A Retrospective Autoethnography Documenting Dance Learning Through Data Physicalisations

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ABSTRACT

We present a retrospective autoethnography grounded in data-driven design. The first author collected her movement data and subjective experience of learning the dance repertoire of modern dance pioneer Isadora Duncan, which together were encoded into the design of a set of plaster artefacts physicalising her embodied dance learning progression. The artefacts reflect the first author's bodily transformation, mirroring her transition from discomfort to ease, and changes in her expressive capabilities.

Our method offers an alternative to documentation of embodied learning through design. Throughout our design process we leverage on the movement data, the field notes and the first author's memory of her journey, all of which constitute entangled and complementary input into her experience of dance learning. We show that the data physicalisations provided a gateway into the intangible experience and allowed for a deep and reflexive understanding of our dataset.

CCS CONCEPTS

• **Human-centered computing → Interaction design**.

KEYWORDS

Embodiment, data physicalisation, dance, first-person perspective, autoethnography, craft

ACM Reference Format:
Tove Grimstad Bang, Sarah Fdili Alaoui, Guro Tyse, Elisabeth Schwartz, and Frederic Bevilacqua. 2024. A Retrospective Autoethnography Documenting Dance Learning Through Data Physicalisations. In *Designing Interactive Systems Conference (DIS '24), July 1–5, 2024, IT University of Copenhagen, Denmark*. ACM, New York, NY, USA, 17 pages. https://doi.org/10.1145/3643834.3661607

DIS '24, July 1–5, 2024, IT University of Copenhagen, Denmark

ACM ISBN 979-8-4007-0583-0/24/07…$15.00
https://doi.org/10.1145/3643834.3661607

1 INTRODUCTION

People's encounters with their personal data is a subject of inquiry that has seen a growing interest in Human–Computer Interaction (HCI) over the past few years. With phones, watches and other wearables all around us, generation and processing of personal data is ever more present in our everyday lives. Designers and artists have turned to materialising such data into physical objects as an invitation for people to touch, feel and reflect on their data [14–16, 24, 41]. Such data physicalisations have been shown to contribute to a more nuanced understanding of people's relationship to their personal data, and themselves [14, 31, 58].

In this work we engage in a data physicalisation design process to create objects that facilitate (self)reflection on past events, and in particular on the first author's embodied learning of the repertoire and style of modern dance pioneer Isadora Duncan.

During an eight-month period, the first author attended dance classes taught by the fourth author, dance teacher and Duncan dance expert, Elisabeth Schwartz, to learn Isadora Duncan's dances. With the goal of documenting her learning process, the first author collected field notes of her experience and of the conversations between the expert and herself, where they together unravelled some of the reflections that came out of the dance practice. Additionally, the first author recorded her movements using sensors, namely inertial measurement units (IMUs), during each class. With one sensor attached to the wrist, and another to the chest. After eight months of recording her dance movement, the first author held a large set of quantitative movement data accompanied by qualitative data, documenting her first-person experience of learning three of Isadora Duncan's choreographies. After an initial analysis of the quantitative and qualitative data, we went on to model the movement data in three dimensions. These models were then fabricated as physical artefacts made of plaster. Once fabricated, we brought the artefacts back into conversation with the research team, the authors of this work, and ran both a micro-phenomenology interview

and a team discussion about the artefacts' potential to represent the learning process.

In this paper, we present our design exploration of the first author's learning progression through our mixed data set of quantitative movement data and qualitative first-person data. We describe the data collection, analysis and data-driven design and fabrication of the plaster artefacts physicalising the first author's embodied transformation as she learns the dance repertoire over time. We then describe the findings from our interviews and conversation among the team members. Our findings show the artefacts to be evocative of the characteristics particular to the first author's learning experience and motor skill development. Our contributions are threefold: (1) We provide an example of a *retrospective autoethnography through design*, constructing a self-reflexive narrative of the first author's embodied learning. (2) We contribute with a singular set of artefacts, made from the reflexive design process, with a rich set of quantitative and qualitative data that faithfully represent the first author's journey of learning the Duncan repertoire. (3) Finally, we show how the design artefacts served to *communicate* and *reflect* on the first author's embodied learning experience and progression.

2 THE ORIGIN OF THE PROJECT

2.1 Who We Are

In this project, we are a team of technologists, dancers and designers. We came together to work on documentation of Isadora Duncan's legacy. All five authors contributed to this work with their different backgrounds.

The first author was involved throughout all stages of the project. She is an interaction design researcher. The second author is an interaction design researcher and trained dance artist. She initiated the collaboration and played an intermediary role supporting the first author with guidance throughout the entire project. The third author is a design researcher working with bio-design and 3D-printing, and collaborated with the first author on the data encoding and material exploration phase of the project. The fourth author, is a dancer, pedagogue, dance historian and Duncan dancer, and is transmitting her Duncan dance knowledge to both professional and amateur dancers, including the first author. The fifth author is a researcher specialised in sound, music and movement, and collaborated with the first author on the data analysis.

2.2 Learning Isadora Duncan's Repertoire

The first author was first introduced to Isadora Duncan through an ongoing long-term research collaboration initiated by the second author since 2019 with the fourth author, the Duncan expert. Isadora Duncan (1877-1927) is one of the central figures in the history of modern and contemporary dance and a part of the 'Free Dance' movement in the early 20th century. She broke with the rigid codes of classical ballet, and sought to express the 'natural movement' of the body. Today, the Duncan repertoire continues to live on through oral transmission from one generation to the next, and one commonly refers to different generations of Duncan dancers, according to where in the genealogy of the dance transmission they are in relation to Duncan herself. The fourth author, Elisabeth Schwartz, is a third generation Duncan dancer.

In her classes, Elisabeth transmitted the foundations of Isadora Duncan's movement qualities and the idea of 'natural movement', consisting of continuous movements originating at the *solar plexus* (the chest area) as well as fluidity and perpetual transformation in movement. Elisabeth taught three of Isadora Duncan's heroic dances from her Soviet period from the early nineteen-twenties, Dubinushka, Varshavianka and Polonaise. These dances can be described as agitprop, where a strong connection to the ground and *strength* in the movement qualities are essential to the expression of the political commitment that these dances convey.

2.3 Motivation

The first author initially joined Elisabeth's dance classes in order to better understand the dance style of Duncan through her own moving body and to use that in a somaesthetic design process described in our previous work [6]. Our overarching interest leading up to both this work, and our previous one, was in documentation of dance and the opportunities for interaction design and design practice to encourage and facilitate documentation of embodied dance knowledge.

Qualitative first-person data, in the form of field notes from dance rehearsals and conversations with the Duncan expert, provides us with 'subjective' accounts of the lived experience of embodying Duncan's dance repertoire. And IMU data provide us with 'objective' measures of the same phenomena. Our intention with collecting both IMU data and first-person data was to analyse and represent the intimate emotional and bodily experiences of learning a new dance repertoire. We were looking to explore how the two types of data complement or augment each other.

The intention behind physicalising the data is to design artefacts that allow us to attend to our data differently, through touching and feeling them. The idea is that both the physicalisation process as well as the interaction with the final artefacts, will evoke the past embodied experiences that generated the artefacts. In particular, we are interested in the potential of data physicalisations – the design artefacts –, and the process of physicalising data – the designing –, to facilitate sense-making and retrospective reflection on past events [11, 43, 48, 58]. Through the process of physicalising data we spend time with and engage with the evolving meanings of the data – and of the artefacts – as they transition through various contexts [49]. We aim for this process to bring new understanding of the data in its different assemblages, and we leverage on how data goes from raw numerical data to visual representations on a screen, culminating in physical manifestations encoding this data. Specifically within our work, the dynamic data assemblages move from IMU data captured by sensors on the first author's body, to plots on a screen, into physical artefacts. The process of attending to our data differently through the process of physicalisation provides us with design material to accurately narrate and document the data's story within the physical representation.

3 RELATED WORK

At the intersection of dance and interaction design and HCI research, we situate our work within literature using first-person methods, engaging with the body and dance practice in the wild,

as well as literature using design, arts and crafts as a means for representing and reflecting on personal data.

3.1 First-Person Methods

First-person research methods are qualitative methods that make use of the researcher's own subjective experience and tacit knowledge as a source of knowledge. In HCI, first-person methods include autoethnography [30, 36, 47], autobiographical design [4, 22], micro-phenomenology [20, 45, 51, 52] and soma design [38, 56] among others, and typically require long-term commitment to the phenomena studied [17].

In autoethnographies, researchers may be reporting on their observations of living with (or without [47]) a technological system in a real-world context, such as Homewood writing about her experience of illness being shaped by the use of a Fitbit, eventually opposing the intended commercial use of the self-tracking technology [30]. And Höök's autoethnographic accounts of horseback riding used to translate experiences of movement qualities to design [36]. Furthermore, in retrospective autoethnographies the researchers carry out reflexive analysis of past experiences [27, 32, 39, 47, 62]. Gaver and Gaver reflect on their use of their self-built system, where they communicate with each other over a large distance by sending coloured light [27]. The authors used their system for more than two years, and through their retrospective autoethnography they unpacked the emotional importance that the system came to have for them, as well as the features of this simple communication setup that contributed to its importance. Furthermore, through a retrospective trioethnography, Howell et al. explore failure in design research, and more precisely what we as design researchers can learn from failure [32]. In the trioethnography the three authors enter a dialogue where their individual experiences are juxtaposed, and the similarities and differences of their different voices are highlighted. Then, critical reflection on their past research projects using this method, let the authors investigate failure in their past work while grounding their reflection in their subjective emotional experience.

Across various first-person methods in HCI, the practitioners provide detailed, mostly written, accounts of their first-person insights in order to document and share the process of data collection and analysis. Micro-phenomenology provides a technique for articulating first-person experiences [51]. It is an interview technique that traces back one's lived experience and helps articulate tacit knowledge that would otherwise be hard to express or even evoke. In an opera performance where the singer and audience were interconnected with an interactive corset, the audience experiences of feeling the singer's bodily efforts through the corset were explored with micro-phenomenology, providing insights into the shared intercorporeal experiences facilitated by the technology [45].

The above examples of first-person methods demonstrate the value of including the researchers' and designers' subjective voice in interaction design research, as such methods contribute to an intimate understanding of people's motivation and experience of a design and of an interactive system. Our work aligns with such methods, their values and their benefits. We present a design process informed by the first author's experience of learning a new dance repertoire, and a retrospective autoethnographic design leading to the fabrication of physical artefacts representing the past experience. Using micro-phenomenology we elicit how the physical artefacts make the past embodied learning experience tangible to the research team.

3.2 Designing With the Body and Dance Practice

The body as a site of knowledge is becoming an established idea within HCI methodologies. The moving body is at the center of both theory and design methods in the field, such as movement for ideation [61], movement as design material [33], movement qualities transferred to design [3, 36], and soma design [37, 56].

There is a growing literature on the design, development and experience of interactive systems for dance practice, in contexts such as dance learning [53], dance making (choreographic tools) [8], dance documentation [13] and performance [19, 20, 22, 57]. Indeed, dance has been a subject of interest in HCI literature for the past two decades or more [42, 63].

Dance, in all its forms – from learning to performance – is ephemeral by nature. And documentation of dance is a subject of contention as there is no formalised, nor extensively used method for documentation of dance practice. Attempts to create universal notation systems of movement, like Labannotation, or Benesh movement notation, have shown limited success when applied to interaction design and even as a documentation approach overall. These notation systems are neither extensively taught nor practiced and as a result few people are fluent. Additionally, practitioners have a tendency to resist the use of notation systems that generalise or standardise their artistic practice and expression [2, 29], as they tend to constrain their vocabulary and approach to dance. Furthermore, these systems can be problematic as they claim to be universal while they are built from their creators' western perspective of movement and dance [1, 46]. In consequence, much of dance knowledge and repertoires are either documented idiosyncratically [8, 12, 21] or not documented at all, and therefore at the risk of being lost if it is no longer practiced.

In our work, we bring together qualitative data from dance practice, quantitative movement data and craft materials to design artefacts that serve to document a dance learning process of a century old dance repertoire. With this approach, we attempt to explore ways in which interaction design and design practice can serve as alternative tools for documentation of dance practice.

3.3 Physicalising and Crafting With Data

Data physicalisation is starting to gain recognition as a domain of its own right, with its own vocabulary and frames of understanding [31]. In large part drawing from the traditions of data visualisation, Jansen et al. proposed a definition of data physicalisation in 2015: "physical artefact[s] whose geometry or material properties encode data" [40]. In addition to quantitative data encoded into the properties of an artefact, approaches also include the use of metaphors and imagery [31, 40, 44].

A variety of motivations stand behind encoding of data into physical form [35]. In a study identifying the design dimensions going into data physicalisations, Bae et al. analysed 47 data physicalisations from research articles across multiple HCI communities. The

authors organised the works into categories of functional purposes: *Reflect, Analyze, Educate, Express, Collaborate, Enjoy, Unspecified*. Their study shows a majority of the physicalisations aiming for reflection and analysis. However, the intentions behind reflecting on or analysing data may differ, and these are often goal- and productivity-oriented [7, 58]. An example is Khot et al.'s physicalisation of biomedical data to encourage physical activity through reflection [44].

Alternatively, previous works have also shown the use of data physicalisations for reflection and understanding of data with more critical or transformative intentions. For example Desjardins et al. worked to materialise otherwise invisible Internet of Things-data in the home, emphasising the value of diversifying and diffracting (in new materialist terms) our encounters with these data as it contributes to different understanding of the data around us, and the social and political contexts in which it is entangled [14]. Furthermore, with 3D-printed porcelain cups, Desjardins and Tihanyi encoded ambient sound data onto the surface of functional cups. They demonstrate the possibilities of interpretation, and for the artefacts to spur imagination through tactility [15]. Friske et al. physicalised and sonified personal data in a process they describe as "making personal data narratives" [24]. Their reflexive process puts emphasis on negotiation between data and material, and the agency of the materials when designing artefacts. In their work physicalising loops, Paymal and Alaoui transferred loops from everyday life into scores that they physicalised using knitting, woodworking and dance performance [50]. The authors show how physicalisation of loops change across different media and assemblages and how these physicalisations trace and document their "embodied qualities including their hesitations, mistakes, and uncertainties" [50].

We present a design process of crafting with data captured from the first author's eight-month learning process of the dances of Isadora Duncan. The specificity of our work is to propose a retrospective autoethnography of the experience of learning to dance through crafting with the dance data, and reflecting on both the craft process and the dance learning process through interacting with the resulting artefacts.

4 METHODS

We present research through practice in the form of data-driven design of physical artefacts that represent the learning of Isadora Duncan's repertoire. We, the authors of this paper, collaborated in an open-ended design process over a period of a year to design and fabricate artefacts that physicalise the data collected during an eight-month long period of learning the Duncan dance repertoire.

Our method includes fabrication based on both qualitative and quantitative data of the first author's movement captured during a dance learning process. In our design process we work with data as two representations of the same phenomena: first, field notes in the form of autoethnographic data of the learning experience, second, a large amount of movement data collected using an IMU during each dance class. We use these data to explore ways of creating data physicalisations that represent the learning progression.

4.1 Eight Months to Learn the Dance and Collect Data

The Duncan dance expert led the dance classes and transmitted the choreographies of the three heroic dances by Isadora Duncan, as well as her knowledge and understanding of the movement qualities that make up the foundation of Duncan's dance.

Over a period of eight-months, the first author collected field notes of empirical first-person data after each dance rehearsal she attended. This qualitative first-person data is in the form of an autoethnographic journal. It was constituted by voice memos and written reflections on her experience learning the dance repertoire as well as conversations with the expert. Building upon our previous work [6], we summarise of the outcomes of analysis of this data in the following section (5). The collection, analysis and use of this data in an adjacent design project is detailed in our previous work.

During this eight-month period of documenting her process of learning the dances, the first author also captured her movements while dancing the three choreographies, Dubinushka, Varshavianka and Polonaise, 'in the wild' [54]. She recorded herself using two wireless IMUs [1]. We chose to record movement using the IMUs because they are easy and seamless enough to bring 'into the wild' to the dance studio, without disrupting the dance practice. In conversation with the expert, we decided to place the IMUs at the wrist and the chest in an attempt to capture the qualities that are central to Isadora Duncan's repertoire, namely the ever-expanding and -retracting movement of the *solar plexus* and the continuous movement and perpetual transformations of movement present in the extremities.

The recordings of IMU data were synchronised with video and audio recording made during rehearsals with a setup using MuBu for Max[2], a toolbox for multimodal analysis of sound and motion. The recording setup was running from the first author's laptop and placed in a corner of the dance studio. Our full quantitative data set consisted of recordings from a total of 14 dance rehearsals, with 10 separate recordings of Dubinushka, 12 of Varshavianka and 13 of Polonaise. Each recording included 32 raw sensor variables (see details in section 6.1), 16 for each sensor (wrist and solar plexus), as well as synchronised video and audio.

4.2 A Year to Analyse and Physicalise the Data

Following the data collection, we performed initial analysis of the data using seaborn, a data visualisation library for Python using matplotlib [34, 60]. We started processing the raw sensor data from all recordings of all three choreographies, then moved on to plot processed data. The purpose of the initial analysis was to probe for intriguing patterns and meaning in our data that could serve as design material. It also provided us with a first step towards creating a three dimensional model from numerical data.

Next, we encoded the data from the analysis into three dimensional models in the 3D modelling software Rhino. Finally, we tried different approaches to fabricate and craft physical artefacts based on the 3D models.

The overall process of physicalising the data took form as a *retrospective autoethnography* from the perspective of the first author,

[1] https://ismm.ircam.fr/riot/
[2] https://ismm.ircam.fr/mubu/

where the data analysis, data encoding and fabrication of physical artefacts were grounded in reflections from her field notes, from her experiences learning the three choreographies the year before. The physicalisation process served as a way for the first author to reflect on her past experiences. Thus, the design process of physicalising the data draws from journal data and reflection on IMU data all correlated with the first author's memory of the learning.

4.3 An Interview to Reflect on the Artefacts and the Learning Process

The final stage of this research is a reflection on the artefacts. The research team collectively discussed the value and quality of the resulting artefacts during a conversational study as well as micro-phenomenological interview with the first author carried out by the second author. We detail the method and report on the results of these reflections in section 7.

5 LEARNING THE DUNCAN DANCE REPERTOIRE AND COLLECTING DATA

In her classes, Elisabeth transmitted the foundations of Isadora Duncan's style and movement qualities. In this section we describe these movement qualities and how the first author learned them in the dance studio. Finally, we outline the movement qualities that stood out in the first author's learning process.

Considering the design process as a *retrospective autoethnography* from the point of view of the first author (who also led the work), we write this and the next section (5 and 6) using the first-person pronouns I and me.

5.1 Duncan's Qualities

Duncan turned to nature in her search of the 'origin of movement' and what she called 'natural movement'. She took inspiration from nature in her dance style in ways where the rhythms of the ocean waves and undulating movements from natural elements like wind and trees were expressed through the moving body as continuous transformations of energy [18]. The movement qualities characterising her style include *fluid movements* and *perpetual transformations*, as energy is continuously transferred from one movement to another. Duncan's constant undulating movements require a central point from which they are organised. This point is the chest area, or more precisely the *solar plexus*. Movements start from the *solar plexus* and follow 'attraction and repulsion', and 'resistance and non-resistance'. All of this brings an asymmetry to the grounding and stance of the body.

5.2 The First Author's Journey of Learning Duncan's Qualities

In the dance studio, Elisabeth often began rehearsals with movements shaped like a lemniscate, the infinity shape. These were focused on movements across the three-dimensional plane and with continuous oscillations from one leg to the other. She would often remind her dance students to 'stay on the verge of equilibrium'. This helped me feel the energy transferring from one movement and one body part to the next. In Elisabeth's transmission, as for Isadora Duncan, it was not a question of imitating movement, rather she encouraged us to feel the movement from within.

As described by Elisabeth, I am tall and slender and the main quality characterising my body movement is lightness, giving my posture and gait a floating quality. I had to work for a long time to start feeling and embodying a sense of grounding, the opposing force to the lightness already present in my body. And grounding was essential to the three dances Dubinushka, Varshavianka and Polonaise that I was learning.

From the first few rehearsals, I understood from Elisabeth's teaching, through use of words and emphasis on weight and grounding in the warm up, how the connection to the ground was needed for our movement qualities to be more 'natural'. However, I struggled to find the grounding in the dance movements and on my own. I often did not realise how light footed I was until Elisabeth pointed it out to me. Sometimes this became visible to Elisabeth through my arms and hands, and she pointed out that I should keep my arms down. Before she led my attention to my hands, I was unaware of where they were or what I did with them. As a result, my hands were light, would float up, and then throughout my body starting at my feel, I would loose the grounding. During rehearsals we would spend time just walking with arms and hands relaxed, and work on feeling the weight of the hands. This helped me become aware of my hands.

Together with guiding my awareness, Elisabeth reminded me to have the movement originating at the *solar plexus*, with a clear and strong intention in mind. Over time I started sensing a stronger grounding in opposition to my lightness. During one of the last rehearsals where I documented my experience I noted that "during today's class I had a [moment of realisation] where I came to understand the movement of the the torso, the mobility and engagement of the torso and upper body. I felt it in my body. I felt more movement within the same movements that were more static or rigid before."

I documented my progression and the bodily effects of my progression through first-person accounts in addition to the IMU recordings.

6 DESIGNING THE ARTEFACTS

Following data collection we went on to design and create our data physicalisations. In this section, we explain how we use both the qualitative and quantitative data to inform the design of our physicalisations.

6.1 Analysing My Data

With the same environment as for our recording setup, using MuBu forMax[3], I labelled the IMU data based on the synchronised video and audio recordings to separate and split the data of the three choreographies. From there on we (primarily the first author together with the fifth author) worked with ten to thirteen different recordings of each choreography.

Following this initial processing of the IMU data we moved on to analysing the data. Our initial visual analysis consisted of line plots and distribution plots (kernel density estimates) of raw data, to get a sense of (1) the variation over time or temporal change in

[3] https://ismm.ircam.fr/mubu/

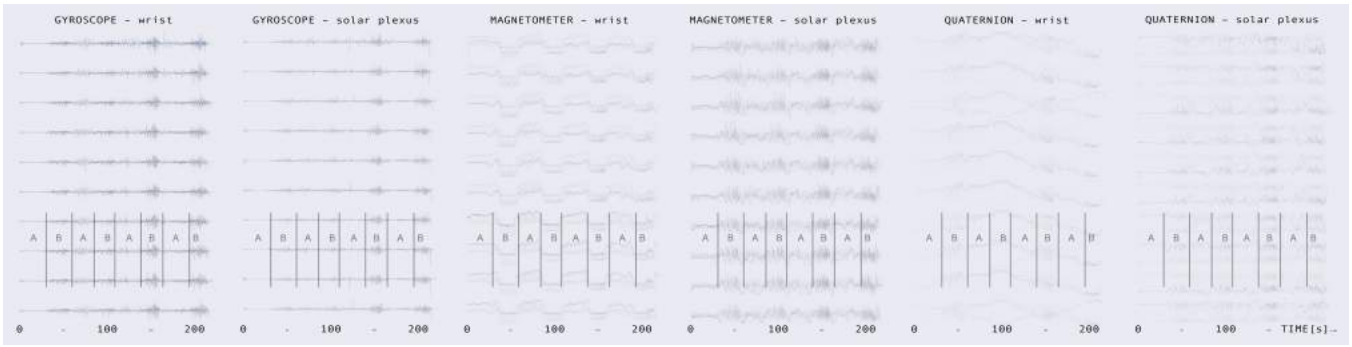


Figure 1: In the line plots of the raw data we recognised the distinct A-B pattern of the choreography Dubinushka. The plots show first to last recording from top to bottom (from November 2021 to June 2022), with time on the horizontal axis.

intensity of movement (derived from the accelerometers data), and (2) an average representation of all the recordings together grouped by different intensities.

6.1.1 The Line Plots. We plotted line plots of all the raw IMU data (2 ×16 sensor parameters[4]). And already in the raw data plots we saw clear patterns triggering interest. In the line plots of Dubinushka I clearly recognised the repeating A-B structure of the choreography. The first segment, A, was of lower intensity, then follows a high intensity segment, B. This A-B structure repeats 4 times. The pattern was visible across different sensor parameters, and in the data from both the wrist and the *solar plexus*. We see the repeating A-B pattern in data from the gyroscope, magnetometer and quaternion in Figure 1 which all represent my orientation throughout the dance.

See also Figure 2 for a line plot of accelerometer data (a single axis) from the IMU on my wrist from the choreography Dubinushka. Here too we can see the repeating A-B pattern in the choreography.

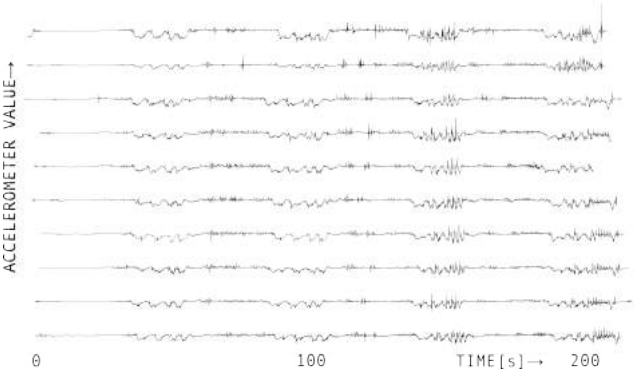


Figure 2: This line plot show first to last recording from top to bottom with accelerometer data on the vertical axis and time (in seconds) on the horizontal axis.

[4]3D accelerations, 3D rotation velocities, 3D magnetometers, quaternions (4), Euler angles (3)

Furthermore, using functions for signal processing from the SciPy Python library[5], we plotted the accelerometer data with high-pass and low-pass filters, looking for potential changes to the patterns of my movement qualities over time. The low-pass filtering allows to focus on the slow movement changes, and typically emphasises the change of the device orientation in regard to gravity. With a low-pass cutoff frequency of 5Hz, I did see a small change of more subtle dynamics in low frequency movements over time. We see this in Figure 3 showing the second low intensity segment from the repeating A-B pattern. As I learn Duncan's continuous and perpetual movement transformation, my movements became less hesitant or jerky and more fluid and smooth. We see this in Figure 3 as the data become less noisy over time with me learning the choreographies. In addition to the increasingly subtle dynamics in low frequency movements, we can see from the first two lines of the plot how I almost did not move at all in the very beginning. These repeating passages of low frequency movement (the A segment) in the choreography Dubinushka consisted of natural movement,

[5]https://docs.scipy.org/doc/scipy/reference/signal.html

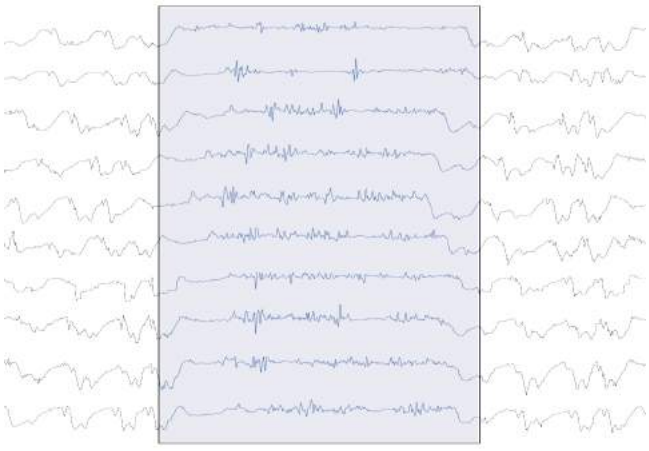


Figure 3: In the low-pass filtered accelerometer data we see a change in dynamics in low frequency movements over time, as the first author learned the choreographies.

almost acting-like, and I was terribly uncomfortable with this in the beginning, which resulted in very little movement in the first rehearsals.

Next, we wanted to compare the high-pass filtered data to distribution plots of the same data, to see if there was a change in 'roughness' over time (related to rapid changes of acceleration, called 'jerkiness' in biomechanics) as I progressed in my learning (the high-pass filter on acceleration also tends to remove all the slow changes on orientation with regard to gravity). The high-pass filtered data (cutoff frequency at a range from 0.1Hz to 0.2mHz) did not show any particular changes.

6.1.2 The Distribution Plot. We plotted distribution plots of the accelerometer and gyroscope data (2 ×6 sensor parameters). In the distribution plot we see the data as probability density curves, where one curve represents one recording. See Figure 4 for a distribution plot of accelerometer data (a single axis) from the IMU on my wrist from the choreography Dubinushka. The density of each curve is proportional in relation to the others across the vertical axis[6]. We cut the distribution plots at range -1.5 to 1.5 [g] of the accelerometer (horizontal axis) and did not include outliers.

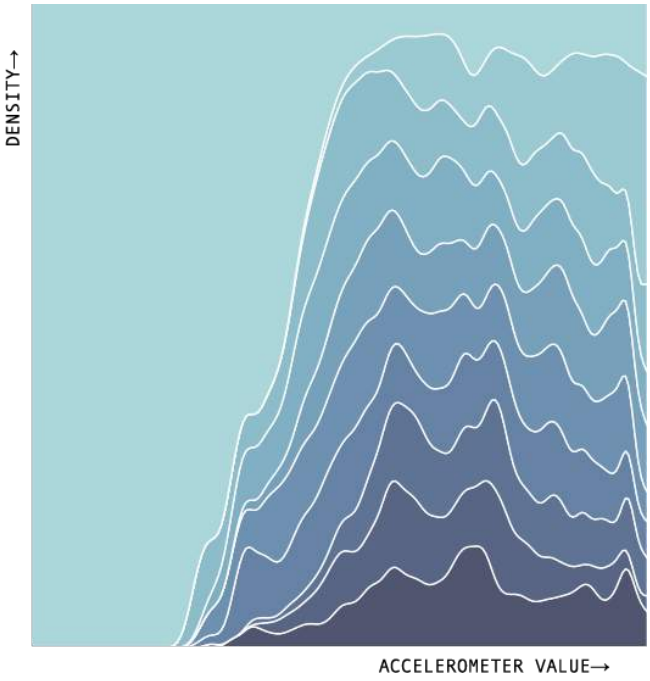


Figure 4: This distribution plot shows first to last recording in the curves from top to bottom with the density of the data on the vertical axis and the accelerometer value on the horizontal axis.

In the distribution plots we did see a change in 'roughness' over time as I progressed in my learning. Indeed, the curves of the plots spread out across a larger density range over time. In Figure 4 we see the peaks of the curve smoothing out across the entire range of accelerometer values. The plot illustrates how I used more variation in the intensities of my movements as I progressed in my learning.

We expected to identify increasing intensity of movements in the data at an earlier stage of the learning process, pointing to it being easier to learn to embody intense dance movements, than fluidity and continuous movement, as these are more complex movement qualities that are harder to learn. In the distribution plot, the changing spread of the peaks on the curves shows how I quickly explored a set of intensities around the middle of the curves, while it took time before I regularly moved with variation on low intensities, seen on the left end of the curves, and high intensities, seen on the right end of the curves. The change in intensities over time as shown in the distribution plot of raw accelerometer data from Dubinushka stood out and triggered our interest.

For the 3D modeling and fabrication, we chose to focus on representing the *change in intensity* and the *repeating A-B pattern* in the movement over time in the recordings of Dubinushka. To do so, we worked only with the data from a single axis of the accelerometer data from the IMU on the wrist, where these factors were clearly visible.

6.2 Encoding My Data in 3D Models and Material Exploration

The process of encoding data into 3D was intertwined with our material exploration. We went back and forth between our data encoding and 3D model, and fabrication method and material selection. The process of data encoding and material exploration was primarily carried out by the first author together with the third author. In this subsection we describe this exploratory process and how we reached our final 3D model and data physicalisation.

From our data analysis we uncovered characteristics in our data of changing movement intensity and a clear choreographic A-B pattern. Together with the research team, we started mapping out options for encoding these data into 3D models. We explored how to encode the data into shape, size and contour – the geometry, and into surface texture – the material properties, of our 3D model. We also considered visual metaphors or imagery from my dance learning in the encoding. We used the 3D modeling software Rhino and the visual programming language Grasshopper to model the artefacts using my data. And we started working with an open source setup for 3D-printing our models with clay using the 300CC_extruder by Reflexlab[7].

6.2.1 The Distribution Plot: Intensity Dynamics. In a model representing all recordings in a single artefact, we encoded the curves of the raw distribution data (see Figure 5a) into the shape of a cylinder (see Figure 5b). Meaning that we have recordings of the same dance stacked on top of each other, as in the distribution plot itself. With this model our intention was to fabricate an artefact with a contour smoothing out, communicating my learning progression. However, the smoothing out of the curves did not show up well. And the printed clay artefacts collapsed with just a bit of overhang (see Figure 5c). From these models we found that all recordings in one artefact ended up with too much information crammed up in

[6]https://seaborn.pydata.org/generated/seaborn.kdeplot.html

[7]https://www.thingiverse.com/thing:5401005

(a) The curves from the distribution plot.

(b) We applied the curves to the shape of a cylinder, seen from the side and from above.

(c) We 3D-printed the model made up of stacked curves from the distribution plot with clay, but the prints collapsed.

Figure 5: Attempts at modelling and 3D printing intensity dynamics with clay.

limited space. The change in movement over time, that we aimed to communicate with the artefact, was hard to discern.

6.2.2 The Line Plot: A-B Pattern. For our next trials we negotiated between form and material, and modelled cylinders with less overhang to avoid collapse. Here, in Figure 6, we encoded the numerical filtered data of a single recording along the contour of the artefact, as well as the texture. Meaning, one artefact equals one dance. Our intention was to show change in dynamics in low intensity movements over time across multiple models. We used the clay 3D-printing design system CoilCAM for these models [9]. At this point we noticed that our datasets were too big to be processed in Rhino and Grasshopper, and we had to compress them to be able to process the models. We printed these models as one clay artefact per dance recording (see Figure 7 for clay prints of the first and last recordings). The pattern that I knew from the low-pass filtered line plots told me something about me learning more variety in subtle movements. However, I did not recognise this change in the clay rendering of the same data.

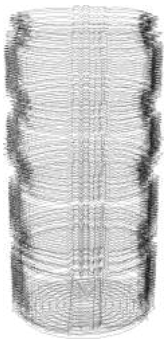


Figure 6: After negotiation between material and data encoding to avoid collapse in our clay 3D-prints, we modelled a straight cylinder with numerical data along its contour and texture.

In a different encoding we used metaphors and imagery from my dance learning to inform the shape of the artefact. In rehearsals, Elisabeth often used the imagery of the lemniscate. Tracing the movement of the lemniscate laid a foundation for continuous movement and created space for dancers to work with perpetual transformation. We modelled a base for a lemniscate-shaped cylinder. Then to build upon this base, we encoded my data into the contour and texture of the artefact with the compressed low-pass filtered data applied to follow the outline of the lemniscate. We explored multiple approaches to modelling the lemniscate. Either as one artefact per recording, or as one artefact for all recordings. We tested clay prints with simplified versions of these models as cylinders (see Figure 8), for quick iterations and to further familiarise with the material properties of the clay and the rendering of my encoded data.

With the clay prints we explored additional factors of material properties such as texture and weight based on the distance between the printed layers (see Figure 9). We spent time getting to know the material and the machine, and made adjustments to the viscosity of the clay, resulting in varying stability in the printed

Figure 7: With clay, we 3D-printed cylinders encoded with compressed and filtered accelerometer data. The first day of recording, in November 2021 on the left and the last day of recording in June 2022 on the right.

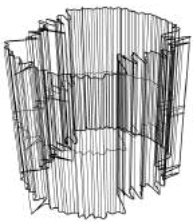


Figure 8: We modelled a cylinder with compressed low-passed filtered data.

Figure 9: We printed the model for iterations with the material.

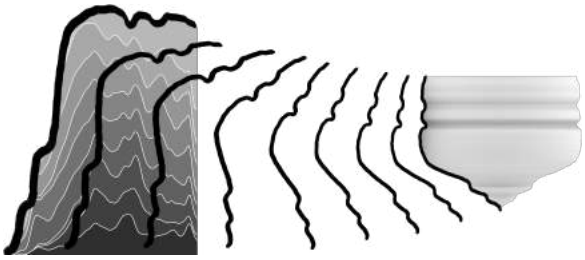
models. We found that data encoded into multiple physical properties of the model made it difficult to interpret the result. Indeed, I was no longer able to recognise the patterns of the data from my learning experience nor the data analysis in the lemniscate model. Subsequently, we moved on to working with only one physical property for data encoding into each 3D model.

Overall, we realised during the modeling process and exploration of materials that with our huge dataset – less is more. This was after we had already reduced our dataset to work with only of the three dances and one sensor variable from the ten recordings. We decided to stick with the following two points for our final design: First, *one* recording/dance into *one* model/artefact. And second, *one* piece of data encoded into *one* artefact property, either texture or geometry.

6.3 Fabricating With My Data

In this subsection we describe the fabrication of the final artefacts physicalising my learning progression. With our setup for clay printing, we faced challenges with the viscosity of the clay and its stability. The designs tended to collapse. We then had limited possibilities for encoding data into the contour or shape of the artefact, and therefore decided to set clay printing aside, and to work with design ideas without having to negotiate the constraints of the material.

First, we iterated on our 3D models. Similar to the model with the distribution plot of all recordings all in one artefact from section 6.2.1, we worked with the curves in the distribution plot, but now separated with one curve per artefact, i.e. one recording from one dance per artefact. We modelled multiple cylinders with their shape based on the curves from the distribution plot, defining the contour of each artefact (see Figure 10a). We modelled a series of options with varying cylinder radius and inclination of the curve (see Figure 10b).



(a) Here demonstrating how the curve from the first recording defines the contour of a 3D model.

(b) We modelled multiple options of shapes for our artefacts.

Figure 10: We used the curves from the distribution plot to create cylinders.

Figure 11: Our final 3D models, with each shape defined by the curve of the distribution plot of accelerometer data from Dubinushka. Meaning, one recording in one artefact – from November 2021 on the left to June 2022 on the right.

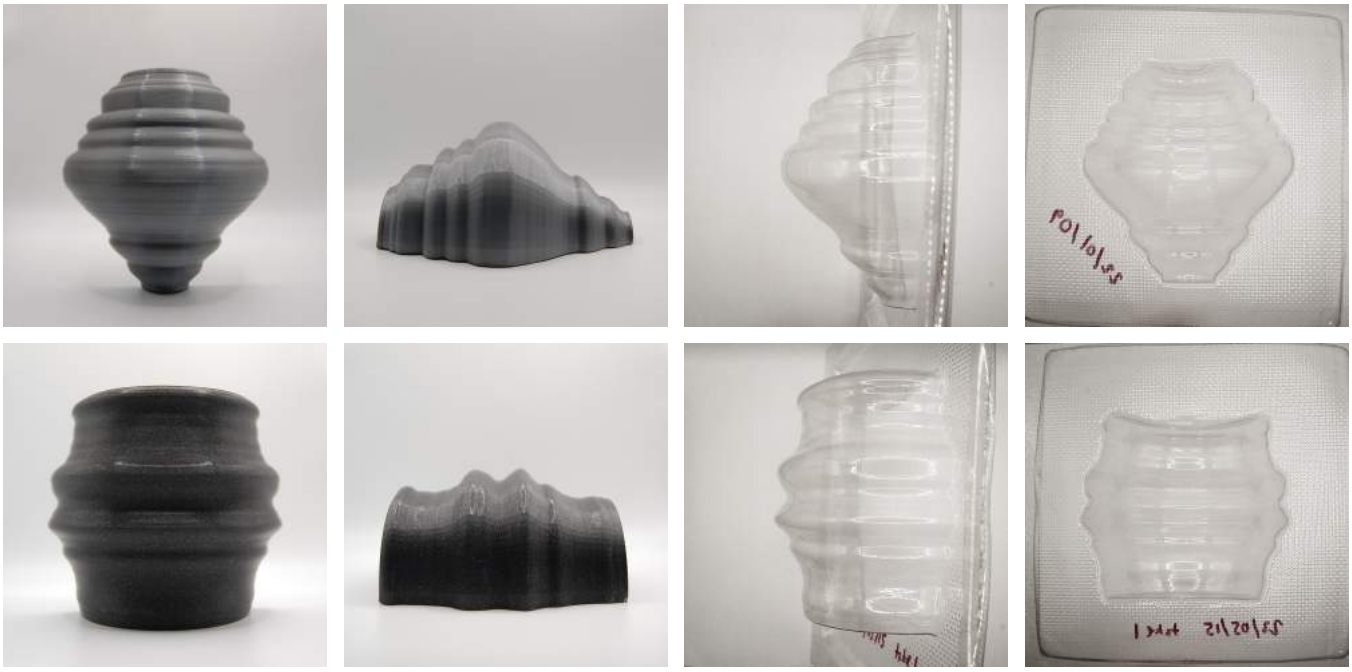


Figure 12: We 3D printed half-sections of our models in PLA that we used to create moulds with a vacuum former for casting our plaster artefacts.

Again, only *one* recording into *one* model, and *one* piece of data (the curve of the distribution plot) encoded into *one* artefact property (the shape of the model).

We found the change over time to be well represented in these models. We adjusted the inclination of the curve and different radii of the objects in order to have artefacts that resonate with my experience of learning the dance over time. We finally reached a set of seven 3D models, each representing one recording, from one day, of me dancing Dubinushka (see Figure 11).

Now, with our 3D models on hand, we went on to fabrication. Casting provided a solution to the smallest overhang leading to collapse when printing with clay, and let us focus on form and texture. We considered casting with regular clay or slip casting clay or concrete or plaster, which are all common sculpting materials. We first made our moulds using a vacuum former, the Mayku FormBox. To do so we 3D-printed half-sections of our 3D models with PLA filament, and used these to create our moulds (see Figure 12). We then cast our models using plaster, two half-sections for each model (see Figure 13).

Plaster as a sculpting material worked well with our plastic moulds from the vacuum former. We chose to not print the models in PLA, rather we wanted to make our final artefacts using traditional sculpting material, so that they would have some weight to them. Crafting in the final stage of the fabrication process also gave me a sense of agency of the final representation of the data. I could go in and polish small bumps and details on the surface of the plaster. And the plaster let us work in quick iterations with the material as there is no need for firing and we see the final result of the model soon after casting. It also leaves a smooth and detailed surface,

Figure 13: With two identical half-sections cast in plaster we created our final artefacts. Here we can see half-sections of two different artefacts.

and finally, it allows one to easily modify the mass and hence the weight of each artefact. I did so by filling up the entire mould to the brim, and scooped out some of the material in the middle as the plaster started to solidify. Then, after the plaster had completely set, I carved out a hollow room to reach the desired weight of each half-section.

Finally, I joined the identical artefacts with glue, and polished the joints on the outside and inside of the final artefact (see final artefacts in Figure 14).

Figure 14: The seven plaster artefacts each representing one day of the first author dancing Dubinushka over a period of eight months, from November 2021 on the left to June 2023 on the right. © 2023 Tove Grimstad Bang.

7 INTERACTING WITH THE DATA

We ran a sharing session with the authors of the paper. Our sharing had two goals: (1) to assess if interacting with the artefacts allows the first author to evoke her embodied experiences of learning the dances (2) to reflect among the research team on the dance learning and subsequent design process and the artefacts' potential to represent the first author's experience of learning the dances and the fourth author's experience of teaching them to the first author.

7.1 Methods

7.1.1 Procedure and Participants. We laid out the artefacts along with individual zines for each of them. The zines contained the data plots that were encoded into the given artefact and notes taken from the first author's journal from the day of recording.

The second author, who is trained in the experience explicitation technique and micro-phenomenology interviews, interviewed the first author about her experience of interacting with the artefacts. She asked the first author to touch the artefact and to go back to the moment of the rehearsal where the data encoded was captured. The goal was to see how touching, feeling and observing the physical artefact supported the embodied memory of the learning of the specific dance encoded. The idea was also to continue probing the retrospective reflection initiated by the physicalisation process.

Following the micro-phenomenology interview, the rest of the research team joined, and engaged in a collective conversation mediated by the artefacts. The team reflected on both the design process and on the relationship between the artefacts' qualities and the learning progression that they represent.

7.1.2 Data Collection and Analysis. The sharing session was audio recorded upon consent given by participants. The first author transcribed the audio recordings. The first and second authors analysed all of the transcribed data inductively, following a reflexive thematic analysis [10]. After an initial read through the full data set, we, the first and second author, read through it again and individually coded it according to what we found noteworthy. We then sorted these codes into themes that captured our experience with the artefacts and the learning of the dances.

7.2 Findings

7.2.1 Evoked Perceptions and Experiences of the Body. Our micro-phenomenology interview and conversation among the research team showed how the interactions with the artefacts revealed three ways in which the first author experienced and perceived her body that have progressed and changed throughout the learning of Isadora Duncan's dance Dubinushka. The first one is her feeling of (dis)comfort with her body. The second one is her relationship to gravity and sense of grounding. And the third one is her embodied expressive capabilities.

The First Author Feeling Comfortable With Her Body. When interacting with the artefacts designed from the three first recordings, holding them in her hands, touching and feeling them, the first author evoked how she felt uncomfortable with her body when she started learning Dubinushka. She speculated on how such a feeling of discomfort is visible with the bulging of the artefacts. They are uneven, with a swelling mid-section, and a conical, skinny lower section. The skinny lower section, and protruding middle make the artefacts top-heavy and unstable. They look as if they may easily tip over (see Figure 15).

Figure 15: The first few artefacts, from the beginning of the first author's learning journey, were top-heavy, bulging at the middle with a conical lower section, making them unstable, echoing her discomfort when starting to learn the dances.

The feeling of discomfort came from the theatricality of the piece. During the micro-phenomenology interview, the first author recalled that "my movement feels fake, and it's very uncomfortable, sometimes embarrassing". Discomfort also came from the fact that she was asked by Elisabeth to be one of the characters of Dubinushka that "alert the other dancers" which put her in the foreground. Dancing with and in front of other people and embodying such character was a source of discomfort for her. The first author reflected on her discomfort by describing her odd perception of her body: "I feel like my limbs are ten times longer" and that "I don't know where to place myself".

During the interview, while the first author was touching and looking at the artefacts, she could see that there is a progression in their shape that was related to her trying to overcome this feeling of discomfort. Indeed, she recalled that progressively, with time and through learning, she felt more comfortable with her body and her movements. Overcoming discomfort was related to how the first author learned how to ground herself, which allowed her to acquire a larger range of available movements and expressions, which in turn gave her confidence in her own body. The first three artefacts

Figure 16: The top opening of the artefact changed with the first author progressing in her dance learning, from small, almost closed to wide open, reflecting how she gradually started feeling at ease with her body.

Figure 17: The base of the artefacts progressively increased in contact surface area with the ground, as the first author embodied grounding in her dance.

have small holes at the top, expanding from the fourth until the last one, echoing the first author opening up with more variety in her movement expression and increasingly at ease with her body (see Figure 16).

Relationship to Grounding. For the first author, the feeling of comfort in dancing was related to finding grounding. In fact, while interacting with the artefacts one by one, she realised that the whole progression of her learning is a discovery of how she embodies or feels gravity or how she relates to the ground. This is visible in the artefact as the first artefact starts with a very small base and surface area in contact with the ground, slowly becoming larger and larger with a growing contact area with the ground (see Figure 17). During both the interview and the discussions among the research team we were struck by the clear correlation between the first author's discovery of grounding and the artefacts' shape with progressively larger contact area with the ground.

The progression in time of the first author's feeling of grounding allowed her to acquire more smoothness in her movement. Her movements felt more natural and more continuous. She mentioned how in the later classes her movement "doesn't die out and [how] it continues to exist throughout". At the beginning, she had an inaccurate interpretation of what grounding meant. She was compensating it with heaviness and moving with her extremities in awkward ways which also contributed to that feeling of discomfort and unnaturalness mentioned above. It was as if her point of grounding was sitting too high up in the body and she needed jut her arms out to not tip over. This echoed how the artefacts were shaped with their bulging mid-sections and conical, skinny lower section of the first few, unstable artefacts, as seen in Figure 15.

As she started to understand that the movement is actually initiated from the center and the solar plexus and successively moved through the extremities, her movements acquired more naturalness and smoothness. Thus, discovering grounding was related to discovering how to initiate movements from the solar plexus which allowed her to acquire a better relationship to the ground and to make her movements more grounded and thus more fluid and natural.

The First Author's Embodied Expressive Capabilities. While interacting with the artefact, the first author was able to recall how she, through time and learning, acquired more possibilities of movement and expression. She started her learning journey expressing essentially one intensity in movement, and then with time was able to perform more nuanced intensities. This is visible in the artefacts' shape and the smoothness of the contour. Indeed, the first artefacts have only one bump at the mid-section, like a vase, meaning that there was one small intensity range that she "explores and the others not so much, so it [is] more like on–off". Then, the artefacts start to exhibit two bumps which represented how she was exploring two intensities in movement. And towards the last artefacts, they take a more even, straight shape, like a pot (see Figure 18).

Figure 18: The artefacts representing the initial stages of the first author's learning were vase-shaped with a single bump at the middle. Over time, they developed two bumps and eventually took on a pot-shaped contour, reflecting the author's expanding movement capabilities.

This meant that the first author gained more homogeneity in the distribution of the intensities that she was able to perform. Thus, learning Duncan allowed her to acquire a larger scope of intensities and nuances in movement and this was visible in the progression of the shape of the artefacts. In comparison with the beginning of her learning journey, the low- and high-end intensities become more available to her as she was able to find more movement expression, specifically in parts of the choreography with subtle movements.

In summary, finding the relationship to the ground made the movement more natural and fluid which in turn allowed the first author to find more available intensities and expressions. And as that happened, she started to feel more comfortable in her body. So all three experiences and perceptions were linked together and were visible in the way in which the artefacts started as uneven amphorae or vases with small bases, and over time became smooth pots with large bases.

7.2.2 *Qualities of the Artefacts.*

Emergence and Surprise. In the conversation among the research team, we reflected on the intrinsic qualities of the artefacts. The authors all reported on being astonished by how the artefacts turned out. For example, as we started looking at the outcome of the artefacts all together, we started realising that the base of the artefacts is related to the grounding in the first author's dance. This was not a feature that we designed for and rather came out as we observed the artefacts. Similarly, looking at them we realised that there was first one single bump, then two bumps, and then the bumps merged into a pot-like shape. This allowed us to reflect on the diversity of intensities that were available to the first author throughout her learning.

Aesthetic Qualities. The team found the artefacts to be poetic and ambiguous. In making the artefacts, there was a negotiation between how much they needed to be objective representations of data and how much they needed to have their own ambiguous and poetic qualities. While we cared that the artefacts were coherent with the data, we wanted them at the same time to be ambiguous in order to allow for different narratives to emerge. Thus, they were not thought of as only perfect representations of data but as artistic objects in their own rights.

Metaphors and Scores. According to Elisabeth, the artefacts are metaphors of the dance, or "crystallisations really, like a physicalisation of a process". She also described them as scores because they physicalise a "dance performance, the feelings, embodiment, and so on". As objects, they were reflexive objects because through designing them and through interacting with them, the first author was pushed to try to understand her own data over and over again and to reflect on her past experience of her dance journey. The artefacts' making was entangled with the first authors' own memory of her learning.

An Eloquent Ensemble. Lastly, the artefacts when put together were seen as an ensemble, not solely as single objects, allowing the team to reflect and better understand the progression of the first author's learning. Indeed, we were able to see the differences between each artefact made clearly visible by comparison to the others. As an ensemble, the artefacts let us reflect on different learning thresholds and on moments that were important, determinant and decisive in the first author's learning such as when she discovered grounding or when her movement became more integrated and more natural or when she started to explore more intensities.

The artefacts put together with the notes from the first author's learning journey revealed different temporalities. First of all, they reveal the progress of the first author's journey through the eight months where she was learning Dubinushka and recording herself. But they also reveal the temporality of the choreography itself, as each artefact is the result of the same 3 minutes and 35 seconds long recording of the dance. They also reveal another temporality which is the time that we spent modeling the data, designing the artefacts and interacting with them to reflect on the dance and design process. They embody all three of these temporalities together. The short temporality of the dance, the embodied temporality of the learning journey, and the post-temporality of modeling, designing and reflecting on them through touch, observation and discussion.

8 DISCUSSION

In this paper we present our retrospective autoethnographic design of data physicalisations. Our motivation to use this approach was to explore design as a means to document embodied practices, here dance. We designed and fabricated a set of plaster artefacts to document the first author's embodied transformation as she learned the Duncan dance repertoire. In this section, we discuss how our design process allowed us to reflect on the embodied practice and how meaning and aesthetic qualities emerged in the artefacts that we created. Finally, we conclude our discussion with reflections around the researcher's role in autoethnographies.

8.1 The Reflexive Design Process and Resulting Data In Different Forms (and Shapes)

Our study proposed a new way to document dance learning through a retrospective autoethnographic design. By turning to data physicalisation as a reflexive practice, we explore the dynamic nature of data collected while learning to dance, as it transitions across different media.

In line with Carpendale and Oehlberg and Thudt et al. we found that the main value of data physicalisation is not so much in the end result, but more so in the time that the designer spends with the data, reflecting on it, crafting with it [11, 58]. For the first author, spending time with the data meant scrutinising its nature and detail at all different stages, while continuously going back to the field notes and to her memory from the actual dance practice and learning. As data moved through different media and assemblages [49], our understanding of it changed and evolved.

When we first plotted the accelerometer data from Dubinushka with distribution curves (in Figure 4), we got a sense of change in intensities in the first author's movement over time. However, despite this being an outcome that we anticipated, knowing how it tends to be easier to learn high intensity movements than low intensity ones i.e. complex movement qualities like fluidity and continuous movement are typically harder to learn, the deeper meaning of this progression and how it took form throughout her learning process was still opaque in these plots. Then, when we used the same curves, from the same data, to create the shapes of a

series of 3D models (in Figure 10b), we started seeing a narrative that resonated with the learning process appear. When we finally brought the plaster artefacts into discussion with the research team, our understanding of the data yet again took a new dimension.

As the physicalisation evolved we were asking questions about what the data *now* came to mean in its new assemblage and new form, making it a reflexive physicalisation process. We wondered at each stage if the current representation was faithful to the data as we knew it and as it previously took form, and whether it spoke to the first author's own embodied tacit knowledge and memory of how her learning progressed. These questions about the data were guided by the first author's subjective experience of the phenomena behind it.

Thus, the process of getting to know the data in depth through analysis, modelling and physicalisation, opened new avenues for reflection from the otherwise 'meaningless' data from the IMUs. It served as a meaningful gateway into the intangible – the process of learning a new dance style. This echoes how musical metaphors were a gateway into understanding the subjective experience of embodying the Duncan style, in our previous work [6].

8.2 The Emergence of Meaning

The evolving understanding of the embodied practice represented in the data, led to a certain unpredictability and surprises in the resulting artefacts.

Eventually, the curves in the distribution plots representing the first author acquiring more variation in movement were the sole set of information from the quantitative data encoded into the final artefacts, and therefore the only data-to-shape characteristic that the first author intentionally designed around. In the artefacts, this shows up across the ensemble as a variation in bumps and smoothing out of the shape, as we show in Figure 18. Meanwhile, the evolution of the growing base (annotated in Figure 17), representing the change of the first author's sense of grounding, emerged as a consequence of this design strategy, and was *not* intentionally encoded into the artefacts. Furthermore, the evolution in the artefacts illustrating the first author's sense of grounding was not visible in the analysis of the IMU data. This unintentionally emerging feature of the artefacts is defined by Hornecker et al. as a 'consequential aspect' in data physicalisations [31]. Indeed, the first author had not considered the growing base before discussing and reflecting on the artefacts together with the research team.

At the beginning of this collaboration, before the first author started recording her movement, the fourth author, the Duncan expert, expressed doubts about the use of temporal sensors and the choice of their placement at the wrist and the *solar plexus*). She considered them to be "two points of information that alone mean nothing", as they strip away the cultural and social context of the century-old history and legacy of Isadora Duncan as well as her individual way of transmitting her knowledge of the Duncan repertoire in our present-day context. However, when designing with the mixed dataset including data from these "two points of information", new meaning emerged from them in return. For example, during the discussion with the team, we were surprised and fascinated to see the dance quality of *grounding* showing up as well as it did coming from data collected from the wrist. The fascination transformed into reflection upon the meaning of *grounding* in the artefacts. Both the second and fourth author discussed how in dance, grounding from the feet is *integrated* in the body and how seeing that reflected in wrist movement shows the *plasticity* of the body. In other words, the grounding evolves from the feet – towards the center, in Duncan's style, the *solar plexus* – and shows up in the extremities, here the wrist.

Another example of 'consequential aspects' that emerged in the artefacts was the 'Greek' vase form or what the forth author described as the 'amphorae'. These shapes organically emerged in the artefacts and were not intentionally designed. The expert brought up the connection to Duncan and her drawing inspiration from ancient Greece. Indeed, during the discussion among the team, the expert was the one who first described the plaster artefacts as ancient Greek amphorae. These emerging 'consequential' properties in our design demonstrate the importance of accounting for complexity, emergence and surprise, and for making space for the subjectivity of the designer in shaping and interpreting the possible outcomes of their design [28].

8.3 The Emergence of Aesthetic and Poetic Values

Furthermore, the artefacts transcended mere representations of data. They became poetic and ambiguous objects that sparked wonder and awe. They functioned as metaphors and scores, inviting interpretations beyond their objective data-driven origins, and enriched the narrative and reflection on the learning journey. Firstly, they spurred unexpected reactions from team members, such as the surprise expressed by both the fourth and the fifth author upon encountering the artefacts, who both only knew the data behind them. The fourth author only knew the dance and how the first author learnt them. The fifth author only knew the data as numerical values and plots. The surprise and awe they expressed when seeing the artefacts highlight the transformative potential of engaging with tangible transformations of data [14].

The ambiguity in the artefacts opened up for speculation and fostered rich reflections and discussions. This underscores the potential of such data physicalisations to make space for the viewers interpretation and imagination. As equally brought up by other authors such as Khot et al. and Desjardins and Tihanyi in their works with physicalisations of data [15, 44]. The ambiguity and poetic nature of the artefacts contribute to making them valuable, as well as opening up for deeper aesthetic engagement with the underlying data. In our discussion with the research team, we realised how in the artefacts the boundaries between quantitative and qualitative aspects were blurred out, which challenges traditional definitions of data [59]. This, again, says something about the transformative potential of design in reshaping our understanding, and the value of design artefacts as research objects [26].

Finally, when viewed collectively as an ensemble, the artefacts provided a holistic understanding of the first author's learning progression. Each artefact represented a distinct moment in time, capturing the progression of her journey and revealing learning thresholds, that were not otherwise available in the data, neither in the initial data analysis, nor in the field notes. Thus, beyond

what we read from displaying the quantitative data, the artefacts communicated a more complex narrative and made for a rich documentation of an experience of learning dance over a long period of time.

8.4 Beyond the Self in Autoethnography

Through this work, and her previous work [6], the first author engaged with a community of Duncan dancers to which she belongs now. This allowed her to value long-term commitment to fieldwork and the resulting intimate understanding of the embodied phenomena at hand. However, the artefacts that this work produced document and represent the embodied transformation of the first author only, the 'researcher-turned-practitioner'. One of the challenges of autoethnography is to engage with communities of practice without the 'researcher-turned-practitioner' taking up the central role. But then, how can we design beyond the self without taking the place of the 'researcher-turned-observer'? One of the critiques of first-person methods is that they run the risk of putting the researcher at the center of the stage [1]. We see a challenge in how to best combine or balance our actions towards understanding, being aware of, being sensitive to and viscerally experiencing the feelings involved in a practice, and of uplifting the interests, objectives and standards of the community of practice and of HCI at large. In our case, the question then is: How can the communities of dance and HCI benefit from such a personal research?

We argue that our approach using first-person methods and a mixed dataset for documentation of embodied knowledge constitutes a move towards resisting the traditional representationalist take on data in HCI, that we often see in data physicalisation and data-driven design, with fixed mappings and interpretations posing as the ground truth [31, 55]. Our engagement in both our embodied and design practices allowed us to create poetic relationships between data and its physicalisation and to let complex and nuanced interpretations emerge out of it. Our numerical IMU data mapped to 2D plots allowed the emergence of new understanding of movement and dance learning. Then, as we attended to different representations of our data through manipulating clay and plaster, we saw new meaning in our data that went beyond the representational mirror of movement. This design process led to a deeper connection to the data, the artefacts and the embodied learning process, as we demonstrate in our findings in section 7.2. Similar to how Gamboa discusses how autoethnography provided her with a "base to express tacit experiences" when studying child–drone interaction in her household [25], our use of autoethnographic methods allowed us to access and give shape to an intangible and tacit knowledge at the core of dance learning, which was otherwise inaccessible in our IMU data alone. Our description of our retrospective autoethnographic design process retraces the entanglements of our embodied, sensory experiences of dancing with crafting physical materials and digital technologies, using a synthesis of numerical data, field notes and memory. As such, our work illustrates an example of data-driven work aligning with Sanches et al.'s proposed pathways for diffractive design practice with data [55]. By revisiting our design approach through a diffractive lens we emphasise the value of experimenting with different ways of connecting to and interpreting bodily data [55], of engaging with materials, reflecting on design artefacts and of relating to humans, non-humans and environments [23].

Finally, the plaster artefacts introduce a new lens to how we see and formulate the subject of safeguarding embodied dance knowledge. We provide an example of data physicalisation as idiosyncratic documentation of dance, which aligns well with the already existing tendency for art practitioners to idiosyncratically document their work, and we argue that despite them being products of the first-author's data, this documentation brings value to the dance community at large as intermediaries between a personal tacit embodied knowledge and numerical data. By materially existing and tracing the first author's Duncan practice, these physicalisations contribute to making the practice continue to live on in different forms. As seen in section 7.2.2, the physicalisations were also interpreted as possible dance scores. Despite them inscribing the first author's learning of Duncan they represent movement patterns and qualities that have the potential to inspire dance movement in other's bodies. Hence, our ethnographic approach moves beyond the sole realm of the first author's story of learning a dance style and repertoire. It produces an ensemble of insights into dance documentation and HCI methods that allow to re-situate the researcher and their body as a site of knowledge.

9 CONCLUSION

In this paper we have presented a study that aims to document dance learning through retrospective autoethnographic design. We described how the first author captured quantitative and qualitative data of her learning of Isadora Duncan's dance repertoire, and how she physicalised the data in a set of plaster artefacts, as representations of her embodied learning process. Through a microphenomenological interview with the first author and a discussion within the research team, we reflected on the artefacts and the design process. We saw them as evocative of the first author's perceptions and experiences of the body and discovered their aesthetic qualities and their collective impact as an ensemble.

The artefacts served as tangible manifestations of the first author's bodily transformation. They mirrored her journey from discomfort and instability to ease and grounding, reflecting shifts in her embodied expressive capabilities. The artefacts' physical attributes, their shape, contour and surface area in contact with the ground, directly correlated with the first author's feelings of comfort, relationship to *grounding*, and range of expressive possibilities throughout her dance learning journey. These physical representations provided a gateway into the intangible, tacit, embodied learning process, allowing for a deeper understanding of the data that made them.

ACKNOWLEDGMENTS

This work was fully supported by the Agence National de la Recherche (ANR) grant ANR-20-CE33-0006- "LivingArchive: Interactive Documentation of Dance".

REFERENCES

[1] Sarah Fdili Alaoui. 2023. *Dance-Led Research*. Habilitation à diriger des recherches. Université Paris Saclay (COMUE). https://inria.hal.science/tel-04059520
[2] Sarah Fdili Alaoui, Frédéric Bevilacqua, Bertha Bermudez Pascual, and Christian Jacquemin. 2013. Dance interaction with physical model visuals based on

movement qualities. *International Journal of Arts and Technology* 6, 4 (2013), 357. https://doi.org/10.1504/IJART.2013.058284

[3] Sarah Fdili Alaoui, Baptiste Caramiaux, Marcos Serrano, and Frédéric Bevilacqua. 2012. Movement qualities as interaction modality. In *Proceedings of the Designing Interactive Systems Conference on - DIS '12*. ACM Press, Newcastle Upon Tyne, United Kingdom, 761. https://doi.org/10.1145/2317956.2318071

[4] Catarina Allen d'Ávila Silveira, Ozgun Kilic Afsar, and Sarah Fdili Alaoui. 2022. Wearable Choreographer: Designing Soft-Robotics for Dance Practice. In *Designing Interactive Systems Conference*. ACM, Virtual Event Australia, 1581–1596. https://doi.org/10.1145/3532106.3533499

[5] S. Sandra Bae, Clement Zheng, Mary Etta West, Ellen Yi-Luen Do, Samuel Huron, and Danielle Albers Szafir. 2022. Making Data Tangible: A Cross-disciplinary Design Space for Data Physicalization. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22)*. Association for Computing Machinery, New York, NY, USA, 1–18. https://doi.org/10.1145/3491102.3501939

[6] Tove Grimstad Bang, Sarah Fdili Alaoui, and Elisabeth Schwartz. 2023. Designing in Conversation With Dance Practice. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*. Association for Computing Machinery, New York, NY, USA, 1–16. https://doi.org/10.1145/3544548.3581543

[7] Eric P.S. Baumer, Vera Khovanskaya, Mark Matthews, Lindsay Reynolds, Victoria Schwanda Sosik, and Geri Gay. 2014. Reviewing reflection: on the use of reflection in interactive system design. In *Proceedings of the 2014 conference on Designing interactive systems (DIS '14)*. Association for Computing Machinery, New York, NY, USA, 93–102. https://doi.org/10.1145/2598510.2598598

[8] Bertha Bermudez and Chris Ziegler. 2014. Pre-Choreographic Movement Kit. In *Proceedings of the 2014 International Workshop on Movement and Computing - MOCO '14*. ACM Press, Paris, France, 7–12. https://doi.org/10.1145/2617995.2617997

[9] Samuelle Bourgault, Pilar Wiley, Avi Farber, and Jennifer Jacobs. 2023. CoilCAM: Enabling Parametric Design for Clay 3D Printing Through an Action-Oriented Toolpath Programming System. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*. Association for Computing Machinery, New York, NY, USA, 1–16. https://doi.org/10.1145/3544548.3580745

[10] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (Jan. 2006), 77–101. https://doi.org/10.1191/1478088706qp063oa

[11] Sheelagh Carpendale and Lora Oehlberg. 2023. 1. Handcraft - Introduction. In *Making with data: physical design and craft in a data- driven world* (first edition ed.), Samuel Huron, Till Nagel, Lora Oehlberg, and Wesley Willett (Eds.). AK Peters : CRC Press, Boca Raton.

[12] Marianela Ciolfi Felice, Sarah Fdili Alaoui, and Wendy E. Mackay. 2016. How Do Choreographers Craft Dance? Designing for a Choreographer-Technology Partnership. In *Proceedings of the 3rd International Symposium on Movement and Computing (MOCO '16)*. Association for Computing Machinery, New York, NY, USA, 1–8. https://doi.org/10.1145/2948910.2948941

[13] Marianela Ciolfi Felice, Sarah Fdili Alaoui, and Wendy E. Mackay. 2018. Knotation: Exploring and Documenting Choreographic Processes. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, Montreal QC Canada, 1–12. https://doi.org/10.1145/3173574.3174022

[14] Audrey Desjardins, Jena McWhirter, Justin Petelka, Chandler Simon, Yuna Shin, Ruby K Peven, and Philbert Widjaja. 2023. On the Making of Alternative Data Encounters: The Odd Interpreters. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–20. https://doi.org/10.1145/3544548.3581323

[15] Audrey Desjardins and Timea Tihanyi. 2019. ListeningCups: A Case of Data Tactility and Data Stories. In *Proceedings of the 2019 on Designing Interactive Systems Conference (DIS '19)*. Association for Computing Machinery, New York, NY, USA, 147–160. https://doi.org/10.1145/3322276.3323694

[16] Audrey Desjardins, Timea Tihanyi, Freesoul El Shabazz-Thompson, Brock Craft, and Julia Saimo. 2023. The Inner Ear: Capturing and Physicalizing Home Vibrations. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*. ACM, Pittsburgh PA USA, 594–607. https://doi.org/10.1145/3563657.3596070

[17] Audrey Desjardins, Oscar Tomico, Andrés Lucero, Marta E. Cecchinato, and Carman Neustaedter. 2021. Introduction to the Special Issue on First-Person Methods in HCI. *ACM Transactions on Computer-Human Interaction* 28, 6 (Dec. 2021), 1–12. https://doi.org/10.1145/3492342

[18] Irma Duncan. 1937. *The Technique of Isadora Duncan.* Kamin, New York.

[19] Sara Eriksson, Åsa Unander-Scharin, Vincent Trichon, Carl Unander-Scharin, Hedvig Kjellström, and Kristina Höök. 2019. Dancing With Drones: Crafting Novel Artistic Expressions Through Intercorporeality. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. ACM, Glasgow Scotland Uk, 1–12. https://doi.org/10.1145/3290605.3300847

[20] Sarah Fdili Alaoui. 2019. Making an Interactive Dance Piece: Tensions in Integrating Technology in Art. In *Proceedings of the 2019 on Designing Interactive Systems Conference*. ACM, San Diego CA USA, 1195–1208. https://doi.org/10.1145/3322276.3322289

[21] Marianela Ciolfi Felice, Sarah Fdili Alaoui, and Wendy E. Mackay. 2021. Studying Choreographic Collaboration in the Wild. In *Designing Interactive Systems Conference 2021*. ACM, Virtual Event USA, 2039–2051. https://doi.org/10.1145/3461778.3462063

[22] Jules Françoise, Sarah Fdili Alaoui, and Yves Candau. 2022. CO/DA: Live-Coding Movement-Sound Interactions for Dance Improvisation. In *CHI Conference on Human Factors in Computing Systems*. ACM, New Orleans LA USA, 1–13. https://doi.org/10.1145/3491102.3501916

[23] Christopher Frauenberger. 2019. Entanglement HCI The Next Wave? *ACM Transactions on Computer-Human Interaction* 27, 1 (Nov. 2019), 2:1–2:27. https://doi.org/10.1145/3364998

[24] Mikhaila Friske, Jordan Wirfs-Brock, and Laura Devendorf. 2020. Entangling the Roles of Maker and Interpreter in Interpersonal Data Narratives: Explorations in Yarn and Sound. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference (DIS '20)*. Association for Computing Machinery, New York, NY, USA, 297–310. https://doi.org/10.1145/3357236.3395442

[25] Mafalda Gamboa. 2022. Living with Drones, Robots, and Young Children: Informing Research through Design with Autoethnography. In *Nordic Human-Computer Interaction Conference (NordiCHI '22)*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3546155.3546658

[26] William Gaver. 2012. What should we expect from research through design?. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. Association for Computing Machinery, New York, NY, USA, 937–946. https://doi.org/10.1145/2207676.2208538

[27] William Gaver and Frances Gaver. 2023. Living with Light Touch: An Autoethnography of a Simple Communication Device in Long-Term Use. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–14. https://doi.org/10.1145/3544548.3580807

[28] William Gaver, Peter Gall Krogh, Andy Boucher, and David Chatting. 2022. Emergence as a Feature of Practice-based Design Research. In *Designing Interactive Systems Conference (DIS '22)*. Association for Computing Machinery, New York, NY, USA, 517–526. https://doi.org/10.1145/3532106.3533524

[29] Anna Heyward. 2015. How to Write a Dance. https://www.theparisreview.org/blog/2015/02/04/how-to-write-a-dance/ Section: On Dance.

[30] Sarah Homewood. 2023. Self-Tracking to Do Less: An Autoethnography of Long COVID That Informs the Design of Pacing Technologies. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–14. https://doi.org/10.1145/3544548.3581505

[31] Eva Hornecker, Trevor Hogan, Uta Hinrichs, and Rosa Van Koningsbruggen. 2023. A Design Vocabulary for Data Physicalization. *ACM Transactions on Computer-Human Interaction* 31, 1 (Nov. 2023), 2:1–2:62. https://doi.org/10.1145/3617366

[32] Noura Howell, Audrey Desjardins, and Sarah Fox. 2021. Cracks in the Success Narrative: Rethinking Failure in Design Research through a Retrospective Trioethnography. *ACM Transactions on Computer-Human Interaction* 28, 6 (Nov. 2021), 42:1–42:31. https://doi.org/10.1145/3462447

[33] Caroline Hummels, Kees C. J. Overbeeke, and Sietske Klooster. 2007. Move to get moved: a search for methods, tools and knowledge to design for expressive and rich movement-based interaction. *Personal and Ubiquitous Computing* 11, 8 (Oct. 2007), 677–690. https://doi.org/10.1007/s00779-006-0135-y

[34] John D. Hunter. 2007. Matplotlib: A 2D Graphics Environment. *Computing in Science & Engineering* 9, 3 (2007), 90–95. https://doi.org/10.1109/MCSE.2007.55

[35] Samuel Huron, Till Nagel, Lora Oehlberg, and Wesley Willett (Eds.). 2023. *Making with data: physical design and craft in a data- driven world* (first edition ed.). AK Peters : CRC Press, Boca Raton.

[36] Kristina Höök. 2010. Transferring qualities from horseback riding to design. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction Extending Boundaries - NordiCHI '10*. ACM Press, Reykjavik, Iceland, 226. https://doi.org/10.1145/1868914.1868943

[37] Kristina Höök. 2018. *Designing with the Body: Somaesthetic Interaction Design.* MIT Press, Cambridge, Massachusetts. Google-Books-ID: 9oZ0DwAAQBAJ.

[38] Kristina Höök, Baptiste Caramiaux, Cumhur Erkut, Jodi Forlizzi, Nassrin Hajinejad, Michael Haller, Caroline Hummels, Katherine Isbister, Martin Jonsson, George Khut, Lian Loke, Danielle Lottridge, Patrizia Marti, Edward Melcer, Florian Müller, Marianne Petersen, Thecla Schiphorst, Elena Segura, Anna Ståhl, Dag Svanæs, Jakob Tholander, and Helena Tobiasson. 2018. Embracing First-Person Perspectives in Soma-Based Design. *Informatics* 5, 1 (Feb. 2018), 8. https://doi.org/10.3390/informatics5010008

[39] Dhruv Jain, Audrey Desjardins, Leah Findlater, and Jon E. Froehlich. 2019. Autoethnography of a Hard of Hearing Traveler. In *The 21st International ACM SIGACCESS Conference on Computers and Accessibility*. ACM, Pittsburgh PA USA, 236–248. https://doi.org/10.1145/3308561.3353800

[40] Yvonne Jansen, Pierre Dragicevic, Petra Isenberg, Jason Alexander, Abhijit Karnik, Johan Kildal, Sriram Subramanian, and Kasper Hornbæk. 2015. Opportunities and Challenges for Data Physicalization. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, Seoul Republic of Korea, 3227–3236. https://doi.org/10.1145/2702123.2702180

[41] Lee Jones, Greta Grip, and Sara Nabil. 2023. Wear Your Heart on Your Sleeve: Using Digital Knitting Machines to Craft Wearable Biodata Portraits. In *Proceedings*

of the 2023 ACM Designing Interactive Systems Conference. ACM, Pittsburgh PA USA, 547–563. https://doi.org/10.1145/3563657.3596007

[42] Stephan Jürgens, Nuno N. Correia, and Raul Masu. 2021. The Body Beyond Movement: (Missed) Opportunities to Engage with Contemporary Dance in HCI. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '21)*. Association for Computing Machinery, New York, NY, USA, 1–9. https://doi.org/10.1145/3430524.3440624

[43] Maria Karyda, Elisa D Mekler, and Andrés Lucero. 2021. Data Agents: Promoting Reflection through Meaningful Representations of Personal Data in Everyday Life. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–11. https://doi.org/10.1145/3411764.3445112

[44] Rohit Ashok Khot, Larissa Hjorth, and Florian 'Floyd' Mueller. 2014. Understanding physical activity through 3D printed material artifacts. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Toronto Ontario Canada, 3835–3844. https://doi.org/10.1145/2556288.2557144

[45] Ozgun Kilic Afsar, Yoav Luft, Kelsey Cotton, Ekaterina R. Stepanova, Claudia Núñez-Pacheco, Rebecca Kleinberger, Fehmi Ben Abdesslem, Hiroshi Ishii, and Kristina Höök. 2023. Corsetto: A Kinesthetic Garment for Designing, Composing for, and Experiencing an Intersubjective Haptic Voice. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–23. https://doi.org/10.1145/3544548.3581294

[46] Hannah Kosstrin. 2019. Hannah Kosstrin – What aspects of your practice / research are invisible to your collaborators? https://provocations.online/invisibilityincollaboration/kosstrin/

[47] Andrés Lucero. 2018. Living Without a Mobile Phone: An Autoethnography. In *Proceedings of the 2018 Designing Interactive Systems Conference*. ACM, Hong Kong China, 765–776. https://doi.org/10.1145/3196709.3196731

[48] Deborah Lupton. 2017. Feeling your data: Touch and making sense of personal digital data. *New Media & Society* 19, 10 (Oct. 2017), 1599–1614. https://doi.org/10.1177/1461444817717515

[49] Deborah Lupton. 2018. How do data come to matter? Living and becoming with personal data. *Big Data & Society* 5, 2 (July 2018), 205395171878631. https://doi.org/10.1177/2053951718786314

[50] Léa Paymal and Sarah Fdili Alaoui. 2023. Physicalizing loops. In *Creativity and Cognition*. ACM, Virtual Event USA, 465–477. https://doi.org/10.1145/3591196.3593365

[51] Mirjana Prpa, Sarah Fdili-Alaoui, Thecla Schiphorst, and Philippe Pasquier. 2020. Articulating Experience: Reflections from Experts Applying Micro-Phenomenology to Design Research in HCI. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. ACM, Honolulu HI USA, 1–14. https://doi.org/10.1145/3313831.3376664

[52] Courtney N. Reed, Charlotte Nordmoen, Andrea Martelloni, Giacomo Lepri, Nicole Robson, Eevee Zayas-Garin, Kelsey Cotton, Lia Mice, and Andrew McPherson. 2022. Exploring Experiences with New Musical Instruments through Micro-phenomenology. In *NIME 2022*. PubPub, The University of Auckland, New Zealand. https://doi.org/10.21428/92fbeb44.b304e4b1

[53] Jean-Philippe Riviere. 2020. *Capturing traces of the dance learning process*. PhD Thesis. http://www.theses.fr/2020UPASG054/document

[54] Yvonne Rogers. 2011. Interaction design gone wild: striving for wild theory. *Interactions* 18, 4 (July 2011), 58–62. https://doi.org/10.1145/1978822.1978834

[55] Pedro Sanches, Noura Howell, Vasiliki Tsaknaki, Tom Jenkins, and Karey Helms. 2022. Diffraction-in-action: Designerly Explorations of Agential Realism Through Lived Data. In *CHI Conference on Human Factors in Computing Systems*. ACM, New Orleans LA USA, 1–18. https://doi.org/10.1145/3491102.3502029

[56] Anna Ståhl, Vasiliki Tsaknaki, and Madeline Balaam. 2021. Validity and Rigour in Soma Design-Sketching with the Soma. *ACM Transactions on Computer-Human Interaction* 28, 6 (Dec. 2021), 1–36. https://doi.org/10.1145/3470132

[57] John D. Sullivan, Sarah Fdili Alaoui, Pierre Godard, and Liz Santoro. 2023. Embracing the messy and situated practice of dance technology design. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*. ACM, Pittsburgh PA USA, 1383–1397. https://doi.org/10.1145/3563657.3596078

[58] Alice Thudt, Uta Hinrichs, Samuel Huron, and Sheelagh Carpendale. 2018. Self-Reflection and Personal Physicalization Construction. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, Montreal QC Canada, 1–13. https://doi.org/10.1145/3173574.3173728

[59] Rosa Van Koningsbruggen, Hannes Waldschütz, and Eva Hornecker. 2022. What is Data? - Exploring the Meaning of Data in Data Physicalisation Teaching. In *Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction*. ACM, Daejeon Republic of Korea, 1–21. https://doi.org/10.1145/3490149.3501319

[60] Michael Waskom. 2021. seaborn: statistical data visualization. *Journal of Open Source Software* 6, 60 (April 2021), 3021. https://doi.org/10.21105/joss.03021

[61] Danielle Wilde, Anna Vallgårda, and Oscar Tomico. 2017. Embodied Design Ideation Methods: Analysing the Power of Estrangement. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, Denver Colorado USA, 5158–5170. https://doi.org/10.1145/3025453.3025873

[62] Jordan Wirfs-Brock, Alli Fam, Laura Devendorf, and Brian Keegan. 2021. Examining Narrative Sonification: Using First-Person Retrospection Methods to Translate Radio Production to Interaction Design. *ACM Transactions on Computer-Human Interaction* 28, 6 (Nov. 2021), 41:1–41:34. https://doi.org/10.1145/3461762

[63] Qiushi Zhou, Cheng Cheng Chua, Jarrod Knibbe, Jorge Goncalves, and Eduardo Velloso. 2021. Dance and Choreography in HCI: A Two-Decade Retrospective. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–14. https://doi.org/10.1145/3411764.3445804