different rhythms too. "Being able to synchronise with the rhythms of another is an important marker of belonging within a culture" (Thomas Turnio, 2008; Brigid M. Costello, 2018). When making interfaces, both look as well as feel is important. The feel of the material device as well as the synchronicity with the people who are going to use the application or device. Otherwise they feel difficult to use, rigid, stiff and unnecessarily resistant.

"Rhythm is a cultural form of communication and our ability to listen and perform rhythms in synchrony impacts our capacity to relate to others and marks our status as a member of a particular culture." (2018, p. 23). This would be helpful in language learning apps, part of learning a language is the rhythm of speech as well as how to produce the language in synchronicity. In this case, the rhythm of the language learning application would be in time with the natural language of the language to be learned, so the learner could become accustomed to unfamiliar rhythms.

However, something is always missing, the feeling of learning from someone and all the cultural and intangible movements they bodily express. "Only the close proximity of live body to body communication was able to transmit the detailed kinesthetic knowledge..." (2018, p36). Learning from a video, or an app, while it is fun and entertaining and even useful, it lacks ability to transfer human-to-human kinesthetic knowledge. And while it can transmit some understanding of "microtiming through movement" by watching someone do something in a video, as Simon Barker, a musician, states in an interview with Brigid M. Costello, "You can't read rhythm, you can't feel it by looking at it, you have to do it." (2018, p. 30). Because ultimately, "the movement is the rhythm". Moreover, "we not only understand rhythm through movement but also need to move in order to understand it; and the way in which we move will impact the quality of our experience" (Brigid M. Costello, 2018, p. 36).

"Because our designs (art or everyday tools) are part of our lifeworlds, shaping us as much as we shape them, interaction designers have a responsibility to pay attention to the movements, rhythms, postures, or kinaesthetic-tactile experiences we build into our systems" (Kristina Höök, 2018). In a world where the demand is greater speed,

effectiveness and efficiency, there are always those who are left out or left behind. The hurried pace, burdened by distractions and discord in urban and city life, there is little time to share experiences, space and breath. Here learning becomes a disconnected memorisation exercise, with no moment to share feelings, i.e. emotional bodily knowledge. Yet, perhaps through somatic exploration of rhythms and materiality of technology, we may learn to find meaning in our machines, our stones, and through this, share experiences and this meaning with each other.

3.4 Modalities

Modalities are what we as living beings do when we interact with an environment, while our senses are what enable us to experience it. Modalities such as gaze, body motion, gesture, speech and touch are how we externally interact with our environment, those around us, and our computing devices. However, we also have internal modalities, as we respond with changes in heartbeat (or sinus rhythm), skin conductance and temperature. Though, these are not directed or intentional interactions, but rather responses by our body, for instance, to maintain an internal equilibrium. These responses can be triggered by sound and light. Frequencies of sound and light permeate through skin, flesh and bone. Just as songs trigger impulses of movement, light and visual cues can illicit feelings, which in turn become movement. Often these are responsive or learnt behaviours through lived experience and emulation of those who are around us, as well as the affordances of an environment, implicitly encountered through culture and living cycles of our everyday. We receive exteroceptive sensory information through touch, sound, sight, smell and taste. Some of these senses can overlap, for instance touch and sound, where sound is a visceral feeling that traverses through the skin, flesh and bone. "...once the ear stops grasping this solid sound the sound very quickly travels to the skin instead – and the skin starts to hear it for you" (Kodwo Eshun, 1998, p. 181; Brigid M. Costello, 2018, p. 34). Meanings and feelings change depending on the tone and volume of voice, and our interpretations of them. Sight or smell can become taste, when we see or smell some food and imagine what it might taste like. This imagining is based on our lived experience, our memories.

Other senses include vestibular, proprioception and interoception. Vestibular is the sense of balance, traditionally understood as the balance of our head in relation to the body, however, balance is an internal sensory experience, intimately connected to our proprioceptive awareness and interoceptive sensations. Proprioception is the sense of body in space and the various pressures, tensions or lack of e.g. feelings of "gravity, magnetism or inertia" (Brigid M. Costello, 2018, p. 35); and interoception is the mind-gut connection, the awareness of gut feeling or intuition. Interoception has much to do with

motion and emotions, for example, daily routines, social interactions and dietary intake: food and medicine.

For those living in cities and urban areas, food is obtained from supermarkets or grocers which are usually picked from shelves or containers. These movements, for the most part, are quite general and do not require training. They do not strain our modalities as the product name is often clearly labelled, the structure of the supermarket usually has rows and signs, and the products are usually within reach. However, the affordances are primarily visual and demand the ability to stand and reach to about two meters from the ground.

However, when harvesting from a garden or foraging in an open terrestrial area, the plant foods are either dug up from the ground, or picked from plants, bushes or trees. Moreover, when foraging, we find our food where it grows. Foraging requires us to interact with and respond to our environment by looking around, reaching out, squatting, and picking our food. Many of us, even in urban areas and cities, pick mushrooms, berries and edible greens. This act of looking around and reaching out to access nutrition in relationship with the immediate environment, is the basis of our human-planet interaction and establishing broad-spectrum general movements.

This action of reaching out and of selecting is much like the actions we do when interacting with touch devices. While we are not taking things directly from our phone, we are selecting or picking things, much as we would a mushroom or berry. The way we hold our phones, as we might pick up a potato. Our hands adapt to the things we pick and reach for, or in other words: “we creatively, dynamically, adjust our movements to the situations, tools, and practices of our culture” (Kristina Höök, 2018). However, the elements in the phone are intangible, we cannot feel them. We only feel, or tacitly respond to, the smooth hard surface of the touchscreen.

4. Methodology

Making devices for our bodies is to make for our sensory experiences, and in turn cultivating an awareness and appreciation of 'body knowledge'. As bringing our sensory experiences into co-making our devices is a relatively new field in HTI, this work adopts exploratory methodologies: "Often, when a research topic is new, it is important to start with a research method that can be utilized in a more exploratory way -- such as surveys, interviews, focus groups and ethnography." (Jonathan Lazar et al., 2017: p. 14). The methods adopted in the microstudies integrate these approaches with modifications to better suit co-making interactions. For example:

- interviews become discussions, dialogues or exchanges
- surveys are for self-assessment of abilities and experiences
- questionnaires are for participants to develop a keener sense of self-awareness (through interoception questionnaires).

For the interviews and surveys, participants also checked and verified the notes made on their behalf, and could make changes to clarify their meaning and intent. Participant diaries were also adopted, in the first study, participants recorded their experiences in writing.

Co-making devices is both the process of making artifacts and establishing responsive methodologies. In HTI papers, artifact contributions are "the design and development of new artifacts, including interfaces, toolkits, and architectures, mock-ups, and 'envisionments.'" (Jonathan Lazar et al., 2017: p. 2). While methodological contributions are "new approaches that influence processes in research or practice, such as a new method, new application of a method, modification of a method, or a new metric or instrument for measurement." (Jonathan Lazar et al., 2017: p. 3). In co-making processes, artifact co-making methodologies are interlaced with the sensory experiences of the participant. They make their devices by responding to the affordances of the environment, materials and their bodies.

This way of sketching and prototyping makes space for bodily expression of making, such as in sculpting clay. This way, sketching becomes "closely intertwined with our experiences and hands-on explorations" (Anna Ståhl et al., 2017). From sketching, we arrive at prototyping "the most effective way for users to evaluate such designs is to interact with them" (Helen Sharp et al., 2019). However, for these microstudies, the idea was to interact with, respond to and, in a way, get-to-know different materials through body-material affordances.

These body-material experiences become internalised through processes of discovery and exploration, which is in contrast to instructive design based on being told what shape to draw and how. Instead, by feeling the body-material affordances, participants feel and experience the shape or form and viscerally respond to it. To get-to-know a form is to discover what it means to you through one's own body knowledge, or somatic experience. Therefore, we aim to meet Kristina Höök's (2018) challenge to identify interdependencies between bodies and elements by cultivating "somaesthetics sensibilities" to "better and more deliberately shape the space of movements invited by technologies" and invite "more meaningful interactions with our lifeworld". By giving space for and value to bodily interactions and experiences, we contribute to the study of interdependence of bodies and interfaces through body-centred experiential and interactive methodologies. From this point of experience or body-centred design, the International Organisation of Standards definition of human-centred design is: "Human-centred design approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques" (2019). I find the IOS definition lacks explicit statements that value bodily experience. Instead it focuses on systems being usable in use cases. While ergonomics is mentioned, there is no explicit statement of the body and its relationship with devices. The design of our everyday items are reduced to "use" and abstract functionality of "ergonomics". There is no mention of body, sensations nor sensory experiences. The cultural integration, involvement, or interaction with devices is not given primacy nor explicitly stated in the definition of human-centred design. Use cases are always embedded in cultures and occur in environments. Responding to the culture, and involving those who are around us, is how we bring about forms, shapes and meaning through bodily experiential design. Therefore, what they seem to be saying is that human-centred design is based on the direct causal mechanisms of physiological human performance in specific use cases of a given element, this is without recognition of the process of evolution or development through everyday use. The intimate process of becoming through making or getting-to-know through experience is very much part of designing for everyday use.

Moreover, it is the process of change, or adaptation, in contrast to "updating" or "improvement", can avoid monotony and tedium. Also, embedding rhythms into systems provide opportunities for entrainment through regular use. In turn, these rhythms become internalised, making them predictive. Adaptive and predictive rhythms can afford relational and responsive interactions to a system. Consistent, predictive and expectant change can also reduce repetitiveness and monotonous mechanical activity, while providing conditions for adaptation and change. Such environments are based on our cyclical planetary rhythms, such as day and night or seasons. The human body relies on

cyclical events, patterns and rhythms to regulate itself. Our computer and social systems are built on our bodily needs, thus designing devices and systems we interact with everyday should be no different.
In some way our devices are an extension of our sensory capacity, or ability, to sense our environment. And just as we are always changing, adapting and moving, so to can our devices. The idea of a completed design ready for mass scale production is slowly becoming redundant. Already we have small-scale adaptive fabrication with 3D printers, knitting machines, CNC drilling machines and laser cutters. Therefore, our methodology can now afford a sense of adaptability through incompleteness and impermanence. Industrial demands of completion can be replaced with responsive systems of completeness through interaction with current environment and available resources. We can begin to redefine what is ready, complete and finished, and establish what is doable, workable and usable in new incomplete cyclical adaptive systems. As highlighted in Anna Ståhl's et al. (2017) paper, exploring interaction sketching processes from a forest: "the everchanging nature of the forest resembled the dynamic nature of interaction design".

4.1 Direction

Integrating the body into meaningful experiences with our devices, and acknowledging and valuing lived and living experiences as a process. The direction is to identify and express the meanings of our feelings, which encompass both sensory and emotional information in a given context. The three microstudies, later described, continue the work of integrating both the internal and external gaze, and thus to fuse both interoceptive and exteroceptive modalities. The study on responsive bodies, 'What shape are you?', is not only an experience for participants, but is also an exploration of my own internal and external observations, both observing the participant, as well as my own internal sensations. While in the two following Stone Balancing microstudies, I was out of the room while the participant was stone balancing. The first stone balancing microstudies was conducted in office lighting (SBOL) and the second was in the dark (SBD) with glow in the dark stones. SBOL was a microstudy to explore sensory-based interactions resulting in an investigation of *completeness*. Completeness is condition of readiness, i.e. when the desired intent has been attained or when all the required pieces have been put together. It can also be understood as a sensation or emotion, such as satisfaction, appreciation or rumination; alternatively, at the end of a conversation. Completeness can also be expressed as readiness in prolonged work processes, such as when a painting or an essay is ready.
Following the SBOL study, Stone Balancing in the Dark (SBD) provided participants with a low-sensory environment. In this environment, they participated in stone balancing with

glow-in-the-dark stones. While all the microstudies incorporated touch and movement, the first two studies mainly attended to external interactions with material devices (i.e. non-digital interfaces) and gaze, rather than our own internal sensory experiences. However, over the duration of the three microstudies, the emphasis of internal sensory experiences became increasingly apparent. The studies went from looking around and touching or holding, towards an inward gaze and into the realm of internal sensory awareness: proprioception and interception. And the gaze technology, while providing me with the participants view of their experience, it also gave me a reason to ask people to remove their glasses. Because when looking out, one is not looking in.

Working within an academic culture there is a strong demand for visual acuity for reading and writing, which is nowadays compounded by excessive computer use, bright screens and smartphones, therefore there is an increasing trend in using corrective lenses. It is a ubiquitous trend, and the increasing number of people who wear glasses is evidence of an imbalance in our places of learning, educational tools, digital technologies, and learning practices. In 2018, the Finnish Association of Vision and Eyecare (NÄE ry) reported an increase in sales of spectacles, while the prices of such eyewear declined (NÄE Ry, 2018). Moreover, increases in cases of depression are evidence of an overall lack of emotional wellbeing in our communities, including educational and academic communities (Teija Honkonen and Raija Gould, 2011). We have built world for the head and hands, while the rest of the body and the institution serves the head.

This is a world of the rational, statistical relevance, critical thinking, reading fine print and typing away at keyboards while staring at screens. Though, as I am studying Human-Technology Interaction, and have enough space to explore bodily wayfinding and responsive pathways, as there is appreciation and recognition for the body, senses and living experiences. For example, by working through multimodal interactions, and the utilisation of a greater variety of devices and mediums that require more body movement and interaction. Yet I am still very much aware of the academic preference to discrete textual, mathematical and statistical evidence as notions of truth, as opposed to body expressions of sensory experience.

However, all studies are made by people, questionnaires are devised by people and interpretations are made by people, all coming from individual lived experiences and perspectives. The inclusion of our culture, habits and routines influence research anyway, so they should have a visible place in science and research. For instance, the way the body is omitted from VR experiences is problematic, similarly the secondary place of body through regular computer use and challenging breathing through lack of rhythmic expression in interaction design. Bringing the body and breathing to the forefront is found in works of indigenous science, or Traditional Ecological Knowledge (TEK), and

other ways of knowing, for instance through storytelling. Highlighting the need to experience interaction, to create environments where feelings and sensations matter. During these studies I also developed a more finely tuned emotional awareness through uncertainty, for example, when interacting with unfamiliar people. I did not want to project my own discomfort onto my participants through emotional detachment, however some discomfort was to be expected. Unresponsive detachment and rigorous control generates objective-subjective dualism, and I did not want to drive the participant in the position of the subjective, the one who does the emotional work, which in turn forces me to play the objective, the one who is emotionally detached. Instead I sought out an equilibrium, an integrity, a tension and pace that suits both myself and, as far as I was aware, the participant. Ultimately, becoming responsive to uncertainty, as opposed to reactive or detached, afforded for more reciprocal and interactive relationships with the participants.

Initially, the microstudies were to be pilot studies to be followed up by larger studies. However, over time, I realised the microstudies were sufficient for the purposes of this work. Microstudies gave me the experience, as well as a collection of small data, I needed to familiarise myself with to do such work, instead of just forcing myself to follow the rules, I wanted to get-to-know sciencing and researching through sensory-responsive living experiences, as one might experience an unfamiliar culture and language. The most valuable lesson was to better know myself in these unfamiliar situations, and learn to live with a greater sense of uncertainty.

4.2 Discovery

The three microstudies were designed to discover shapes and rhythms through interaction and experience. Each study was a process of discovery, where movement and rhythms adapt to the interface. Thus, giving space to comment on existing interfaces and to inspire change for future requirements that suit the community. The involvement of the community in technology development is necessary to make technology for ourselves and each other. But before we design for ourselves, we must first get to know the materials and life around us.

Stones, bones and plants made our first technologies, and they still do today. Bringing something from the natural world into our cities and urban lives implies that we are apart, or separate, from nature, and that our systems are unnatural. For the most part this is often how industry associates with materials coming from forests, deserts and other non-constructed, but rather grown spaces. Stones are split or cut for garden paths and trees into planks for frames in buildings or to imprison a painting. The bigger the city the rarer it is to encounter stones and plants as you might find them in forests or jungles, and

even less so is an intimate body-material interaction with them. Only to walk on them over pathways, admire their decorative attributes or something to build with for our shelters (Val Plumwood, 2007, p. 20).

The associations we have with materials comes from our experience with them. The way in which we interact with the materials forms in-body memories through entrainment and internalisation. In addition to touch and body motion, entraining and internalising information from our environment also relies on both peripheral and central vision: "information from peripheral objects affect human gaze targeting in natural vision" (Elena Hitzel et al., 2015). At present our technologies rely on our ability to experience mainly through central (forward) vision. This leaves the rest of our senses and modalities neglected and severely lacking in sensory nourishment.

The microstudies explore sensations and modalities through two main types of activities: (1) responsive bodies in an environment that explores texture, shape and space, and (2) stone balancing in both office lighting and in the dark. The study for the responsive bodies included five crafted interfaces which I either made or assembled (Figure 4, p. 37), plus one clay shaping task. Participants touch and feel different materials, as well as comment on them with sticky notes. The sensory and bodily experiences of the participants engage the body in its entirety, and not just the hands and eyes typical of reading and writing education systems. While in several activities involved touching with hands, only three out of five involved sitting in chairs or sofas. One was on the floor and the other required standing and looking around.

The two stone balancing studies only involved one activity: stone balancing. The interaction required hand-eye coordination, but it allowed a broad range of abilities without limiting participants with expectations of results nor restrictive goals. Participants were given space to discover their stone arrangements for themselves based on their individual ability. The difference between the two stone balancing studies was that the first one was in office lighting and the second was in the dark. The exploration of stone balancing in the dark reduced visual distractions from other things in the lab, also the participant's own body was not visible. This may induce a proprioceptive awareness, i.e. the internal awareness of the position or placement of our body, especially limbs, in space.

Just as wet clay changes form and texture as we shape, we make rhythms through our movement and feelings, and in turn we become changed through the experience. The form of the clay is the outcome of the rhythm and patterns of our movement. While we in turn internalise the experience.

4.3 Sensory Experiences

Through the shape and form of our bodies in an environment is how we experience. In the same way, pressure changes the size and shape of the eyes, and thus our visual perception. We are in a constant coexisting relationship with the environment. A way to experience this is to take a stone, and roll it on a surface. Each stone will make a unique sound or auditory pattern, each sound will change slightly depending on which parts of the shape rotate on the surface. The sound is the voice of your interaction with the stone in the environment, because it was you that rolled the stone on the surface. The same thing happens to our bodies as we tread on a surface or move through a space. We make patterns in sound and air by our movement. The rhythm of our breath is much like the frequency of the frame rate of a moving image. Our perception is our individual experience, it is what we perceive through each breath, each heartbeat. This respiratory rate, or sinus rhythm, is supported by our breathing muscles, internal systems, and supported by the culture we practise. Our sense of interoception informs our experiences, thus our choices (Sarah N. Garfinkel et al., 2016; Sarah Garfinkel et al., 2019).
And to consider our visual senses, they are very much in relationship to our auditory sense, therefore, vibro-sensations of touch. The peripheral visual sense is to the sides of our head, reaching back by the ears, while our hearing can reach behind us. However, in the present day technological, academic and formal educational climate, all our devices only support narrow forward central visual sense; in short, what is directly in front of us. Our digital interfaces, with which we produce and interact with content, do not support atmospheric audition nor peripheral visual experiences, let alone a diverse range of body-material sensory input.
However, indoor environments are typically in direct contrast to being outside. In the weather there is wind, air pressure fluctuates, there is always motion, or turbulence, in the air outside. This motion of air traverses across any exposed skin, breathing feels supported on a breezy day. This is unlike being indoors, where air is stagnant, stale and immobile. Just as our indoor environments typically have poor ventilation, our indoor living systems do not circulate. There is just a pipeline, from in to out; or, in computational terms input and output. It lacks sensory feedback, turbulent ventilation, as well as circular economies and systems.
From studies and research carried out on dyspnoea since the 1980s, it has been established “the use of a fan to project air onto the face (at room temperature) has been shown to relieve dyspnoea patients meeting the definition of ‘chronic breathlessness’” (Sarah Galbraith et al., 2010; Sara Booth et al., 2016; Capucine Morélot-Panzini, 2017). From this we can understand how air motion assists breathing, and our indoor spaces

need to sustain air circulation, not merely ventilation, as they do at present. It is in motion where we grow communities and work together, not in stagnant, motionlessness. Alternatively, the bounce of a rubber ball offers a clue into how we can understand sensory feedback. It is an immediate response. Unlike a throw, the bounce is achieved from a fall resulting in an immediate incline. The bounce also offers a coherent point where fall and incline meet: when the ball hits the floor. However, the motion of turbulence has no "floor", it has no (or very little) resistance. While turbulence in the air is the result of the loss and gain of air pressure that turbulence relies on to make waves and vortices. As birds and fish ride the waves in air and water, respectively, birds, boats and surfers also can float on the water, and exist in both, bobbing up and down; evidence of the changes in pressure. Though one can see the changes on the water, to know the changes of pressure in the air, we must feel it, we call this feeling 'the wind'. It is oxygen that permeates our existence, and it is natural variation in pressure that supports it. It is from this interdependent relationship of air and water where we explore the interdependence of shape and rhythm, or form and movement.

4.4 Small Data

Before beginning the microstudies, I wanted to develop a method that could work within my local immediate community, in this case the university's centre campus. Within this environment, I advertised the study with posters, word of mouth or email, and asking directly. I interacted with, involve and reached out to newcomers, the local LGBTI (Lesbian Gay Bisexual Transgender Intersex) community and people in my department, course and university. Gathering small local data must involve people from diverse backgrounds, especially those who may not slip into the mainstream. Also, reaching out to people who belong to local groups and communities can help to connect with them. Some of the limits were my own language and (some) social limitations, as it takes me a long time to get to know people and be able to work with them. So, while I want to reach out to potential participants for this study, I also need to consider my own limits.
This working methodology and collection of small data can be applied when working with small local communities. Instead of demanding large sample sizes, we can get to know participants non-invasively and, more or less, on their terms, or at the very least in mutual understanding and agreement. Gathering small data and attending to each participant aims to directly serve the actual people whom you are making something with and for. Moreover, keeping in regular contact with lots of people by means of mass emails, surveys and social media advertising feels ingenuine, superficial, and insincere. Making interfaces for a specific community, mainly requires the experiences of that community. It would also be especially important to include those who get lost in the

crowd, for example, newcomers, extreme cases and non-dominant groups, these people are crucial to be able to provide a complete and comprehensive picture of the population (Kat Ely, 2015; Rose Eveleth, 2019). Then as the interface or system develops, invite more people to participate in ongoing microstudies as the "word gets around" and as the system needs updating.

One of the reasons I worked with this method is that I wanted to avoid the dominant objective position, as well as challenge the historical methods of ethnography and anthropology; where researchers do not acknowledge their own cultural standpoint and established their background, but instead place themselves in an artificial place of authority to analyse other people. For example, "Research conducted without consent and outside a collaborative framework, no matter how well intended, can be a form of colonialism that disregards pre-existing knowledge, potentially harming Indigenous peoples." (Natalie C. Ban et al., 2018). Therefore, this work included diaries, surveys, questionnaires and free form writing, and for many of the participants, English was not their first or home language. It was also important that the participants could understand the activities and provide informed consent. At the same time, I also need to consider my own limitations to set my own boundaries and establish reciprocal ways of working.

For the responsive bodies study 'What shape are you?', I invited participants mainly by putting posters around the university, as well as on an LGBTI community website (Figure 2, p. 31). It was important to find people who do not identify by traditional demographics, but might be implicitly restricted by them, and rather self-identify by their interests and associations. Or people who might feel underrepresented in the local community, and have limited to no access to make or influence the technology they use daily.

Figure 2. Poster for the responsive bodies study 'What shape are you?", exploring sensations, shape and space.

For the stone balancing studies, I wanted to stay close to home as I felt I needed more interaction-based expertise for the feedback. I mainly asked other HTI researchers and students, as well as a few other people at the university whom I knew would provide thoughtful and unique insights into their lived experiences. For the stone balancing studies, it was important that I knew the people well enough that they would be fair minded yet still critical of the study, but not too familiar that they might be too mindful of my feelings.

In future, processes in gathering small data would also support co-authorship and co-researching practices with participants, where they could attain responsibility and ownership of their contribution. However, for these three microstudies all the participants remained anonymous and their participation was completely voluntary. Voluntary participation was demonstrated by completing a consent form which included statements regarding the duration of the study and that they may stop at any time during the study. Moreover, at the beginning of each activity session, I also verbally informed the participant that they may stop at any time, and that I gave enough emotional and physical space to make this choice for themselves at any point during their participation. This, however, can be difficult to gauge, so instead, as moderator it can be sufficient to offer enough opportunities for the participants to make their own decisions regarding their own body and limits.

5. Microstudies

Our bodies respond to the environment and to the interfaces we interact with. We are always in relationship to material and our bodies are always interfacing with material. In order to focus on the relationship of body, movement and material with devices and environment, the three microstudies investigate the interaction of interfaces without digitisation. Here space, movement and shape are explored in relationship through interactions of touch, holding and movement. The space where experience, making, and multimodal internalisation happen, is in an atmosphere with a variety of materials that fill space: what we call *air*. As our cities are filled with self-similar square-like grids, buildings and houses full of 90° angles, books are rectangular, bookshelves to fit such books are also rectangular. Everything is based on rigid forms and beliefs of geometric figuring; solidified by three-dimensional beliefs of space and emotionally detached relationship and interaction with place and people.

The community who I was conducting the microstudies with where people in my immediate environment, namely, those in or related to the TAUCHI unit at Tampere University. Moreover, within the academic environment many people require corrective lenses to alleviate, for example, blurred vision. This is typical in working environments where the main methods of absorbing and producing content demand repetitive and high-precision hand-eye coordinated movement on high-precision interfaces such as working on computers with a keyboard and mouse, as well as reading and writing. In every study at least two participants wore corrective lenses regularly.

Regarding the procedure the microstudies, I moderated each of the microstudies and only one participant attended at a time. Before the workshop or activity, I communicated with each participant by email, giving them an outline of the study, tasks they needed to do before or during the workshop or activity, and a consent form. On the day of the workshop or activity, I would welcome the participant and inform them of the activities: surveys, tasks and/or questionnaires, and would then answer any questions they had. They then did the activities in the prescribed order. For the study on responsive bodies, ‘What is your shape’, the participant and I corresponded by email where I provided information, guidelines and the consent form; they wrote a pre-workshop three-day diary, then participated in a workshop, and finally wrote a post-workshop three-day diary. While for the stone balancing studies, we similarly corresponded by email where I provided information, guidelines and the consent form, they then participated in the stone balancing activities, then completed the optional questionnaires independently over the following days. More details on the microstudies will be described in the following sub-sections.

Because of the small scale of this study, with 3, 6 and 5 participants respectively, small data was more interesting when it came to finding methodology, responsive interfacing and relationship, as opposed to big data with its complex analytics and broad sweeping conclusions. Microstudies are attentive to each participant while also understanding the likely inferences we can make between different bodies and possible interactions when interfacing. However, because of the interdependent relationship required to conduct such studies, I needed to put the data 'on ice' — an essay writing technique referred to as ice-boxing:

> *"'ice-boxing' the essay, that is, putting it aside for a period of time to allow you to gain some distance from it. From this distance, you may come to new realisations about yourself or the topic you're discussing"*
>
> Jennifer Cognard-Black, 2016, p. 68

This process of *ice boxing* gave me the time to distance myself from the interrelation experience of conducting such a study. Therefore, the emotions I might have had regarding the study and participants would have long settled, because no matter how we think we feel, we always have feelings towards other people and situations. By putting the results "on ice", I felt that after a while these feelings settled, and I could then attend to the data with clarity and a more complete sense of the studies. As at this point, all the participants have completed their activities and I could look at all the results in the same session to identify interdependencies and relationships between the experiences and interactions of each participant in relation to each other, as well as their respective environments. I then reviewed the data and made visualisations to present the results as seen in the 'Findings' sections for each microstudy: 'What shape are you?', 'Stone Balancing' (in Office Lighting), and 'Stone Balancing in the Dark'. Each of these microstudies are further divided into the following sub-sections: Setup, Procedure, and finally, Findings.

5.1 Responsive Bodies

Responsive bodies is about acknowledging how bodies respond to and interact with our environment, including "micro-level factors such as the specific location or interaction with surrounding elements" (Anna Ståhl et al., 2017). Additionally, it comprises the way the people and materials around us respond to and interact with us as moderators or scientists, and each other. The interdependent relationship between ourselves, each other and material, as well as environment, is the keystone of human-technology interaction. The affordances of material inform our movement as we shape material and it, in turn, shapes us. The ability to touch, hold and move devices, interfaces and pieces of material

connect the body directly to the material. This variation in material is in response to the limited materiality, e.g. textures and shape, in digital content, such as with smooth touchscreens which rely on visual-touch interaction, or press-button phones.
This microstudy of responsive bodies was titled ‘What shape are you?’. To ensure broader diversity among the participants, posters were put up around the university, and promoted through two online digital channels: the student union (TREY) and the local LGBTI community, SETA Ry.
This study is also an exploration and attendance of my own internal and external experiences (i.e. observations) as moderator. Being able to attend to my own sensory experience, while attending to the participant, is the work of moderating a sensorial responsive study. Here, there is no emotionally detached objective view, but rather it is about sharing space, visibly articulating the tasks and guidelines (including that they can stop and leave at any time), and responding to questions.
From here the participant has a sense of what is expected, can progress through tasks and also knows that they can stop and leave at any time. Their presence, participation and their attention to the tasks is also appreciated, especially as they have made time to participate in the workshop. This is very important to offer appreciation and gratitude and at least attempt to establish an environment where participants feel appreciated and valued. As participants are not subjects to be discretely numerised and objectively studied or observed, they are people who have sensory experiences.

I Setup

For **Microstudy 1: ‘What Shape are You?’**, the space in which this study was situated is called *Olohuone* in Suomi (Finnish), and directly translates to ‘living room’. Olohuone is designed to sustain feelings of restful activity, or *rauha*. In comparison to the lab, i.e. a place intended to be void of feeling or emotion.

Figure 3. Olohuone (Living Room) with five hexagon-based material interfaces and one interface sculpting activity.

The shape of the Olohuone was rectangular, there was a mix of soft furniture such as sofas and exercise balls, as well as hard chairs, tables and coffee tables. Also, large windows extended the view from within the space into the hallway, revealing what is beyond the immediate environment. It was a mishmash of different furniture, and textiles, along with the hand-made interfaces placed in the room.
Each of the interfaces were all centred around the idea of hexagons, organic systems, body knowledge, and sensory experiences, and none of them were electronically interactive. These interfaces created a kind of alternative geometry to the normalised and standard practice to produce right angles, and square and rectangular shapes. The five material interfaces were: Bubbles, Whiteboard, Rubber Mat, Projection Tent and Pieces (Figure 4 and Table 1).

Figure 4. Bubbles (top left), Whiteboard (bottom left), Projection Tent (middle), Rubber Mat (top right), and Pieces (bottom right).

Table 1. Descriptions of the five interfaces, as shown in Figure 4.

• ***Bubbles*** **is an interface made with bubble wrap and a wooden hexagonal frame. The air-filled plastic hemispheres are arranged in a hexagonal-packed array, providing a body-material interaction.**
• ***Whiteboard*** **utilises a whiteboard plastic film framed with cardboard taped over with aluminium tape. Suitable for writing, drawing and erasing.**
• ***Rubber Mat*** **is made from bike tubes cut into rubber strips. Each diamond/trapezium could represent a button or a sensor. The triaxial rubber weave is durable and flexible.**
• ***Projection Tent*** **affords 360° viewing to support peripheral vision, body rotation and motion, as well as some arm motion and gestures. The fabric is flexible to afford touch and stretch body-material experiences.**
• ***Pieces*** **are useful for generating button or sensor arrangements that suit individuals and communities, the size of the pieces are appropriate for many hand sizes, as well as various levels of visual acuity and hand-eye coordination.**

II Procedure

Pre-Workshop Correspondence and Consent, and 3-day Diaries

I alone moderated the microstudy and only one of the three participants attended at a time, usually on different days. Before agreeing on a suitable day of the workshop, I corresponded with each participant by email, giving them an outline of the study, tasks they needed to do before, during and after the workshop, as well as the consent form. The study was entirely conducted in English, but were suggested to use words in their other language(s) if the English words did not surface. Before the workshop, they wrote a pre-workshop 3-day diary (see Appendix for more detail). There was no main unifying focus resulting in their own interpretation of their lived experience. Prompts were offered to consider the following:

- the shapes you interact with
- the rhythms you perform
- how you feel (both emotionally and physically)
- how (your) gender is represented or valued (gender diversity and inclusivity)
- how your way of thinking is represented or valued (neurodiversity)

Then they participated in the workshop, and afterwards wrote a post-workshop 3-day diary.

Workshop

On the day of the workshop, I welcomed the participant and informed them of the six tasks, and would also respond to any questions they had. They then went through the tasks in the prescribed order. During the workshop, the moderator, myself, was present and available to answer questions and provide some guidance throughout the experience. After going through Bubbles, Whiteboard, Projection Tent, Rubber Mat, and Pieces, the participant then shaped their interface out of self-drying clay. While they were shaping it, we would discuss the theme of the study. It was an open discussion were ideas and questions were exchanged and responded to. Once they felt that the interface was ready, I would put away the interface to dry in a locked cupboard, and check it a few days later.

Follow Up

After some weeks, I followed up with the participants. Two out of the three were available for follow up. We discussed the shape of their device, I asked unplanned responsive questions which they responded. I wrote down their responses and asked for confirmation if what I wrote was what they meant. We made some edits to the responses until they felt their intended meaning was expressed in the text I wrote.

Modelling
After the follow up, I made silicon moulds of their interfaces and returned the original clay models. From the silicon moulds, I used foam clay to make soft light foam models of their interfaces. These can be used later for demos or examples of alternative forms of interfaces.

III Findings
'What shape are you?' offers alternative environments to the established industrial architecture of the last 100-200 years. In this space we craft and sculpt shapes to suit ourselves and each other. In this study, 'What shape are you?', there was no singular overall thought, but rather a mix of feelings and experiences, individual to each participant. While each of them where university students working through their degrees, their perspectives where unique to their sensory experience. The main outcome, however, was the observation that they each were able to complete the final sculpting activity and were able to identify when it was complete. From this point we come to the following studies of Stone Balancing, in order to begin to discover what is it that helps us decide when something is ready, i.e. complete or finished.
To recap the study, three people participated in **Microstudy 1: 'What shape are you?'**, all of whom were students at the university. The main activity took 90 minutes, in addition participants kept a diary both three days before and three days after the workshop. The data collected included photos of comments left by or on interfaces (list of interfaces: Table 1, p. 37) (in the form of sticky notes), the sticky notes, photos of the handmade model, audio and transcript of comments on the projection tent.

Participant Diaries
In the participants' diaries they gave descriptions of their feelings, use and lived experiences of their everyday interaction with technology. All three participants used digital technology daily and were quite familiar with navigating the internet and using apps (Table 2).

Table 2. Table showing participant digital technology usage from diary entries.

	P0	P1	P2
Devices	smartphone, iPad, Nintendo 3DS, PC, Bamboo Fun Pen	phone, pebble smartwatch, Bluetooth earphones, iPod	Android smartphone, laptop
Apps/Games	pokémon sun Revolut Camera STEAM (The Witcher) Adobe Acrobat Word Bamboo Dock CLIP STUDIO Music player	Whatsapp Messenger Alarm Instagram Phone lock Notifications Music player	Facebook Instagram Snapchat Email Calls
Web services	Reittiopas, Gmail, Onnibus Calendar, University website, Moodle, Facebook, Foreca (weather), Yle Areena, Zalando, Reddit, Wizards.com, YouTube	Weather, Time, Bus service, YouTube, Google Maps	Facebook, Dropbox

To recap the prompts for the pre- and post-activity 3-day diaries were: shapes, rhythms, feelings, gender diversity and neurodiversity. Figure 5 (below) illustrates the frequency of each prompt within the diaries. The method of analysis depended somewhat on the writer's style, but in general text chunks on the same topic where counted as one. For example, whole sentences or several consecutive sentences on the same topic could include one or several prompts. For example, here the prompts *feelings* and *shapes* are both relevant:

> *Sometimes I would like them to be a bit more uplifting. For me this is more about color but it could be about shape as well – like I already pointed out before I like circles. This also reminds me to note in this diary that I hate triangles. I avoid using triangles in my home or on my clothes. I think it feels too sharp but I don't know why.*

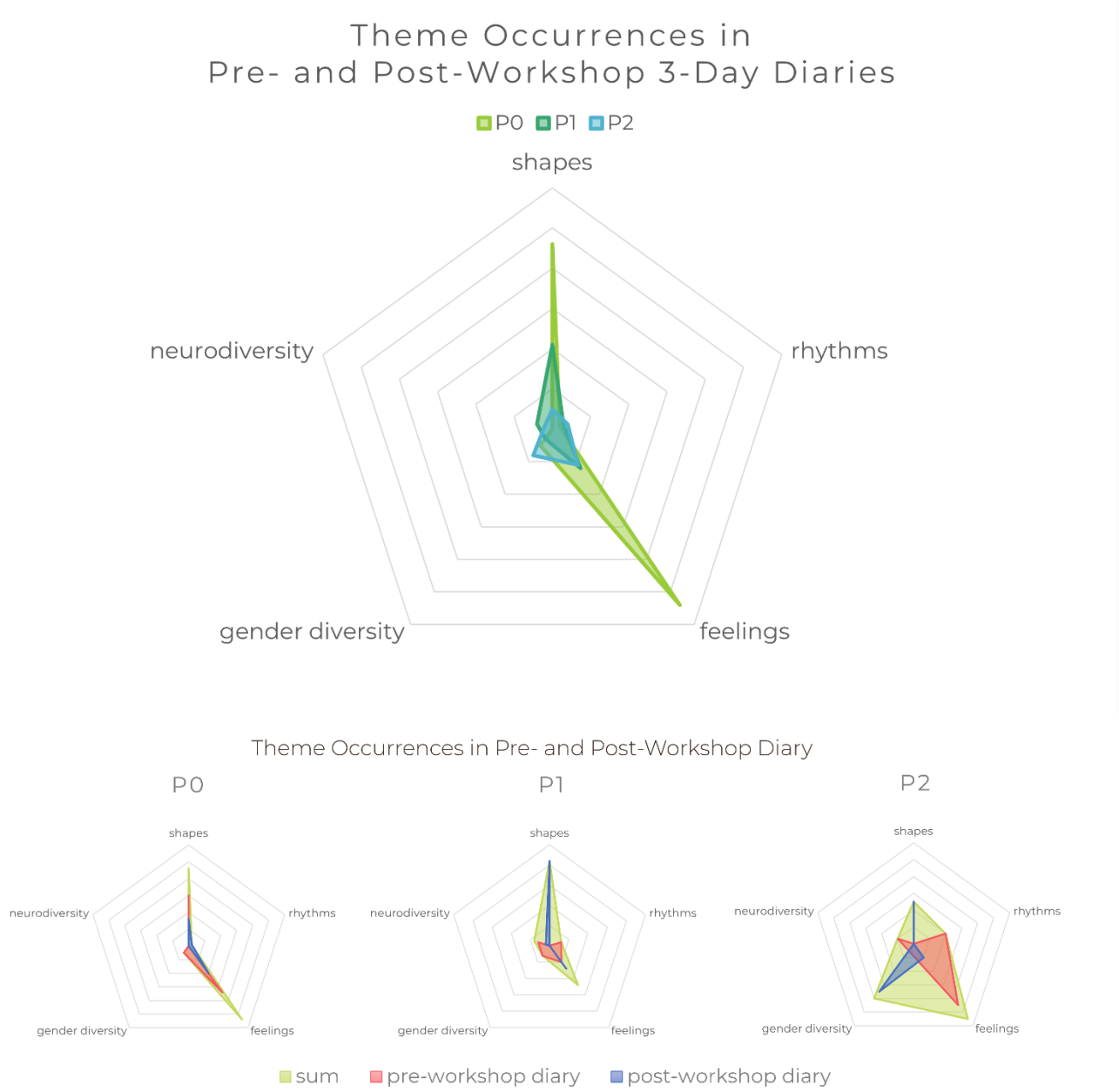

Figure 5. The number of times the themes (shapes, rhythms, feelings, gender diversity and neurodiversity) were mentioned in the pre- and post-activity diaries.

The occurrences when the themes were mentioned or referred to demonstrated that participants were awareness of the themes presented. It also hints to what the participants are being exposed to or immersed in. Here are some of the participants' observations according to each theme:

SHAPES involved identifying the shapes in the environment, here one participant consistently noted the shapes, while two of the participants focused more on the shapes after the post-activity diary.

> " *When I walked home afterwards, I realised that I was looking at almost everything and wondering why it is the shape that it is.*

" *an extension from yesterday(?), am paying more attention to the shapes of things as they happen, but as the day passes by, i'm reflecting more after the fact*

RHYTHMS are identified when participants interpreted rhythm as either their personal rhythm of activity or as a beat as in music. Though there seems to be difficulty being able to analyse them.

" *I haven't been working according to my usual rhythm and routine during the previous week.*

" *I play a lot of games which always make me feel a range of emotions and rhythms whether they have a clear story or not, or any music.*

" *Still, I can't really analyze the rhythms.*

FEELINGS include a range of emotional-physical, or psychophysiological, feelings.

" *I play a lot of games which always make me feel a range of emotions and rhythms whether they have a clear story or not, or any music. This is especially true with console games since I'm holding the controller and moving myself.*

" *This has actually sometimes lead me to have panic attacks, and therefore I have come to sometimes associate stress with technology because it usually happens when I feel like I'm getting bombarded with messages, emails, and calls. Perhaps this relates somehow to addictive behaviour.*

GENDER DIVERSITY, or gender inclusivity, mainly plays a role in these areas: game character, form filling, online profiles, and when shopping for clothing, footwear or accessories.

" *I tend to view exclusiveness as the norm so it felt relatively inclusive not to have to choose the gender written out, but just based on appearance of the character, although it was quite clear it was binary in any case.*

" *I did not sense any gender exclusiveness or inclusiveness today, apart from the fact that on [the university's course management system] your profile picture is very generic by default, not gendered like on Facebook. You also don't have any field for gender in the profile information which I personally like more than being able to choose the "other" option sometimes present.*

" *Gender inclusiveness is extremely low like on almost all fashion sites, since you have to choose whether you browse "women's clothes" or "men's clothes" and the site even asks whether you are a man or a woman to determine how they market you their clothes when you buy something.*

> *One thing I sometimes notice are questions about gender. I have transgender friends, and not all forms give an option other than 'male' or 'female'.*

NEURODIVERSITY: or mental processes, was the least visible prompt in the diaries. This could be because participants did not know what to look for or they did not have the experience or language to articulate their observations. One participant identified how the apps and websites they visited were function related, thus more about neuro-inclusivity, connecting how function (or doing something), is related more to how they think, than their gender. Disconnecting gender identity or expression to the way they think:

> *...everything is function related, so i think more neuroinclusive than gender inclusive.*

Additionally, another participant did write how experiences with their technology did not match their way of thinking:

> *alarm on smartwatch: i think i've forgotten that long press the down button on the watch triggers the quick launch settings*

Participant Experiences

When interacting with *Bubbles* (Table 1, p. 37), all the participants wanted to pop the bubbles of the bubble wrap, but they each managed to restrain themselves. One participant expressed an interest in trying to make a wooden frame like Bubbles but would paint it black or green, other participants commented on its symmetry, that it was aesthetically pleasing, and the frame's sturdiness.

Two of the three participants used *Whiteboard*, one made a drawing and the other wrote their comments (Figure 6, p. 44). The participant who made the drawing, also expressed a desire to have "a full wall parallel with these", and that it was cold. Another participant also stated that the aluminium taped frame was cold: Cold (aluminium foil).

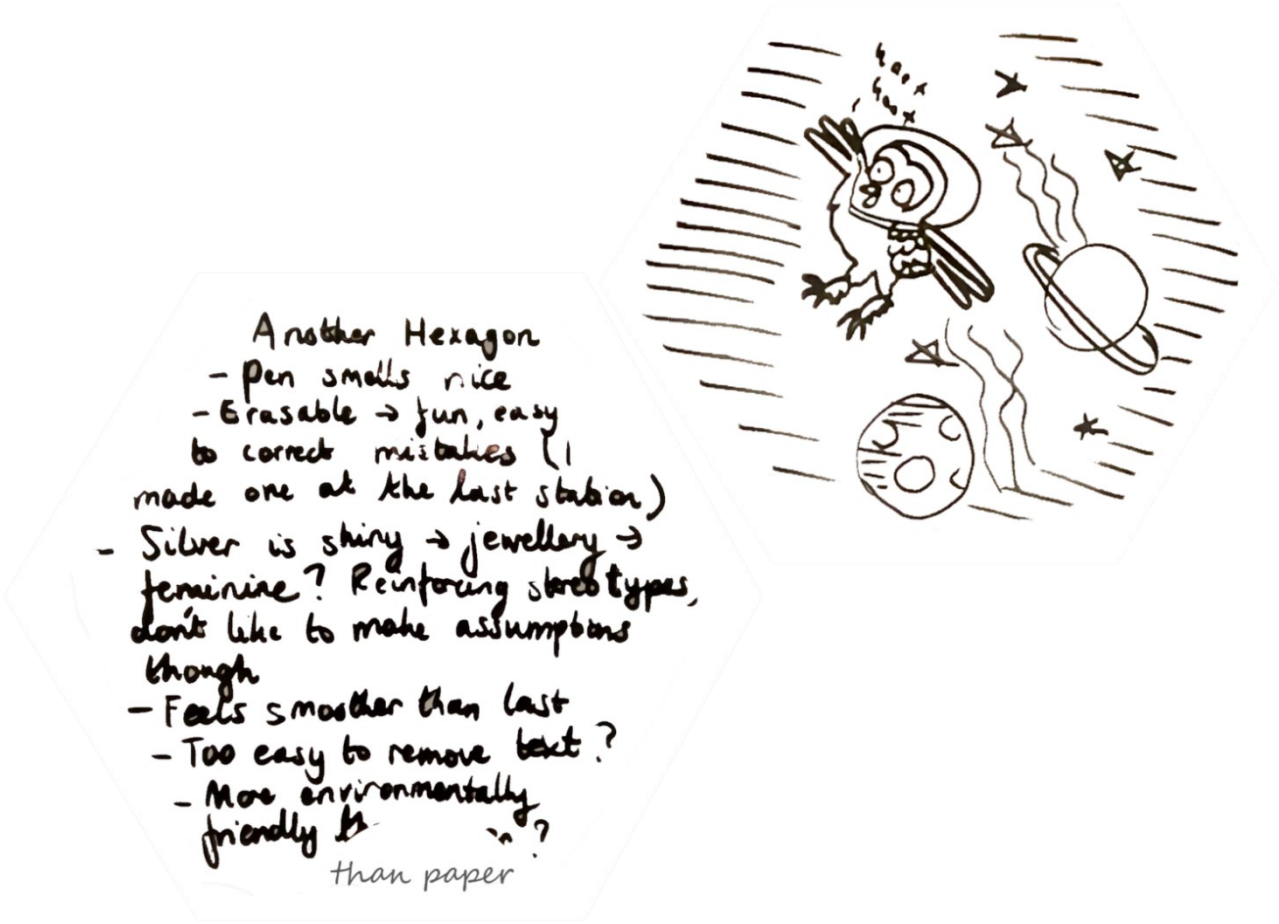

*Figure 6. **Whiteboard** use from two participants (one participant did not draw or write on Whiteboard).*

Rubber Mat was made from reused bicycle tyre tubes brought about some mixed feelings. And questioned what is typically considered to be technology:

> *Technology is probably broader than I think*

> *Not everything has to be perfectly and symmetrically arranged.*

The main problems participants raised with the rubber mat, is the smell, its texture, and the concern if it got hot:

> *Sticky? doesn't feel nice to play with for too long*
> *- the smell*

> *if that burns it will smell really bad and is probably toxic so it's kinda scary*

However, one participant thought it was inspiring:

> *The simplest model gave me the most ideas?*

Perhaps alluding to the number of sticky notes they filled, thirteen, while only four in each of the two previous interfaces.
For *Projection Tent*, participants verbally expressed their thoughts from within the tent. The participants associated both feelings of safety and fear from within the tent:

" *Umm it feels kind of safe. And it's not especially dark. If it was dark maybe it would not feel especially safe.*

" *I think that when the tent moves it kind of gives me a little bit of fear because it might fall down, it feels.*

" *...it is like a soft material an' kind of stretchy, I guess, so but then it is kind of half covered but then not all the way covered, so I'm not completely...well I'm not claustrophobic, but I think if someone was maybe they would be okay in here, and then there is the hole in the front, so I can see people walking past if I wanted to, but then at the same time I'm kind of half exposed, I guess it's positive and negatives, and then there is like a big mirror in front of me which is kind of ah scary because I don't like to look at myself in the mirror that much.*

So perhaps the overall shape is fine, even the somewhat small size was not a problem for the participants. However, the tent would require more stability to reduce anxiety levels while participants moved around the tent or in and out of it. Also reducing the mirror size might make it less prominent or distracting. One participant thought the tent itself was 'kind of beautiful', however the projection setup was 'ugly':

" *I don't know, this thing feels kind of like, in the way, but then it is a necessary thing for the projection to like I don't know it's kind of like ugly, but I think everything else is kind of beautiful, and but I guess it is a necessary part of like ...necessary part of the projection thing...*

This would also need to be considered when refining the setup of the mirrors. Alternatively, as the participant pointed out, we accept the unattractiveness through the necessity of the mirrors.
When participants expressed the kinds of images they would like, they were looking around the tent, imagining what could be there. They painted images with their words:

" *It would be nice if they had a lot of colour*
Except if it's night I guess that's nice too
And ah it would be really pretty if it had some aurora
But I guess it would be nice if it had animals
Like a big picture going around
But then it would be nicer if it was fully round [spherical]
But I guess it could have sections
I could also see it having rain that would be nice
But I guess I feel like it would be something that I would normally see above me because it is above me
Some kind of associating it with the sky

" *Firstly a night sky, that would be..wait..that's kind of why people come here over to Finland...Auroras! *laughing* night sky, auroras...ah what else? Um...falling...wait...meteors [meteors...ok] and the end of the world would be night *laughing* nonnonono...it's just like seeing everything burn around you and yet your still in the same space...that would be an interesting.*

" *I guess what else, kind of images I like in here, something peaceful or like something that feels peaceful, and feels like dark so maybe some space things, like some planets or some stars, something I don't have to think about too much...*

" *...maybe they could project that film in here, that would make me happy because I think that was a really good film. Yeah, I could watch a film in here, if I had a comfy chair.*

Figure 7. A wordcloud of participant suggested experiences for the ***Projection Tent****.*
(Neither the colour, font nor font size bear any statistical significance.)

When playing and interacting with *Pieces* (Figure 8, p. 47), participants noted their observations on sticky-notes provided (Figure 9, p. 47). They noted the "unpleasant" smell and some of the remaining chalk dust (bike tubes have some kind of chalky powder in them). The arrangements can be made into forms, such as the *siili* (the Finnish word for hedgehog), or the Greek infinity symbol. Alternatively, intuitive forms can be arranged without any representation of existing elements or symbols. One participant also expressed their perspective of what is feminine or masculine, e.g. "Masculine tyres

but possible to make into feminine form". Emotions can also be attributed to certain shapes, e.g. "spikes...angry".

Figure 8. Activity 5: These are the arrangements each of the three participants made with ***Pieces****.*

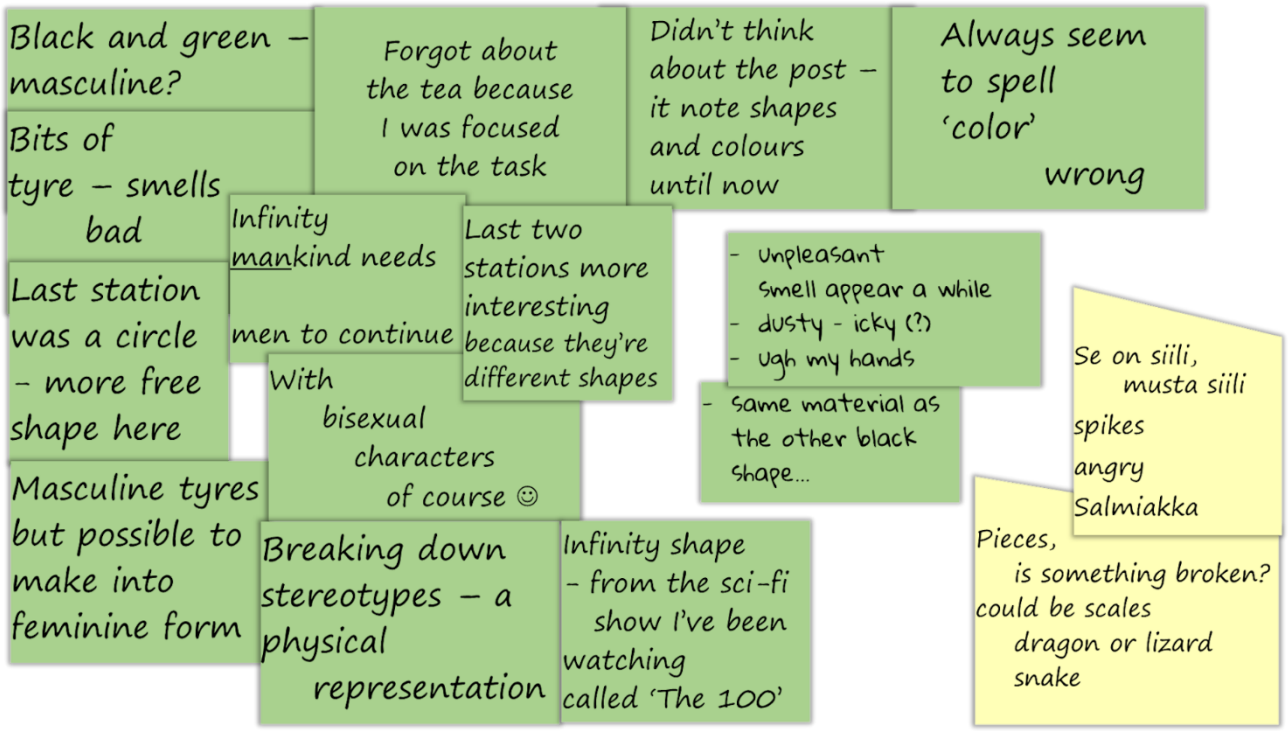

Figure 9. Digital transcriptions of sticky-notes from interactions with ***Pieces****. The type of the note is representative of the shape and colour of the sticky-notes used during the study; two participants had the same type of sticky-notes, so they are differentiated with different handwritten style fonts.*

Follow Up

The findings for the follow up came from a 60-minute interview where I presented them their sculpted device which they could hold and interact with, then I asked questions and they responded, I would then type their responses on the computer, which they would verify or clarify. As the follow up was not based on a survey or pre-written list of questions, the format was more discussive, thus making the questions different and responsive to the situation.

Only participants P1 and P2 where available for the follow up. Participants P1 and P2 had very different shaped devices (see Figure 10, p. 50), P1's shape was cube-like with rounded corners and edges, while P2's shape was circular, inspired by the form of an owl with little ears at the top left and right of the device.

Responses to their sculpted device:

P1 "It's a die. It's a very typical shape, but it's fun to play with." And "When it roles, it sounds like cogs turning."

P2 "I did it round because it is nice to be different, and I put a keypad because I prefer it to the touchscreen."

Here participants interacted with their device and expressed their preferences and their sculpting choices.

Naming their device:

P1 "I don't do that. I don't give names to things."

P2 "Not a fruit. The Owl. Because it knows all and it is so wise, and it thinks about the future."

P1 did not have the need to name their device, but P2's fondness for owls informed the outcome of their device.

Comparisons to existing devices:

P2 "For starters it fits in the pocket. It's small. It will not have a cable for charging. You can fix it yourself. It is multipurpose and when you get bored with it you can change it's parts, or swap them."

P2 identified differences between their sculpted device and the commercially available devices. They also expressed their needs through this responsive process.

Device use case(s):

P1 "it can be used as a device that is used to measure satisfaction level - like when you have surveys there's an alternative for extremely dissatisfied to extremely satisfied. This can be represented with faces / emotions, which can be selected from. So, you pick from them to show how satisfied you are with a product."

P2 "I would like to combine my laptop and phone, and other devices. It is multifaceted, multipurpose. It has many different things, it is like a smartphone, but more. It could be a device for both professional and leisure, a combination for both work and fun. My gadget

will not have shortcuts because it will be so simple, you will just know how to use it. It will move with the natural rhythm of your body."
Here participants explored what could be through use cases that are responsive to their living experiences.

Alterations or other versions of their device:

P1 They would like to change the colour to "Full black or darker grey." and they "Might add a face." Also "If I made a new shape it would not be far off from this shape. Maybe a ball. Then we can build more and play a game of tic-tac-toe"
P2 "It wouldn't have many external buttons, only the indented buttons. It would still be round, which is more practical. Maybe not the "ears" because they break. Maybe a bigger screen and a smaller keyboard."
Having the model in hand, the participants ideated what could be their next steps, that is if they were to take their sculpted device further. This highlights the ongoing process of doing or making. Here participant P2 identified a pain-point and how to work through it. Overall, through the process of holding, touching and playing with their sculpted device, the participants expressed the ability to interact with their device, explore what 'could be', identify use cases, and work through next steps and pain-points. Before working through digital systems or virtual environments, sculpted devices can offer material interfacing methodologies to interact with what could be.

IV Moderator's Experience

Regarding my own experience while observing the participants, began from the moment the participant walks in to do the 90-minute activity. I greet them, make some light conversation, offered tea (and biscuits if there were some), then I proceeded to explain the activities and answer any questions they may have had. At this point, I am aware of my feelings and thoughts, while interacting with the participant, feeling somewhat anxious, though sufficiently prepared.
Moreover, as each participant was different, and I naturally felt different about each of them, it was important to maintain a level of consistency throughout the study.
After explaining the study and the activities, as well as answering any questions, the participant would cycle through each of the five activities independently. To recap they were the Bubbles, Whiteboard, Rubber mat, Projection tent, and Pieces (Table 1, p. 37). While the participant went through the five activities, I would sit on a purple sofa furthest away from the activities, and just watch. I would feel emotions drift and permeate my body, on occasion in a state of turbulence and complexity, sending pulse waves through the lengths of connective tissue, membranes, nerves and receptors. I felt my feelings, letting them float around generating sensation, allowing them to tumult within me; as my mind then remembers and thinks. The emotions become memories and thoughts. My

body is a treasure trove of lost artefacts and forgotten moments triggering my mind into wakefulness. All the while observing someone else.
The closest mathematical or physics equivalent to this sensation would be turbulence. However, as mathematics and physics has yet to formulate what is turbulence, we are limited to equations pertaining to laminar flow, vorticity (through eddies), chaos (as in a pendulum or double-pendulum) and diffusion. It is an experience that permeates the whole body, much like a perfect fluid, with no stress, viscosity nor heat conduction, it just flows with no resistance. This happens when I allow myself to be in the moment, observing, allowing my own inner monologue flow by.
Once they went through the five activities: Bubbles, Whiteboard, Projection Tent, and Pieces; they then made their own handheld model for a handheld device (see Figure 10, p. 50). During this hand-making activity, we had an informal and open discussion about the previous activities, as well as other topics related to the study; the participants also often had questions, which I did my best to answer. These discussions were not recorded and kept private between myself (in the role of moderator) and the participants.

Figure 10. Participant sculpted devices with approximate longest length in centimetres, from left to right: Po's palm shape: 7cm, P1's cube-like shape: 2.5cm, and P3's circular 'Owl' inspired shape: 9cm.

During this last activity, I wondered how and at which point the participant decided when their model was ready. Granted it was the last activity and they might have just wanted to go home. However, each participant did complete the activity, and each piece was unique to them. With sculpting, there is often more space to tweak and adjust than with stone balancing, particularly if you are stone stacking. This is much like writing a poem or prose compared to coding. Poems can be very free form, like sculpting, while coding has more constraints and limitations to do with the material properties of minerals and metals, like

stones. Therefore, from material interfaces and the exploration of space, we come to a material discovery of stones through stone balancing.

5.2 Completeness

From the non-electronic multi-activity workshop focusing on interactions with various non-digital interfaces and moving through environment, we begin to migrate from the external to the internal. The expression of completeness is verbal, gestural and gaze-based, meaning we can predict completeness by someone's multimodal expression.
With stone balancing we experience interfacing with one type of activity, and can move towards internal sensations, i.e. interoceptive awareness, to interact with the stones in order to balance them. Stone balancing requires no training nor specific talent, and can be done without any formal education. It also does not demand high-precision repetitive movements nor fine attention to detail. For some, stone balancing is meditative, and typically, a solitary practise, thus possible to explore internal modalities and sensations, e.g. interoception. We can also look for specific multimodal indicators of intent and meaning through the fusion of verbal, gestural and gaze cues. Moreover, the forms of stone are not defined by human design practices, but rather as a result of the earth's inherent processes. The activity of balancing or arranging the stones is open to interpretation by the participant.
I had previously painted several stones with a glow-in-the-dark paint and coated with lacquer. I chose to use six of them as it was enough to make a stack or an arrangement on the small standing table. The glow-in-the-dark elements provided a similar experience to the VR game Luna, developed by Funomena. In the game, the player is presented with several island worlds that are suspended in space surrounded by a night of stars; in game, the player plays with interactive puzzles and activities on each of these island worlds. The small standing table is similar to an island world, and the stone balancing activity is a comparable puzzle or activity.
Once the participant has completed their stone arrangements with the gaze tracker, they would then remove the gaze tracker and the lights would then be turned off, the stones then glowed, appearing to hover in mid-air, as the table was covered in black fabric. The glow-in-the-dark environment emulates a VR-like experience in reality where only the stones were visible. Furthermore, being in the dark was visually synonymous with wearing an VR headset, where one is unable to see one's own body. Although some VR games provide an avatar body.
This approach explores proprioception, interception and vestibular sensations, i.e. internal bodily experiences. In the following microstudy, the stone balancing task was done in the dark to further explore these internal sensations and experiences.

Additionally, in both stone balancing studies the moderator, myself, waited outside the room during the stone balancing activity to provide the participant with a solitary independent experience. Due to the special interest in interoceptive awareness in these two microstudies on stone balancing, I offered participants three optional interoceptive questionnaires to complete:

1. Interoception: Mindful body awareness tracker for DECD (Emma Goodall, 2016).
2. The Interoception Sensory Questionnaire (ISQ) (Lisa Fiene et al., 2018)
3. Multidimensional Assessment of Interoceptive Awareness (MAIA) (Wolf E. Mehling et al., 2012)

These questionnaires and outcomes are discussed in section 4.4.

I Setup

Six people participated in **Microstudy 2: 'Stone Balancing'**, which took place in office lighting, hence the acronym: SBOL. The activity took 5-10 minutes, but 60 minutes were given for discussion and questions, as well as to allow for technical problems with the gaze tracker. The data collected included pre- and post-activity surveys (Appendix: Microstudy 2: Survey), gaze tracking data (gaze co-ordinates, videos of scene with and without gaze tracking), and photos of stone stacks, as well as three optional interoceptive questionnaires (MBAT, 2016; ISQ, 2018; MAIA, 2012).

II Procedure

While for the stone balancing studies, we similarly corresponded by email where I provided information, guidelines and the consent form, they then participated in the stone balancing activities, then completed the optional questionnaires independently over the following days.

SBOL was conducted in a lab environment. The standard equipment in the two studies were: a height adjustable standing table and glow-in-the-dark stones. Both studies use the same stones, however one more stone was added to SBD to offer additional choice when selecting stones to stack (during SBOL one participant indicated that they would have liked more choice in stones). The SBOL also included a gaze tracker (Dikablis from Ergoneers), a computer-stand and table, and a laptop to record the gaze tracking and video. The stone balancing studies were conducted mainly in the Gaze Lab (Figure 11), and one time in a cave, aka Simulation Lab, (Figure 12).

For the stone balancing studies, after the stone balancing task, I invited them to ask any more questions, complete a post-activity survey or we discussed their experiences.

Figure 11. Stone Balancing Gaze Tracking Lab Setup: stones, standing table, Dikablis gaze tracker and Dell Precision 4800 (Windows OS) laptop.

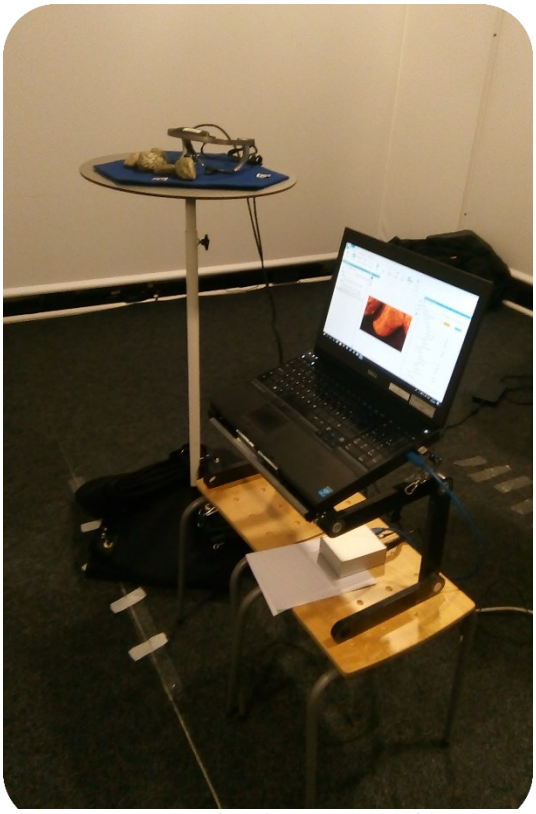

Figure 12. Stone Balancing Gaze Tracking Cave Setup: stones, standing table, Dikablis gaze tracker and Dell Precision 4800 (Windows OS) laptop.

The Gaze Lab was preferred because it was easier to make room reservations independently, and all the equipment was easier to store there too. However, the cave had better ventilation and any LED lights were less visible, so it was easier to create a completely dark environment. In the SBOL study, the stone balancing activity was conducted under typical office lighting with fluorescent and incandescent lights. The dark environment was used after the participant completed the activity; it was used to demonstrate the VR-like effect from the glow-in-the-dark coated stones. However, only in SBD, without gaze-tracking, did the participants do the stone balancing activity in the dark and photos were taken under UV-light (Figure 23, p. 64). The gaze tracker was not utilised in the SBD, the reason for this is that in the post-activity survey of the previous study (SBOL), all participants indicated discomfort when wearing it. Additionally, stone balancing in the dark was the

main focus, and wearing the gaze tracker would have added unnecessary processes to the procedure. Moreover, I was not sure how participants would react to being in the dark, and how much effort they would need to maintain their balance in the dark. Adjusting to the dark, once the lights were off, I suspected that it might be more difficult to do stone balancing in the dark, than in the light, therefore their comfort and ability to do the task in the dark, was more pertinent than collecting gaze tracking data (which had already been achieved in the previous study).

III Findings

The outcome of the pre- and post-activity surveys showed that all six participants either had no previous experience with stone balancing or they might have played with stones as a child. Four out of the six participants required corrective lenses (glasses) which they needed to use while they were awake or most of the time. All the participants personal evaluation of their ability to focus ranged from 2 to 5 (1 = 'not good' to 5 = 'good') (Figure 13), and the number of hours they can work while standing was around one hour for most participants, though two participants could stand for hours (one explicitly said: five hours) (Figure 14). Even though the participants found the gaze tracker: uncomfortable, heavy, unnatural or distracting (Figure 16); all participants had enjoyable feelings regarding the activity overall, such as: content, relaxing, enthusiastic, and fun. In reference to doing the activity, they used words such as: pleased, focused, challenging, purposeful, and interesting (Figure 15).

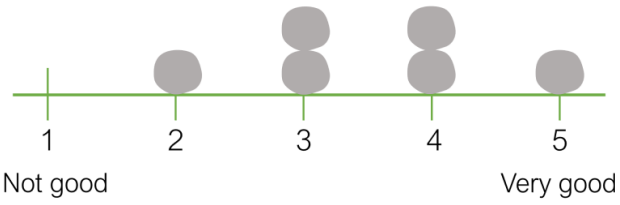

Figure 13. Focusing on one task participant self-evaluation.

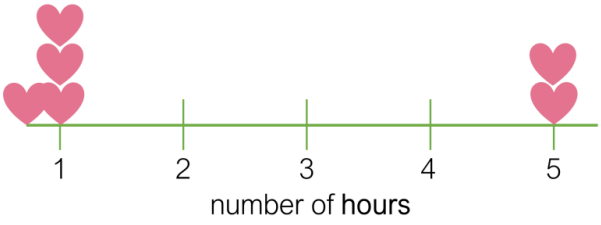

Figure 14. Doing a task while standing participant self-evaluation.

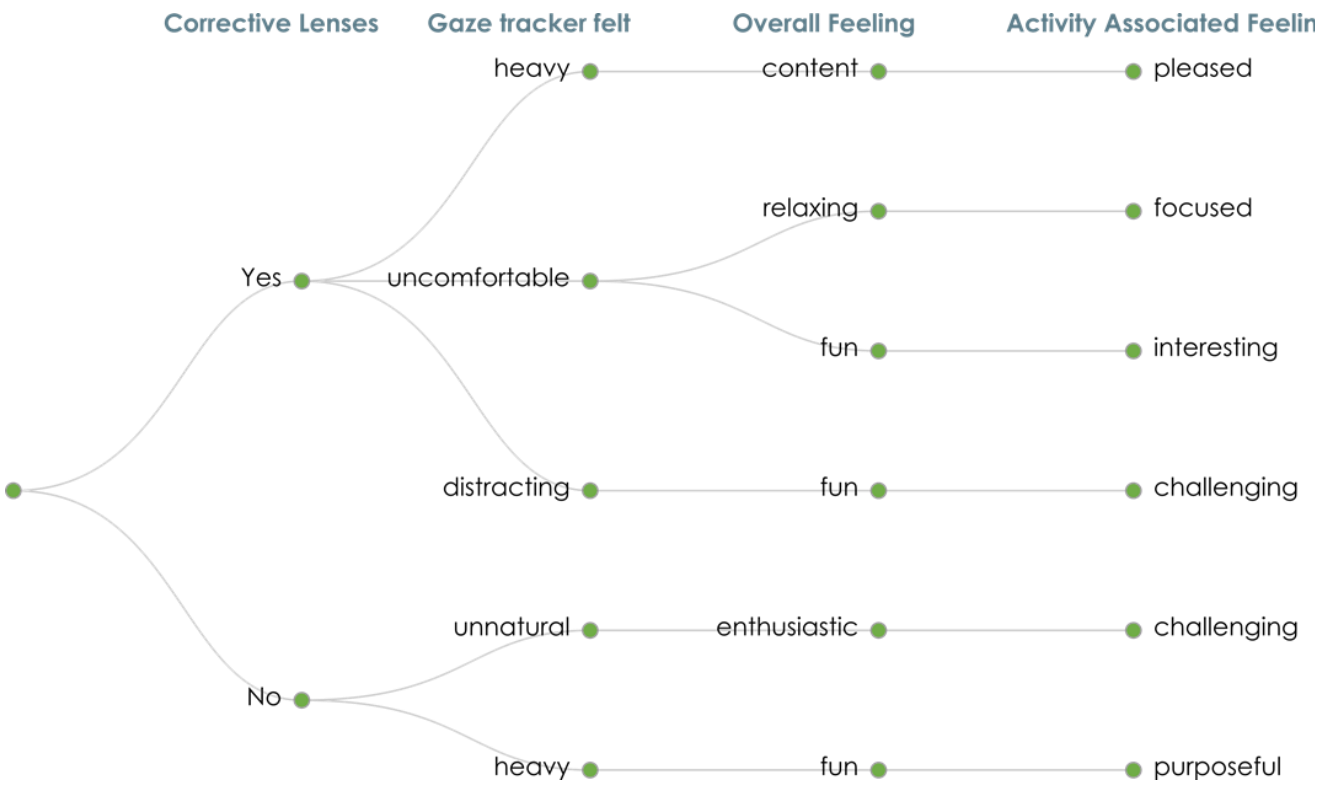

Figure 15. Results from pre- and post-activity survey.
Wore corrective lenses (yes) or not (no) → how the gaze tracker felt → how it felt overall → how the activity felt.
(made with Rawgraphs.io)

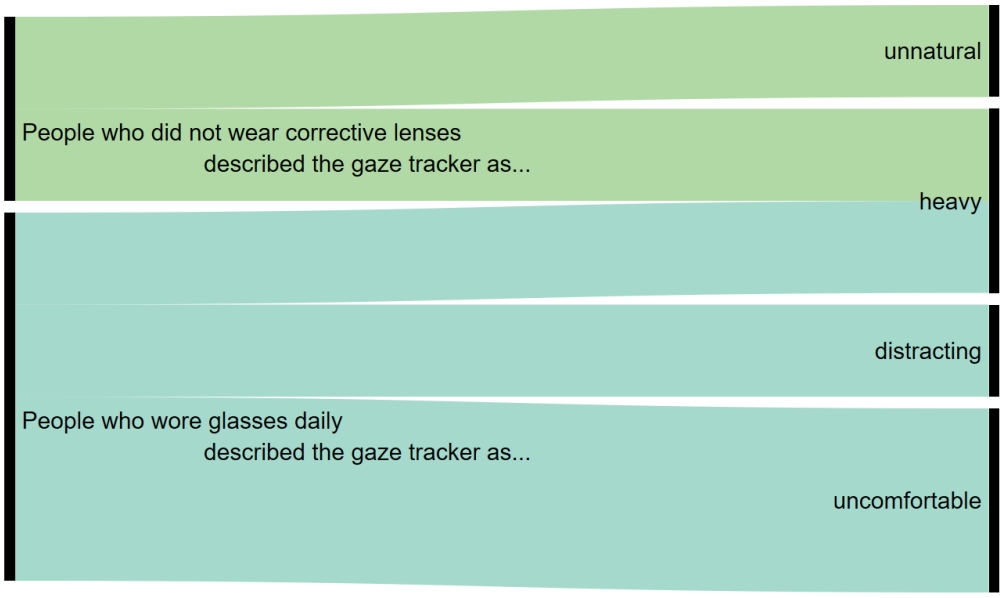

Figure 16. Words participants used to describe the wearable gaze tracker. (made with Rawgraphs.io)

During SBOL participants wore a gaze tracker while performing the stone stacking (Figure 11, p. 36). In the post-activity survey, when asked "Use one word to describe how the gaze tracker felt.", participants used the words: uncomfortable, distracting, heavy or

unnatural. Moreover, in discussion with some participants, to establish their own personal baseline of tolerance and comfort, it was revealed that they were expecting to tolerate a certain level of discomfort in relation to the gaze tracker. It is also worth noting that four (out of the six) participants wore glasses daily (but not wearing the gaze tracker), so they were quite accustomed to wearing something on their face/head, yet they still expressed equal discomfort in relation to the gaze tracker. Finally, all participants were able to identify different feelings in relation to the gaze tracker and to the activity itself.

What I am looking for is more of a creative or artistic '*end point*', a point of divergence or completion. It is not an arithmetic decision, or based solely on calculations, it is an emotional decision, instinctual and intuitive. By combining material and visual indicators, as well as gaze, we can more accurately identify a natural, or human, completion point. Observing the position of the hands, in complement with gaze evaluation and appreciation, there is greater certainty in knowing when an interaction is finished. Hand position alone does not indicate completion, but needs to be fused with gaze. In further studies, we may investigate expressions of satisfaction, appreciation and rumination through this fusion of touch and gaze. This technique supports a more intuitive and instinctual decision-making process, which is how we usually make decisions — even when making decisions with data and charts. When exploring complex data, emotions, instinct and intuition are always present.

Figure 17. Participant stone stacks from Microstudy 2: Stone Balancing (2018).

In the study, the three completion times were identified as:

- Stack completion is calculated when the touch and gaze points have been calculated, it is indicated by the completed stack before the hands have left the scene.
- Touch completion is indicated by the hand removed from the stack and away from the table
- Gaze divergence is indicated by at least one significant displaced pursuit away from the stone stack, or the end of the video (e.g. #2).

Here are the times (in seconds) for the stone balancing study (participants 2-5, one participant did two stacks, gaze tracking was not recorded for the first participant), they include Stack, Touch and Gaze, as well as the differences:

	Releasing: releasing stones until hands away from scene	Looking: Gaze on stack until point of divergence
range	1-4 sec	7-13 sec
average	2.5 sec	10.17 sec

Table 3. Ranges and averages of differences from stack-to-touch and touch-to-gaze completion times. Analysis done by watching scene video with blended left and right crosshair

Figure 18. Stacked percentages (%) showing ratios of Releasing and Looking durations. made with datawrapper.de

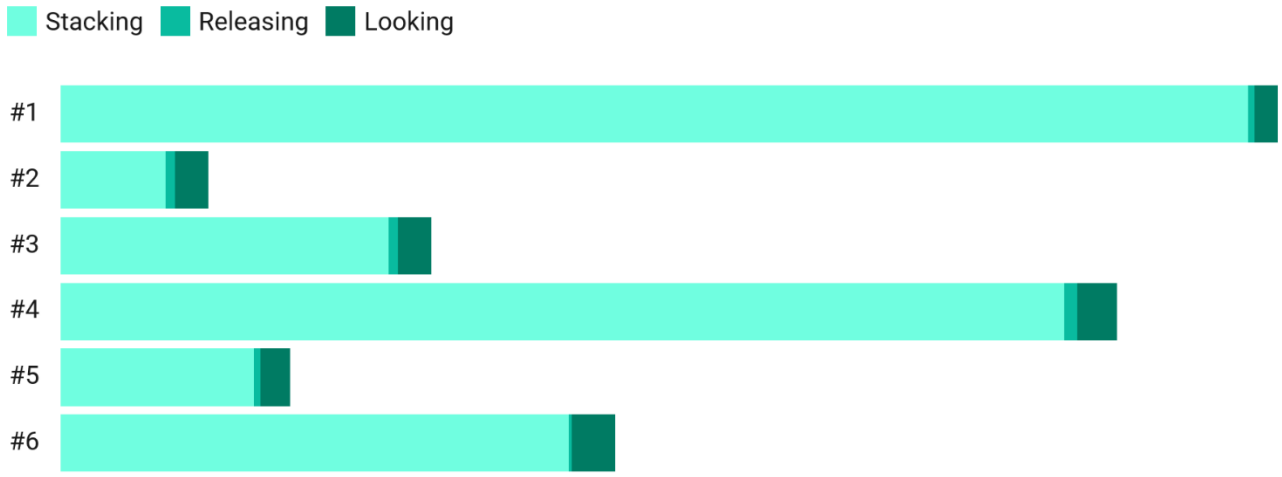

Figure 19. Stacking, Releasing and Looking durations. This shows that Release and Looking durations are in relation to each other, though irrespective of Stacking duration (for dataset, see Appendix: Tables of Results). made with datawrapper.de

From this small dataset, we can visualise a consistent pattern of shorter duration between *releasing* and *looking*. And overall releasing duration was approximately 1/4 of the length of looking duration, except in #6 which was 1/13th of the time, here the participant spent more time looking at their work.

Figure 20. Images of the moment of Release: just as the participants were letting go of the stones.

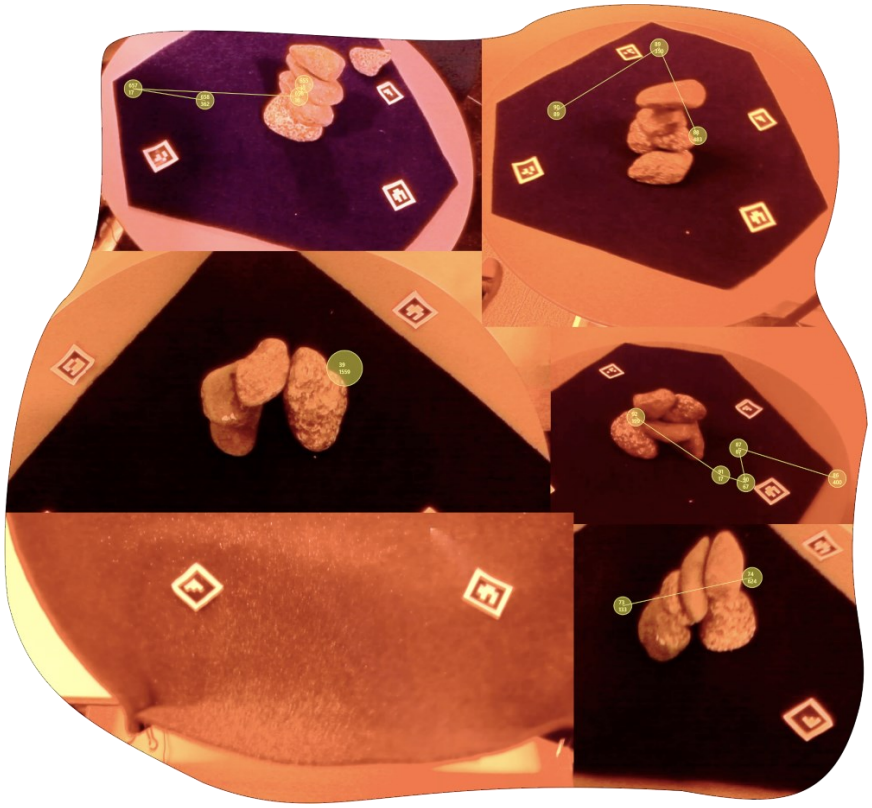

Figure 21. Looking ends, depending on each case, sometimes it is the moment when or just before the participants begins to looks away, other times they look elsewhere and return their gaze, or their gaze begins to be less focused, i.e. with longer pursuits between fixations. (note: there are no gaze tracking points in the bottom left image)

All participants looked at their stone arrangement for some time after completion. Completion can be identified in three ways: verbal cue, hands leaving the stones or the table, or when the gaze is directed away from the stones. All participants gave a verbal statement indicating completion, with phrases such as e.g. “I’m done” or “I’m finished”. For the purpose of this analysis, it could also be identified when hands leave the table or scene view (i.e. the video). However, the lingering gaze of the work is also an indicator. Looking at one's work upon completion can be a moment of satisfaction, appreciation and/or rumination.

5.3 Low Sensory

To minimise sensory triggers, allostatic load, bodily discomfort and distractions; the environment needed to offer a low-sensory experience. All the lights were turned off to minimise visual distractions, including the bright office lighting (incandescent and florescent lights). However, some LED lights from computing devices were still on in the room. A clear path was made to the stone balancing activity, and there was enough space to move without bumping into any furniture. Dark theatre fabric was draped over the table and a pair of noticeboards on wheels. As in the previous study, a piece of thick felt was fixed to the table to minimise impact sounds from stones hitting the table when they would fall down, the theatre fabric added an extra layer of sound and impact absorption. The soft luminosity of the painted stones visually indicated the stones’ positions. Additionally, as per the participation guidelines: restrictive clothing was avoided, and no shoes were worn (only loose-fitting socks). The gaze tracker was also not utilised in this study. That way the participant could attend to the task of stone balancing. In the previous stone balancing microstudy, one participant indicated they would like more stones to work with; therefore, one more stone was added, making it seven glow-in-the-dark stones for this microstudy.

The glow-in-the-dark environment provided a comparable experience to Funomena’s Luna. To recap, the table represents an island world, and the stone balancing activity, a puzzle. The dark room is analogous to wearing a VR headset, where our own body is not visible, yet it is a relatable experience in our everyday, for example, as we search for a light in the dark. However, not seeing your body in a virtual game or experience, is something new, and therefore, for many it can be difficult to relate to.

Once the participants had removed their shoes, jewellery and other restrictive items, they would stand in front of the table (without the gaze tracker) and I would turn the lights off and remain outside the room. They completed their stone stacks or arrangements in the dark where only the glowing stones were visible. And as in the previous stone balancing study, appearing to hover in mid-air in the dark room with the black theatre fabric as a

background and surface. The low sensory VR-like experience affords the independent exploration proprioception, interception and vestibular sensations through movement and body-material interaction in tandem with our internal sensory experiences.

I Setup

Five people participated in **Microstudy 3: 'Stone Balancing in the Dark' (SBD)**. The activity took 5-10 minutes. The data collected included one post-activity survey (Appendix: Microstudy 3: Survey), and some discussions and follow up emails, as well as the same three optional interoceptive questionnaires as in the previous Stone Balancing study.

III Procedure

SBD was conducted in the same gaze lab but with a different setup (Figure 22). The same height adjustable standing table and glow-in-the-dark stones were used. However, one more stone was added to SBD to offer additional choice when selecting stones to stack. The reason for this seventh stone, was that, during the previous stone balancing microstudy, one participant indicated that they would have liked more choice in stones. For the stone balancing studies, after the stone balancing task, I invited them to ask any more questions, complete a post-activity survey or we discussed their experiences.

Figure 22. Stone Balancing in the Dark Lab Setup: Stones, standing table, screens, black fabric, UV lamp and NOKIA 3 smartphone camera (smartphone is not in the image).

Since the gaze tracker added discomfort and unnecessary weight to the participant, I felt that there was insufficient cause to use it in this follow-up microstudy. Here the process was refined to only one activity, one updated post-activity 10-question survey, and the same three optional interoception questionnaires. Thus, excluding the gaze tracker and the pre-activity survey. Similarly, participants were asked to wear comfortable clothing, as well as remove jewellery, glasses and shoes. Though some participants kept their watches on, and may have had earrings on and worn restrictive undergarments. For the same reasons as in the SBOL, such requirements were necessary to ensure their balancing experience was not hampered or distracted by their clothing, footwear or accessories.
All participants were able to stack stones in the dark, all participants expressed enjoyment and pleasure. Playing in the dark was not a problem for the participants. Most participants set out to challenge themselves by trying to make a tower, though all participants ended up applying artistic strategies when they could not achieve the tower (or five- or six-stone stack). Artistic strategies resulted in sculptures, rather than stacks. Furthermore, as there were no grading systems or rewards structures, participants were free to set their own challenges or just enjoyed creating forms with the stones. However, for one participant I remained in the lab, this participant was talking while doing the activity; for the rest of the participants I left the lab and stood outside the door, the participants then did not talk.

III Findings

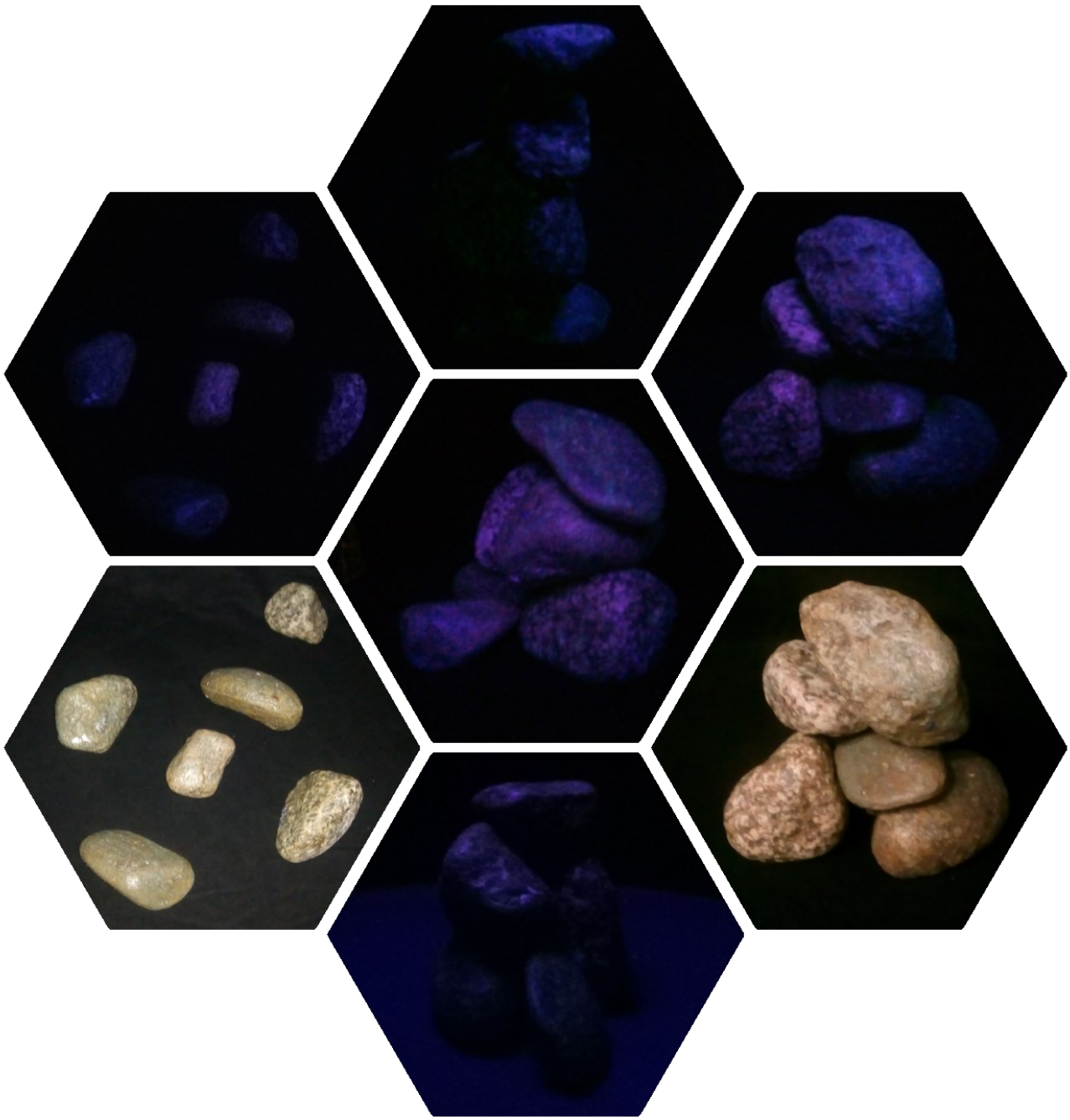

Figure 23. Stone stacks and arrangements under UV light, and two also under phone camera flash.

Participants adopted a blend of strategies when balancing the stones in the dark, this mainly included excitement, playfulness, experimentation and self-challenging. (Figure 24). In this study, four out of the five participants described their approach as artistic, and the one remaining participant described it as constructive, no one felt that it was competitive (which was the third option in the survey). Also, most of the participants described their stone stack as a "sculpture", and one described it as a "tower". From the participants word choices to describe their respective approaches, it could be surmised

that more sensory-based approaches were adopted, as opposed to calculated or strategic methods. The stone balancing activity in the dark was described as fun, peaceful or exciting, by each of the participants. Using one word, they each described their own feelings as joy, concentrated and focus. One participant saw living beings or animals in the form of the stones: "When I changed my approach into a more artistic one I started seeing the stones like they could form some kind of living beings/animals so I made some kind of a rock family sculpture". Also, another participant enjoyed the glowing aspect of the activity: "I was enjoying it very much, the glowing stones and the darkness made it very interesting". Participants also described the stones as smooth, "nice, the weight was calming" and one participant "was drawn to the flat round ones".

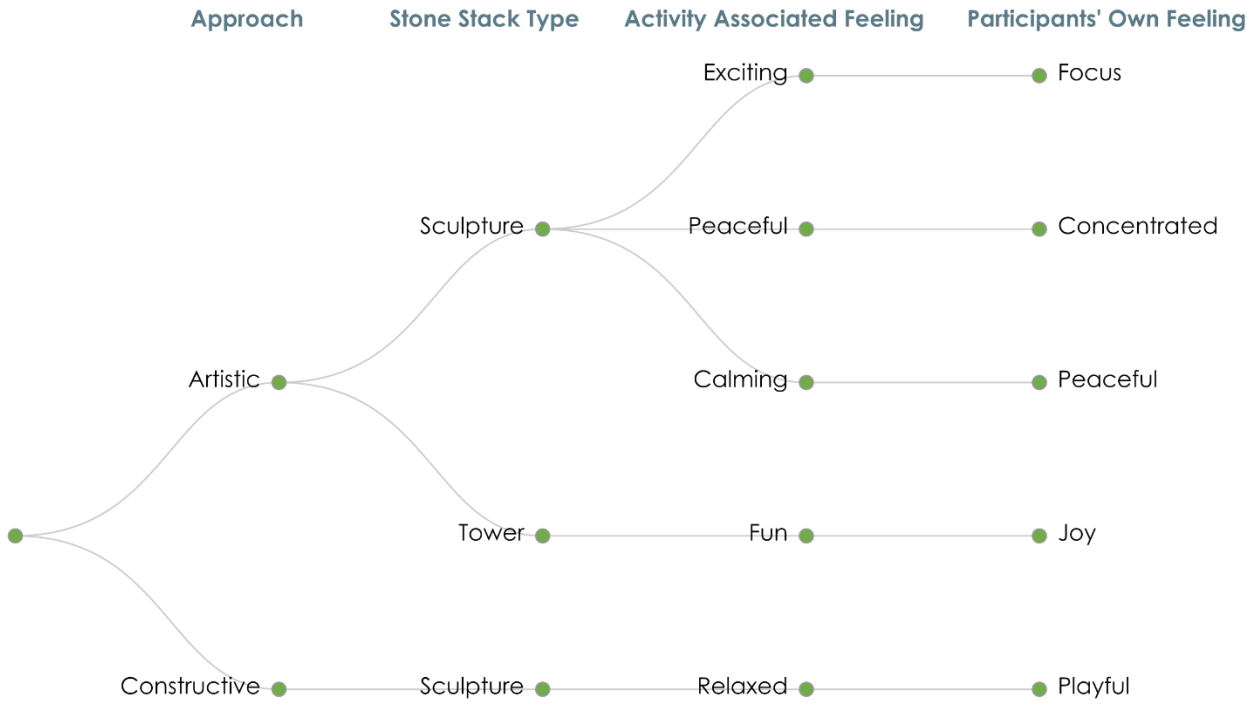

Figure 24. Relational results from post-activity survey.
Approach: artistic, constructive or competitive → describe your stone stack → how it felt to stack stones in the dark → you (the participant) felt while doing the activity
(not in order of survey)(made with Rawgraphs.io)

5.4 Interoceptive questionnaires

The three interoceptive questionnaires were used to give participants an opportunity to self-assess their own internal psychophysiological, or interoceptive, states. These optional questionnaires were completed online in Google Forms. Participants completed the questions in order to provide feedback on the questionnaires, and not to provide information on their internal sensory experiences. It was necessary for them to complete the questions to provide feedback. Therefore, their responses were necessary to provide

evidence of their experience and that their feedback of the questionnaire was based on their lived experiences. The links to the questionnaires were sent to participants by email and they typically completed them within a week after the stone balancing activity. Each survey was optional, and it was not required to do all of them. Additionally, not participating was also considered feedback, from here we can infer lack of interest, time, willingness/motivation, or value to do the survey, among other reasons. By sending only a link, there is of course the risk that it can get passed around, or that it was someone else who did the surveys; however, it was unlikely, as the surveys take 10-30 minutes and it would serve no purpose to input some meaningless information as information of interest was the feedback.

	No. of questions	**Stone Balancing in Office Lighting**	**Stone Balancing in the Dark**
No. of Participants in microstudy	-	6	5
Average Participation % in Interoception Questionnaires	-	39%	60%
Interoception: Mindful body awareness tracker for DECD (Emma Goodall, 2016).	20	3	3
The Interoception Sensory Questionnaire (ISQ) (Lisa Fiene et al., 2018)	60	2	3
Multidimensional Assessment of Interoceptive Awareness (MAIA) (Wolf E. Mehling et al., 2012)	32	2	3

Table 4. Number of participants who completed the interoception questionnaires.

Participants also gave feedback on these questionnaires; in the feedback, participants primarily commented on their length, arrangement and ease to answer. For the Mindful Body Awareness Tracker (MBAT), participants described it as easy, neutral and interesting. One participant identified two limitations:

- *You can answer all the options at the same time so that should be restricted.*
- *It would be good to have a possibility to explain your choice with each answer because it is highly personal and people might have the need to explain what they meant.*

The first limitation is a matter of changing the settings in the online form from tick boxes to radios. The second depends on the purpose of the future study, and if it is necessary to have further explanations of answers.
Another participant also indicated possible indicators for medical intervention:

> *...anyone answers to some of them no it would indicate some kind of medical problem?*

Offering medical advice is not part of this research work, however, such a questionnaire could be applied as a selfcare app to regularly assess one's own health status.
And another participant preferred quantifiable questions:

> *It felt a bit vague to answer - I like quantified information that I get on wearables like Apple Watch.*

The design of the questionnaire was not to give a feeling of countable certainty, but rather the space to self-assess and self-evaluate. Such feedback is evidence that nonquantifiable questions feel vague and uncertain. This is the aim of the study, to afford participants to resolve their own feelings of uncertainty through independent interoceptive exploration, developing one's own body knowledge and self-awareness without the verification, comfort and confirmation of numerical metrics — even though this may cause feelings of uncertainty in some people.
For the second questionnaire: Interoception Sensory Questionnaire (ISQ), one participant pointed out that:

> *the same thing was asked from many viewpoints, because feeling pain, noticing pain, being able to describe pain and feeling the need to do something about the signal can be very different things*

Therefore, such body-knowledge explorations can provide multidimensional perspectives on one's own experiences. However, while they are in depth and multidimensional, the other participants who did the ISQ described it as "extremely long" and "repeating too much".
The third and final interoceptive questionnaire, Multidimensional Assessment of Interoceptive Awareness (MAIA) (Wolf E. Mehling et al., 2012), raised interoceptive insights such as:

> *It brought to mind how I 'test' my body when I have food allergy symptoms.*

> *This was a good one but for me it was a bit too abstract because it didn't differentiate between individual sensations and feelings*

> *It reminded me that I need be more regular with my yoga/meditation*

> *like sometimes you can be aware, but consciously ignore, it's like part of self awareness is also being able to control the affect of awareness, but still be aware*

" *The questionnaires gave the participants a moment to self-assess their feelings, both physical and emotional, and consider their associations. The MBAT tracker was accessible for most participants. While the ISQ was particularly long, one of the participants pointed out how there are different states of awareness of feelings, or in their example 'pain': (1) feeling pain, (2) noticing pain, (3) describing pain, and (3) needing to do something about the signal. Having such a multidimensional view of one's own sensations can provide clearer identification of emotions and physical sensations, as well as how these interact.*

6. A Sense of Completeness

Through the experience in sculpting, in the responsive bodies microstudy ‘What shape are you?’, we find an intuitive sense of completion in response to the environment, including the presence of the moderator and the pre-established duration for the activity. And in the first stone balancing study (in office lighting), participants indicated completion through the multimodal expression of touch, gesture and gaze by releasing and gazing at their stone stack or arrangement. As participants were not asked what their feelings were at the end of their sculpting or stone balancing tasks, in further studies we could inquire about feelings of appreciation, satisfaction or rumination, for example.
In the braiding of experience, internalisation and body knowledge, the physio emotional (or psychophysiological) become valid ways of expression through interaction with material. In this way, devices become extensions of our ability to sense and experience our environment. From here our expression and experiences become enmeshed with the methodologies of making interfaces, i.e. devices. Our ability to be aware of our interactions with our environment can feed into the emotional expressions of sculpting, stacking and arranging. This attention to body knowledge and awareness of material and environment can inform our movements and responses. From here we can have greater adaptability and responsiveness to the shapes and forms of our interfaces and devices. Therefore, this methodology offers an attendance to our physio emotional experience through proprioceptive and interoceptive affordances, such as expressions and experiences of ‘Fun!’.
Fun was a word that came up quite frequently during the two stone balancing studies, in part because the word itself is short and simple, one of the first words we learn either as children or new language learners in English. When describing stone balancing *in office lighting, SBOL,* (both fluorescent and incandescent lighting), the participants identified feelings of contentment, relaxation, enthusiasm, and fun. And *in the dark, SBD*, participants expressed also expressed relaxed and fun, as well as calming, peaceful and exciting. Furthermore, words to describe the act of “doing” stone balancing were: pleased, focused, challenging, purposeful, or interesting, even though participants were wearing the gaze tracker. The descriptors participants applied to the activity can be refined to three clusters: contemplation, absorption and elation (Figure 25, p. 70).

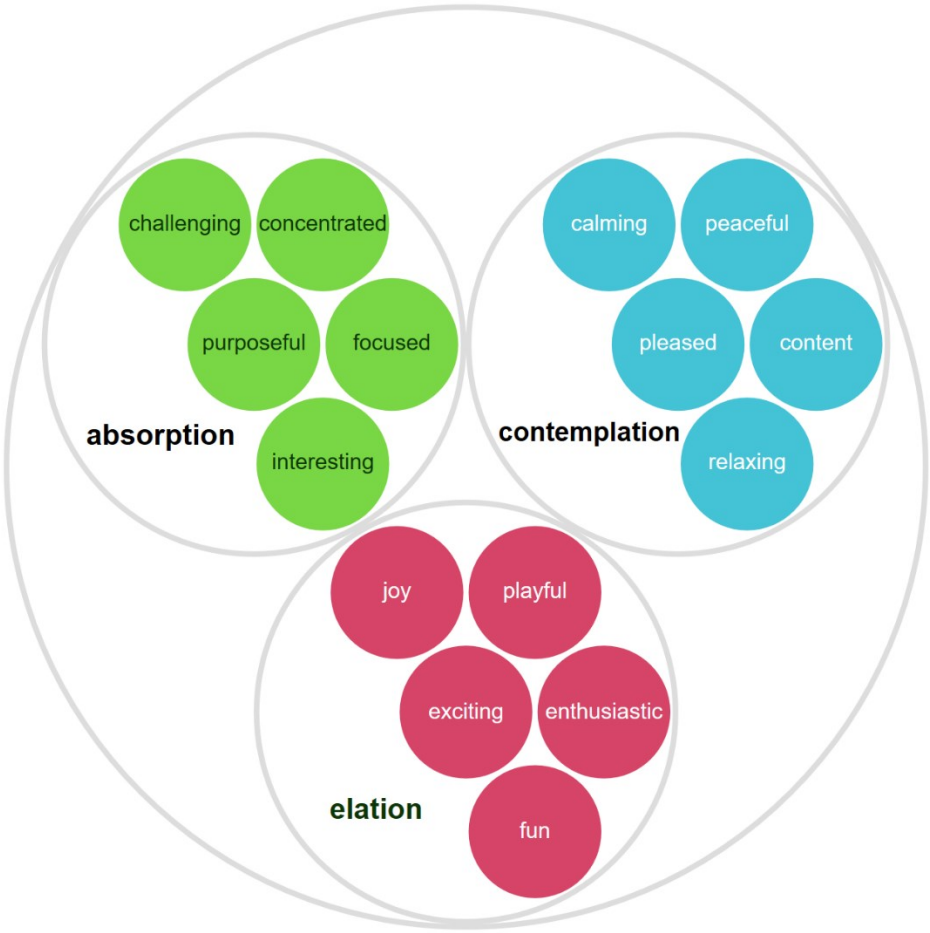

Figure 25. Word clusters that describe stone balancing activities. Words came from the post-activity survey in both Stone Balancing microstudies (SBOL and SBD).

Moreover, when doing *stone balancing in the dark* they found the activity to be fun, peaceful or exciting. While their own feelings when doing the activity were joy, concentrated or focus. Making stone arrangements afforded a balance set of feelings mixing various pleasant feelings in harmony with concentration and focus.
From these feelings of absorption, contemplation and elation how does the participant arrive to their completed piece. The outcomes, in the following sub-sections, show that there is a variety of approaches and arrangements of stone balancing. For example, some participants understood balancing in terms of stacking as many of the stones vertically, and the end-point is when all the pieces are visibly stacked together. Alternatively, one participant, arranged the stones in a way they felt was a balanced arrangement. In that case, how does one then decide when the piece is then complete? That is beyond the most common reasons such as materials have run out, the allocated amount of time has ended, or the physio-emotional reasons like tiredness or hunger. How then does a participant achieve satisfaction with the result? To be able to appreciate or evaluate one's own work. By observing the gaze tracking videos, from SBOL (the first stone balancing microstudy), their hands revealed the moment of completion, or *release*. This is when they stop

touching the stones and no longer return to them. However, it was more difficult to identify a singular gaze end-point, as the gaze tended to linger on the stone arrangement. This lingering gaze, or *looking*, in itself is an indicator of completion, for instance, to evaluate, or look at our work with feelings of satisfaction, appreciation or rumination. This combination of hands letting go and lingering gaze may well be what informs us of, not a point in time, but rather a duration of completion. And the relationship of *releasing* and *looking* that signifies *the end*.

The sense of completeness, finished or readiness can afford repairability and adaptability through practices of incompleteness and impermanence. Here we also permit ownership of a device, not only in terms of monetary exchange, but by being able to make modifications, updates and repairs as needed. At present, mass production only offers customers a completed ready product that they are often not permitted to repair or even change the battery. Instead, with cyclical methodologies and processes for making or co-making interfaces, the work becomes responsive to the limitations of ourselves, environment and community, and not to the demands or requirements of industry. Like our breathing rhythms, here our work is process of contracting and expanding, refining and developing, and decay and growth. The peaks and troughs of a sine wave visualise the highs and lows of circular systems. Though unlike a sine wave, our lives and ways of working are not so regular and predictable. So instead of ready, complete and finished, we replace it with doable, workable and usable in this ongoing responsive methodology.

7. Discussion

This work has been an exploration of relationship between body, material and environment through shape, rhythm and sensory experiences. And how our sensory body knowledge can inform stages in making and development, such as evaluation of the environment, moment of completion, and feelings and expressions associated with interfaces. Here the work offers methodologies where sensory experiences are a primary form of evaluation and testing in HTI and HCI — because sensations matter.

In 'What shape are you?', participants proceeded through the five activities, they experienced devices with hexagon-based forms and a space that was soft with sofas and carpets like a living room. The room also had large windows that extended the view to the hallways. The participants then worked with clay to sculpt their device by means of the shape and rhythm of their body, i.e. through motion and pressure of their hands, along with any tools such as a pen that might have been available. The only requirement was to sculpt a device for themselves, i.e. they only needed to consider their own needs and interaction with the material. Each participant decided when their model was complete with the clay, tools and time available.

The artistic end-point, or moment of completion, is situated when the clay model is put down, or when hands are removed from the stone arrangement. This sense of completeness is not a decision based on discrete numerical calculations nor the formulation of words. This emotional decision, based on sensory experiences, entrainment and internalisation, is body knowledge. It can be explored by observing gesture, gaze and speech modalities, in combination with awareness of internal sensations, i.e. interoception. In the first stone balancing (SBOL), it was observed that the end-point was signified by the hands pulling away from the stone stack and the gaze lingering. All participants also would call out when complete, but this was also because I was outside the room. This duration of completion, and not one identifiable end-point, indicates that the hand-gesture alone does not necessarily indicate completion, and can be fused with gaze and speech, and even touch-interaction for touchscreen interfaces. In further studies, this fusion of touch, gesture, gaze and speech can be investigated along with bodily expressions of satisfaction, appreciation and rumination. Such a study can explore what emotional, intuitive and instinctual processes are involved when making decisions based on data, charts, info graphics and data visualisations.

Also, the responsive bodies study offered participants a way to evaluate the current environment. The participants were immersed in an environment with hexagonal interfaces, alternative to the typical square or rectangular environments in cities, for example. This led participants to notice the difference between their everyday environment and the one in the study: "[I] am paying more attention to the shapes of

things as they happen, but as the day passes by, i'm reflecting more after the fact". Through experience of difference, participants were able to observe their everyday environment, and take note of its patterns. They commented more on the shapes of the interfaces as well as devices, not taking the rectangle or square for granted, but pointing it out: identifying what is ubiquitous. When the hidden is named, it becomes visible. From here participants can identify what could be, rather than what is. This responds to Kristina Höök's (2018) challenge and involves a more autobiographical approach through our own sensory experiences: "Ethnographies in general tend to make us stuck in *what is* rather than *what could be*. The active creative element in an autobiographical design provides a better path to design.". To make new or emerging technologies responsive to current environments, we first evaluate *what is* and then explore *what could be* through autobiographical sensory experiences.

Before attending to the next steps, there were some limitations and pain points in regard to the microstudies. In the responsive bodies study, the projection tent was wobbly and the frame ends jutted out (although covered), and while this work does embrace incomplete devices, the experiences of the participants in the tent might have been compromised by its somewhat fragile composition. One participant even pointed out that this made them feel anxious: "I think that when the tent moves it kind of gives me a little bit of fear because it might fall down". Therefore, the participants did not touch the tent much and were not able to press into the somewhat stretchy fabric, as the whole tent would move. Participants also were not so keen on touching or holding the rubber mat because the rubbery feel and smell: "Sticky? doesn't feel nice to play with for too long - the smell". At the same time, in pieces they did interact more with the same material, moving the pieces around; though there were still comments regarding the smell and rubbery feel. Additionally, in the stone balancing studies, participants were required to stand in one place to balance only one set of stones, so they did not walk around as in the responsive bodies microstudy. Also, the table was a bit wobbly, despite efforts to stabilise it, making it more difficult to balance the stones. As indicated in the findings of SBOL, the gaze tracker was uncomfortable, in part because it restricted or limited head movement. Therefore, to afford more movement, other gaze tracking technologies need to be investigated.

Interface usually refers to a material device or a digital environment; however, it can also be anyone or anything we interact, or interface, with. We become accustomed to ubiquitous technologies and interfaces, especially those we interact with regularly. However, when those familiar interfaces are changed, our interaction with them becomes disrupted. "Once people are used to the particular rhythm of an interface, anything that changes that habitual rhythm can be very disruptive and cause them to lose sync with the

interface." (Brigid M. Costello, 2018, p. 41). It is these rhythms, movements and patterns of regular interaction that become our everyday and cultural expression.
The rhythm of breathing is interdependent with the experience of the body, the body from which we perceive a moment. The body is what makes each experience unique, the body also responds to immediate environments, and these responses are dependent on air quality and circulation, temperature, humidity, luminosity, population and location, such as outdoor or indoor — making each bodily experience unique to that individual at that moment. The pace in which we speak and share our feelings and experiences is from the body's biomechanisms responding to environment. Sensory experiences become movement and words, i.e. communicate. These motions in turn transform the body from one state to another, making sensory expressions intimately entwined with bodily experiences. Here, the complexity and interdependence of cause and effect, or body and material, become evident.

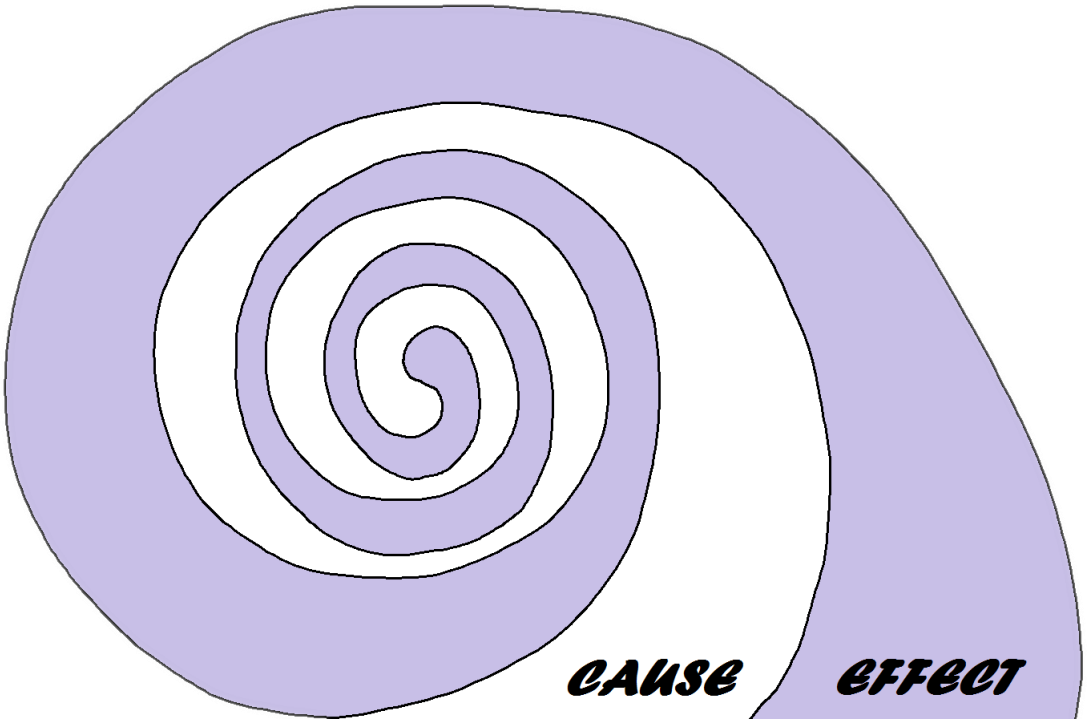

Figure 26. The interdependent relationship of causal mechanisms.

Our digital interfaces still mainly rely on visual cues, which in turn are interdependent with touch, i.e. physical interaction, with the keyboard or touchscreen. We reach out to touch a key, button or move a slider. But when these elements change abruptly, we are not just learning to live with a disruption, but become resilient and adaptive to change. We would like change to be gradual, predictable and constant, however, it can also be abrupt and disruptive. Much like some of the sudden changes in our temperaments, and atmospheric weather and climate. So here the idea of fault tolerance comes into play to

develop an understanding of ourselves in relation to each other as we get to know new people, technologies and environments.
The next steps of this work would be to make a material environment that affords responsive sensory experiences. To let us feel whatever it is we feel when we interact with a given space. Between the experiences of the multi-interface environment and the interoceptive experiences of stone balancing in both light and dark, the next step is to make a low-sensory glow-in-the-dark experience. This room would reduce the demands of our visual sense with simple sculptures to touch, as well as some soft "invisible" shapes, painted matte black so they cannot be seen in the dark environment. This environment would draw attention away from the visual towards awareness of interoceptive and proprioceptive sensations.
The multimodal environment would afford whole-body motion and less reliance on vision. This can help to evaluate proprioceptive and interoceptive self-awareness as one negotiates the shapes and forms in the room. By combining 'What shape are you?' (Responsive Bodies) and *Glow-in-the-Dark* Stone Balancing (Low Sensory) we make a real-virtual space. Thus, the evaluative process would seek to find out how participants experience such *real-virtual* spaces.
The area of study would investigate physio-emotional balance with a biosensing wrist strap to measure heartrate variability (HRV), skin conductance, and skin or body temperature. While environmental sensing devices could provide information on atmospheric temperature, moisture and motion. As beings, "we are already inside out, already porous" (Susan Kozel, 2008), thus able to gather much information through biosensing wearables, and avoiding cumbersome technologies or invasive techniques. We already established that the wearable gaze tracker was uncomfortable. This is also why VR-glasses have not become everyday technologies like mobiles or smartphones. To justify such discomfort the content needs to be important enough to the user, or the interaction needs to be engaging or entertaining enough that the discomfort is blocked out. However, blocking out discomfort means that we are no longer aware of it, and the physical effects may well still be present. Therefore, future studies would be directed toward spaces that are interactive, freeing participants from head-mounted devices, such as VR-glasses, and instead utilising biosensing wrist straps and atmospheric sensors. This combination of sensing ourselves in relation to our environment has many applications, and not just in game development. This kind of technological implementation has applications in architecture, city and urban planning, interior design, and healthcare. This relationship we have with our environment may well bring us closer to a sensory responsivity that has been lacking in our computing and technological fields. In other words, to repair the disconnect between our technologies and our bodies, and involve interested people who might at first seem to be unlikely

candidates for technological development. Thus, satisfying the aim of this work: to explore sensory experiences, along with shape and rhythm, to study the interaction of body, material, and environment.

8. Summary

By exploring sensory experiences through body-material interfacing, we can rediscover our relationships to material and environment. The places where we develop technology, namely offices, afford a limited range of movement and many hours standing or sitting at a computer. Alternatively, other activities can be studied that afford more diverse movements, such as moving through and interacting with forests and other open terrestrial landscapes. Also, by exploring body-material affordances of material, we can become familiar with new ways to move with material, and thus our technologies. These responses to material, can be articulated as a co-evolving relationship with materials and technologies (Fotini Markopoulou-Kalamara, 2016), which in turn influences our cultural practices, movements, interactions and experiences.

"The link between materials and ongoing performances of practice is rather intimate and dynamic" (Elisa Giaccardi and Elvin Karana, 2015). We transform with our materials. We are moulded by the resistance, rigidity, texture, flexibility and elasticity of the materials we use and the technologies we interact with, as well as through the forms we make with them. In the microstudies, the non-digital interfaces were made out of: wood, cardboard, aluminium, rubber, textile, plastic and stone. Also, being non-digital, they afforded general movements, i.e. non-repetitive and low-precision interaction. This way, the body-material sensory experiences can be explored.

These body-material and proprioceptive transactions traverse our nervous system, through connective tissue, moving internal fluids throughout our body, shaping us through the rhythms we move with. However, many of our technologies generate excessive resistance through high-precision non-adaptive repetition with small buttons and tiny font sizes; thus, making demands on vision and proprioception without suitable entrainment. These resistive mechanisms permeate our interfaces, working environments and body-material interactions.

During the three microstudies, I felt that I became more aware of my own internal sensory experiences. This awareness afforded responsive interactions, rather than a reactive or prescriptive interactions; as moderator, with awareness, I was able to contextually respond to my participants. This was expressed as being responsive to the situation, while avoiding being reactive or distant, and giving enough space and time for the participants to experience the activities in their own way. I also did my best to avoid projecting my own discomfort onto my participants; as well as avoiding desensitising techniques that dull my sensory experience, such as emotional detachment or compartmentalisation. Instead I acknowledged my emotional discomfort and adapted to the unfamiliar or uncomfortable situation. I now feel that I managed to achieve an equilibrium which offered sufficient physio-emotional space that suited both myself and

the participants. Thus, achieving responsive, reciprocal and interactive relationships with the participants.

In reference to learning to make sourdough bread with a YouTube video, Brigid Costello (2018, p. 37) describes her cyclical learning process: "Each cycle of observing and doing would reveal more subtleties in the rhythmic actions that needed to be performed until finally, after a run of successful loaves, I could truly say that the rhythmic knowledge was in my body and I no longer needed the video.". This rhythmic knowledge of working with dough is much like the rhythmic knowledge of working with clay and the device sculpting activity in the first microstudy (Responsive Bodies). Over time and through the process of making we learn when something is ready, or complete. We develop a sense of completion through a feeling of satisfaction along with the practice of doing.

The methodologies carried out in the microstudies, namely sculpting devices and arranging elements, can offer implementations that are incomplete (by industry standards). When something is incomplete it affords a lower threshold to modify it; this affords the user to make changes to devices according to their tastes and requirements, while also familiarising themselves with the technologies. Therefore, the process of making an interface does not mean it is ever complete, instead it is relationally adapting with the user through their mutual interaction. The interface becomes something that comes into shape through the movement of making, through the rhythm of doing, and the experiences we internalise.

Figure 27. Listening with feeling and sense. A collaboratively designed 3D model. (Illustrated by Olli Koskinen in Autodesk)

Responsive sensory experiences, for instance, the feeling of being in a forest or by a lake, is lacking in our technologies and built environments. By moving towards sensory experiences, we can repair the disconnect between our body, and the devices and tools we use every day. This has been explored by studying the interaction of body, material, and environment, and reaching out to those who may not feel welcome in spaces were technology is studied and made. Through the exploration and study of shape, rhythm and sensory experiences, this work offers opportunities to integrate listening, feeling and sensing into the way we make our interfaces. This increased somatic awareness will bring more meaning and value into processes and methodologies that inform fabrication and production of our technologies. Figure 27 (p. 78) offers a representation of how body and material interact, the form of the light red turbulent spirals are in response to the green catenoid with an internal expanding and contracting spiral structure. The intimate relationship of body and material is the same, both interacting and forming the shape of the other. It is through the stone, a material vital to computing, technology and construction, we regain an internal sensation towards complete interactions through seamless transitions. But we cannot make such seamless interactions if we cannot even feel them:

> *"How can we begin to move toward ecological and cultural sustainability if we cannot even imagine what the path feels like?"*
>
> Robin Wall Kimmerer, 2014

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Appendix

Microstudy 1: Diary Task

Diary writing instructions (instruction descriptions may have slightly varied for each participant, but each of the five main points were included, as well as the description for a pre- and post-workshop three-day diary):

For three days before the workshop, I'd like you to keep a daily diary about your everyday interaction with technology e.g. devices, software and websites. I'll need the diary to be mainly in English for research purposes, but feel free to use Finnish if English does not have terms you need. And when writing, please consider:

1. the shapes you interact with
2. the rhythms you perform
3. how you feel (emotionally/physically)
4. gender diversity (gender inclusivity)
5. neurodiversity (inclusive and accepting of different ways of thinking)

After the workshop, I'll also ask you to keep a three-day daily dairy as the one before the workshop.

Microstudy 1: Follow up

P1

How does your shape feel today?

It's a die. It's a very typical shape, but it's fun to play with.

After the experience, I started paying more attention to shapes, but that only lasted a little while. The attention dwindles within a day. So the first couple of hours there is more active thinking going on in relation to shapes, and I'm analysing how it could be changed. After a couple of hours it begins to dwindle.

After the experience, I noticed, on YouTube the designers use box model based on material design, out of convenience. With website content you need to adapt to different screen sizes, so follow the box model makes it easier for the designers. Not so sure about it being easier for the users, but from a design stand point it makes sense. It makes sense in the way it is economical. Balancing efficiency with asthetics, and the box model allows for that.

P2

Tell me about your device and how you made it:

When I did this I was low on energy, but now I have some new ideas. I did it round because it is nice to be different, and I put a keypad because I prefer it to the touchscreen. Can't remember what the ears are for. it was inspired by the owl, which is my favourite animal. Why does it have to be square? Eyes are round.

What is your device for? What would you do with it?

So, I guess, I would like to combine my laptop and phone, and other devices. It is multifaceted, multipurpose. It has many different things, it is like a smartphone, but more. It could be a device for both professional and leisure, a combination for both work and fun. My gadget will not have shortcuts because it will be so simple, you will just know how to use it. It will move with the natural rhythm of your body.

What name would give your device?
I don't do that. I don't give names to things.

What does it sound like when you roll it?
When it roles, it sounds like cogs turning.

If you chose the colours what colours would you choose?
Full black or darker grey.

What else might you do?
Might add a face.

What could you attribute to each face on your device?
It could be used as a psychological tool - with the different faces as a personality test - so people might identify with the faces on the device.
To elaborate on the previous thought, it can be used as a device that is used to measure satisfaction level - like when you have surveys there´s an alternative for extremely dissatisfied to extremely satisfied. This can be represented with faces / emotions, which can be selected from. So, you pick from them to show how satisfied you are with a product.

If you had some more clay, what would you do with it?
I wouldn't know what to do with it. Because I would need to create something out of nothing. If I made a new shape it would not be far off from this shape. Maybe a ball. Then we can build more and play a game of tic-tac-toe :)

Describe more about your device.
This is something from my childhood. And I think our imagination has limitations. 20 years ago many people wouldn't have imagined a touchscreen. I have asked my nan, did she ever imagine like these kinds of things? She said that technology has changed more than ever in her lifetime.

You don't have many buttons on the device? How would you give meaning to the buttons?
The meaning behind the buttons depends on how the button feels and their tactile functionality. Each button will be different. So if you are in the dark you will be feeling the icons. You can shape the buttons to suit what you like or feel is important. More indented buttons, because there is less risk of them breaking or falling off. And it is comfier to touch.

What else you do with it?
Don't have to sit down.

Do you want your device to know you better than you know yourself?
Yes. No...that's scary.

How is your device different or maybe better than current technologies like phones and keyboards?
For starters it fits in the pocket. It's small. It will not have a cable for charging. You can fix it yourself. It is multipurpose and when you get bored with it you can change it's parts, or swap them.

If you could have another opportunity to make another device, what would it be?
It wouldn't have many external buttons, only the intented buttons. It would still be round, which is more practical. Maybe not the "ears" because they break. Maybe a bigger screen and a smaller keyboard.

What would you call your device?
Not a fruit. The Owl. Because it knows all and it is so wise, and it thinks about the future.

Microstudy 2: Survey

This survey was conducted verbally, answers were spoken, then transcribed, and finally checked and verbally confirmed by the participant.

Pre-Activity Questions

- What can you tell me about stone balancing?
- Have you tried stone balancing before?
  If so, what is one word you would use to describe the feeling of stone balancing?
- Do you need corrective lenses?
  If so, what strength?
  How often?
- For what activities?
  How good are you at focusing on one task at a time? (i.e. not multitasking)
  Not good (1) - very good (5)
- How long can you comfortably do a task with your hands standing up?

Post-Activity Questions

- How did the activity feel over all?
- Use one word to describe how it felt.
- How did it feel to wear the gaze tracker?
- Use one word to describe how the gaze tracker felt.
- How did you feel doing the activity?
- Use one word to describe how the activity felt.
- Any other observations, comments, etc.?

Microstudy 3: Survey

The survey was made using Typeform.com. Questions:

- How did you feel while doing the activity?
- Use one word to describe how you felt while doing the activity.
- How did you feel stacking the stones in the dark?
- Use one word to describe how it felt to stack stones in the dark.
- How did the stones feel in your hands?
- Rate how much you relied on your vision (0) to your hands (10).
- What word would you choose to describe your stone stack?
- What word would you use to describe your approach?
- What else could you say about your experience?

Interoceptive Questionnaires

These are the participants feedback responses to the three interoception self-evaluation questionnaires.

MBAT: Interoception: Mindful body awareness tracker for DECD (Emma Goodall, 2016)

It felt a bit vague to answer - I like quantified information that I get from wearables like Apple Watch.
[no feedback]
It was easy
Pretty neutral, although in my point of view questions are such, that if anyone answers to some of them no it would indicate some kind of medical problem?
You can answer all the options at the same time so that should be restricted. It would be good to have a possibility to explain your choice with each answer because it is highly personal and people might have the need to explain what they meant. Otherwise it's an interesting questionnaire, I liked answering it.
It was easy to fill in.

ISQ: The Interoception Sensory Questionnaire (ISQ) (Lisa Fiene et al., 2018)

A questionnaire it was
[no feedback]
Hmm.. this was maybe a bit too long and repeating too much.
In this questionnaire you could choose every option, which is a problem? I think the results might be very confusing without freeform answer but if it is not a problem, it's good that it had really many options and the same thing was asked from many viewpoints, because feeling pain, noticing pain, being able to describe pain and feeling the need to do something about the signal can be very different things.
this was extremely long and by the middle of it, the heading of the boxes was no longer visible so I had to scroll up to see which was which...

MAIA: Multidimensional Assessment of Interoceptive Awareness (MAIA) (Wolf E. Mehling et al., 2012)

[no feedback]
It brought to mind how I 'test' my body when I have food allergy symptoms.
Some of the questions were kind of, that there were not correct answer (because it depends and scale seemed a bit "wrong", like sometimes you can be aware, but consciously ignore, it's like part of self awareness is also being able to control the affect of awareness, but still be aware)
This was a good one but for me it was a bit too abstract because it didn't differentiate between individual sensations and feelings
It reminded me that I need be more regular with my yoga/meditation

Stone Balancing: Tables of Results

Words participants used to describe stone balancing:

contemplation	absorption	elation
pleased	purposeful	exciting
content	focus/focused	enthusiastic
relaxing	interesting	fun
peaceful	concentrated	playful
calming	challenging	joy

Completion times and differences between stack-to-touch and touch-to-gaze times from crosshair video analysis (minutes:seconds):

Event#	Stack	diff.	Touch	diff.	Gaze
#1	06:02	00:02	06:04	00:07	06:11
#2	00:32	00:03	00:35	00:10	00:45
#3	01:40	00:03	01:43	00:10	01:53
#4	05:06	00:04	05:10	00:12	05:22
#5	00:59	00:02	01:01	00:09	02:20
#6	02:35	00:01	02:36	00:13	02:49

Completion times and differences between stack-to-touch and touch-to-gaze times from gaze path video analysis (minutes:seconds.milliseconds):

Event#	Touch Release	diff.	Gaze Divergence
#1	06:03.964	00:13.610	06:17.574
#2	00:33.396	00:11.978	00:45.374
#3	01:41.516	00:10.738	01:52.135
#4	05:06.441	00:06.694	05:13.135
#5	01:00.040	00:02.881	01:02.851
#6	02:35.349	00:08.448	02:42.797