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Physicalizing loops



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ABSTRACT

In this pictorial, we followed a Research through Design (RtD) inquiry where we explored the concept of loops as a design material. Using an Ethnographic design methodology, we aimed to create artifacts that represent the ways in which content can be repeated, distorted and modified in loops. Our process consisted firstly of the practice of noticing loops in everyday life. This led us to curate a portfolio of loops' occurrences in objects and living organisms from our surroundings. Secondly, we organized the loops that we noticed in a typology and created a score that instantiates such a variety of loops. Finally, we followed the score to produce 1. knitting work, 2. woodwork, 3. lino printing, and 4. dance performances as art-based physicalizations of different instances of loops. Our study of loops uncovers a designerly way to reflect on a daily phenomenon (loops) through making physical artifacts and dancing.

Authors Keywords

Data Physicalization; Score-making; Knitting; Printing; Woodworking; Choreography; Craft.

INTRODUCTION

Our work originated from noticing loops as a constitutive component of everyday life, in objects and living organisms that we interact with.

In this pictorial, we define a loop as a sequence of repetitive organized and recognizable patterns that returns to their starting point.

We embarked on a Research through Design (RtD) inquiry where we explored the concept of loops as a design material. Using an Ethnographic design methodology, we aimed to create artifacts that represent the ways in which content can be repeated, distorted and modified in loops.

In this pictorial, we present an account of our design process as well as the reflection that came from it. Precisely, we report on the design process that we followed starting with the practice of noticing physical representations of loops [35] in our surroundings and in particular in objects and living organisms that we interact with daily. We then curated a portfolio of loops' occurrences in our daily life [24]. Based on what we noticed, we created a typology of loops and a score that captures the variety of loops that we delineated. Finally, we followed the score by creating new art-based

physicalizations of the loops through 1. knitting work 2. woodworking using computer numerical controlled milling machine (CNC) 3. lino printing and 4) dance performances.

We contribute with an ethnographic design inquiry that investigates how information can be looped, i.e., repeated and modified. Our design study explores the generative potential of loops as design material. We contribute with design exemplars that represent different traces and intermediate forms [18] of the knowledge that we gathered of the concept of loops. We reflect and discuss our design process with regard to how it leverages the performative potential of score-making and embodying and physicalizing the score to craft various artifacts. We also highlight the value of cultivating an embodied state with the materials crafted. Our work contributes to the larger Interaction Design community by demonstrating the potential of scores for sharing (loops) patterns across craft domains and fabrication methods [15]. Our score-making practice allows work to translate from machine to machine [15] by transmitting a sequence of actions that can be applied to both manual and digital fabrication. In summary, our pictorial contributes with a creative and self-reflexive design process that demonstrates the value of an embodied and performative act of scoring and physicalization.

PREVIOUS WORKS

Recent works in HCI and interaction design have explored how craft can provide opportunities for technological innovation and sites for critical reflections on the making and the interaction with technology [29], with similarities between the act of giving form in digital work and traditional craft [26].

At this intersection, a substantial amount of innovation allowed to bring fabrication machines into crafts in creative domains such as textiles [8], knitting [31], wood-working, and ceramics [30].

Our attention is directed towards the approaches adopted by HCI researchers and interaction designers to craft physical artifacts with the aim to represent, reflect [34], narrate [5], or even speculate on people's behaviors, choices, experiences and data [3]. In particular, we are interested in how they explore design concepts and manipulate design materials in physicalization and crafting processes.

Ambiguity in Design

The design research literature has recognized the value of going beyond the pursuit of perfection and allowing for ambiguity and uncertainty in the creative process. Gaver et al. propose to view ambiguity as a resource [13]. They showed that ambiguity can foster deeper and more meaningful relationships with interactive systems. Dove et al. studied ambiguity in the context of learning by observing strategies used by students in Lego design [9]. They proposed strategies for designing tools and environments that support students' creative abilities by cultivating ambiguity. Similarly, Beghetto argues that uncertainty can serve as catalysts for creativity [2]. In our project, we embrace the uncertainty inherent to the process of craft-making with the body. Our physicalizations capture our personal performance of a score, which is rewritten with each realization. Each artifacts shows traces of our embodied qualities including our hesitations, mistakes, and uncertainties.

Crafting and Physicalizing Data

Researchers in HCI have exploited recent develop-

ments in tangible computing and digital fabrication to encode data in physical forms, creating a new research interest in HCI called 'Data Physicalization' [17]. Data physicalization consists of transforming data sets into physical data-driven objects that help users to explore, understand and communicate data [22].

Most of the research found in the literature is focused on how to design such physical data-driven objects [19], how to curate the data, how to design the mapping, and how to provide valuable representations of data [33].

The experimentations that emerged from these designs emphasize how the tangibility of the data representations allows users to think and reflect on problems through physically interacting with and experiencing the artifacts that represent them [20]. This has been shown to open new opportunities to incorporate, experience, and make sense of data in everyday life and the stories they can tell [25,27].

Beyond the projects using data physicalization to solve problems, we are rather interested in how scholars and designers used craft to provide physicalizations of personal data. These creative endeavors provide tangible and aesthetic artifacts that promote self-reflection [34] and that tell stories from data. For example, Desjardins et al. exploited the capacity of data physicalization to bring people closer to their IoT everyday data. They designed 3D-printed porcelain cups that physicalize datasets of everyday ambient sounds [7]. Their design shows how such artifacts allow experiencing data through the tactility and storytelling enabled by the forms created on ceramics. Rosner et al. describe their collaboration with a ceramic artist to design a bowl that records an audio message through surface undulations [30]. Their process unveiled tensions in the entanglement of code and clay. Friske et al. produced a series of hand-crafted artifacts in yarn and sound that author personal data narratives [11].

We are inspired by these design inquiries. Like them, we contribute with an embodied, creative, craft-oriented, and self-reflexive design process. However, our

physicalizations result from data that are not captured in people's daily usage of technology or IoT (among others) but rather represented on a score we created from scratch to explore the concept of loops. Moreover, the specificity of our work is to propose physicalizations using multiple media, going from knitting to controlling a milling machine to lino printing to dancing. We provide a (self) reflection on the experiences that are both common and specific to exploring each medium.

The concept of the loop

Loops are constitutive components of life, present in objects and living organisms that we interact with. Moreover, the concept of the loop, or its underlying characteristic, repetition, has a long history that goes back to thousands of years of human craft and art making [16, 21]. As shown in Tim Ingold's book "lines", lines are constitutive of human organizations and structures, and these lines often appear in loops that emphasize repetition and patterns [21]. The concept of loops is also a core component of programming languages (e.g., for-loops, while-loops, recursiveness) that allows data to be iteratively modified by a program. In dance, the notion of repetition is part of a dancer's practice [10]. Loops have been widely explored in choreography [6,28] to play with a movement, repeat it, distort it, and modify it. Thus, loops are a concept or a phenomenon that is ever-present yet widely overlooked. Our pictorial illustrates how we can use loops as a generative design material.





METHODOLOGY

We followed a Research through Design (RtD) [37] and particularly an Ethnographic design process [4] where we documented our process through sketches and photographs, personal notes, and videos. We used this collection of documentation to support our self-reflection on the design process.

Our process consisted first of noticing loops [35] in our surroundings. We then engaged in the practice of score-making in order to produce a score that captures the variety of loops that we delineated. Finally, we engaged in multiple physicalization endeavors in order to represent this score through various media that we practice and are interested in exploring.

Noticing

Our ethnographic design process emerged firstly from observing our surroundings and noticing the omnipresence of loops. Subsequently, we initiated a practice of deliberately noticing occurrences of loops already present in a variety of daily sites, both ecological and technical, such as our apartment, office, public transportation sites, and urban gardens. The singularity of the practice of “noticing” in comparison with “observing” is that it relies on deep and slow listening and attuning the body to what is perceived, which allows one to be mindful of what can be felt and sensed [23]. Anna Tsing calls the “arts of noticing” [35] methods that cultivate awareness of the diverse actors, whether humans or non-humans and that engage in alternative and embodied ways of knowing. Noticing something, beyond observing it, implies seeing it in a way that transforms and unsettles the viewer. It causes them to pay attention differently and be implicated in a site differently. Concretely, our practice consisted of slowing down and opening our perceptual channels to perceive what surrounds us, whether human or non-human, with new eyes, curiosity, and sensitivity. We then documented them visually and curated a portfolio of loop occurrences that we illustrate on the next page.

Score-making

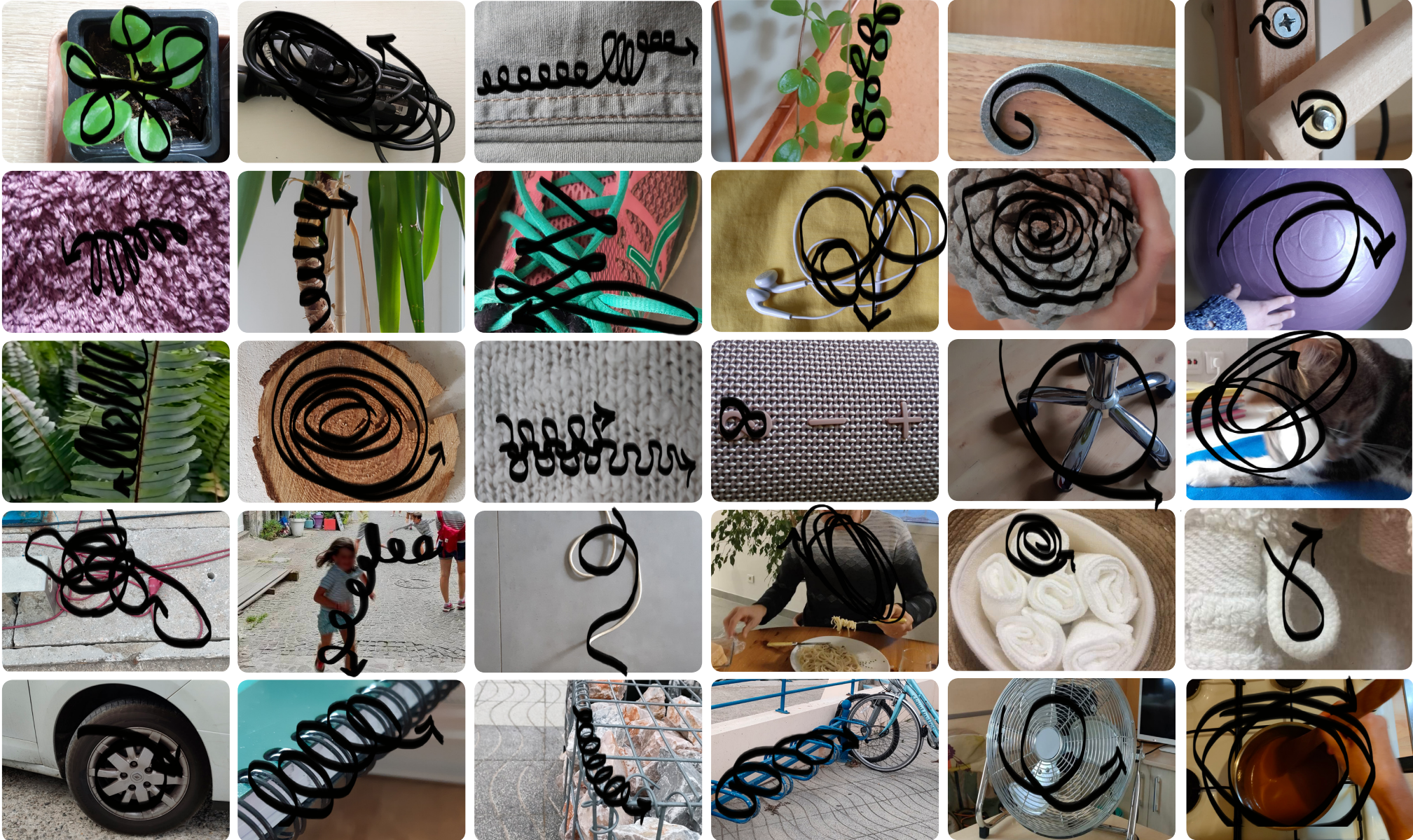
From the loops identified throughout our practice of noticing in our daily life, we engaged in a score-making process where we abstracted the loops again by drawing various graphical expressions of them. We saw how one can play with

loops by modifying and distorting them using various types of data as input (e.g., a movement or image). We then distilled these sketches to develop 6 main categories of loops that we structured into a final score that instantiates them in time. The score offers an opportunity to share a sequence of actions across various material explorations and crafting.

Physicalizing

Finally, we physicalized the score that contains the abstracted loops into new art-based physicalizations. In our physicalizations, we chose to engage with mainly physical processes. We cared to follow the score by choreographing our gestures to produce the artifacts or dance the score. We selected four media that the authors practice. It was important to choose crafts that we were already familiar with in order to leverage on our previous expertise when performing the score. Knitting and lino printing are crafts that the first author practices and engages with. Choreography and programming (hacking and tweaking) a CNC machine are crafts that the second author practices and engages with. Having four different media offered a diverse range of ways of embodying and performing the score.

NOTICING LOOPS IN DAILY LIFE: A CURATED PORTFOLIO



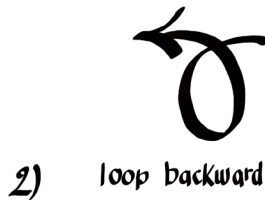
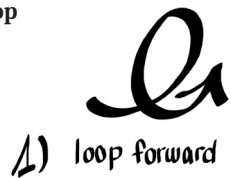
TPOLOGY OF THE LOOP

Based on the small-scale and large-scale loops that we noticed in our daily life, we distilled a graphic typology of loops expressing a “simple loop” as a line that returns to its starting point either through a repetition 1) forward or 2) backward determined by the direction and chronological sequence in which it is performed. For instance, the transformation from a forward to a backward loop can be done by inverting or mirroring the sequence. Our typology delineates a “modified loop” as a loop where an error is 3) introduced once in an accidental manner or 4) sustained in a way that modifies the pattern longer. Finally, our typology delineates “a noisy loop” as loops where a noise as a fundamental change is 5) introduced to shift the pattern or 6) cumulated until it breaks the pattern in a chaotic way.

THE SCORE

We constructed a score that instantiates the typology of loops that we distilled. The goal of using a score is to organize movement in a temporal sequence following the patterns of the different loops. We aim to follow such a score by performing the sequences of movements while knitting, woodworking, lino printing, and dancing. Thus, all of the artifacts produced and the dances performed are manifestations and traces of the score and the various loops that constitute it.

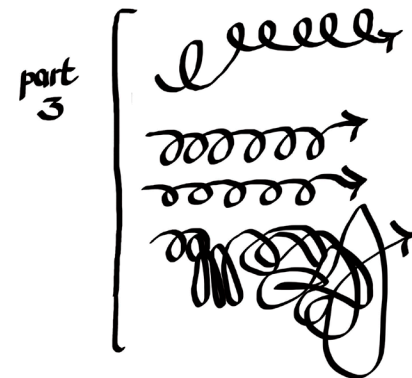
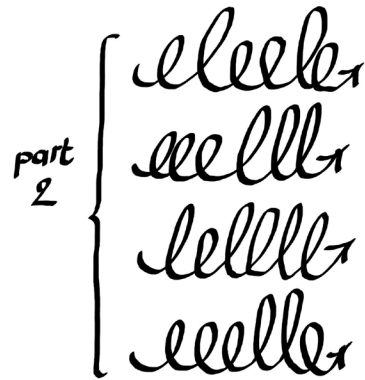
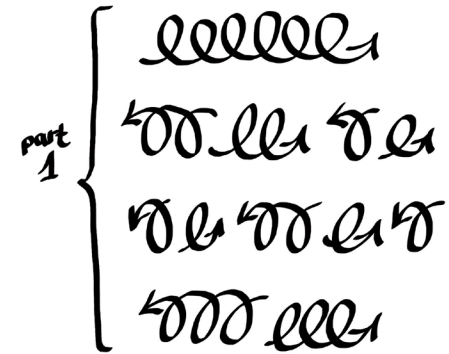
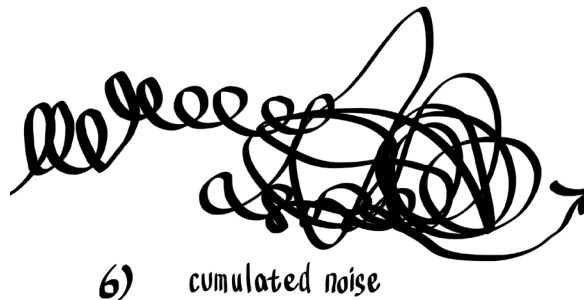
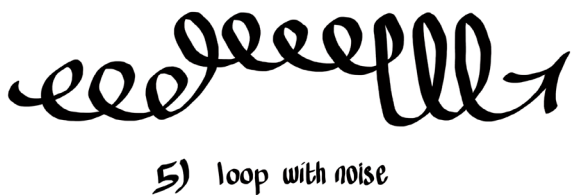
The simple loop



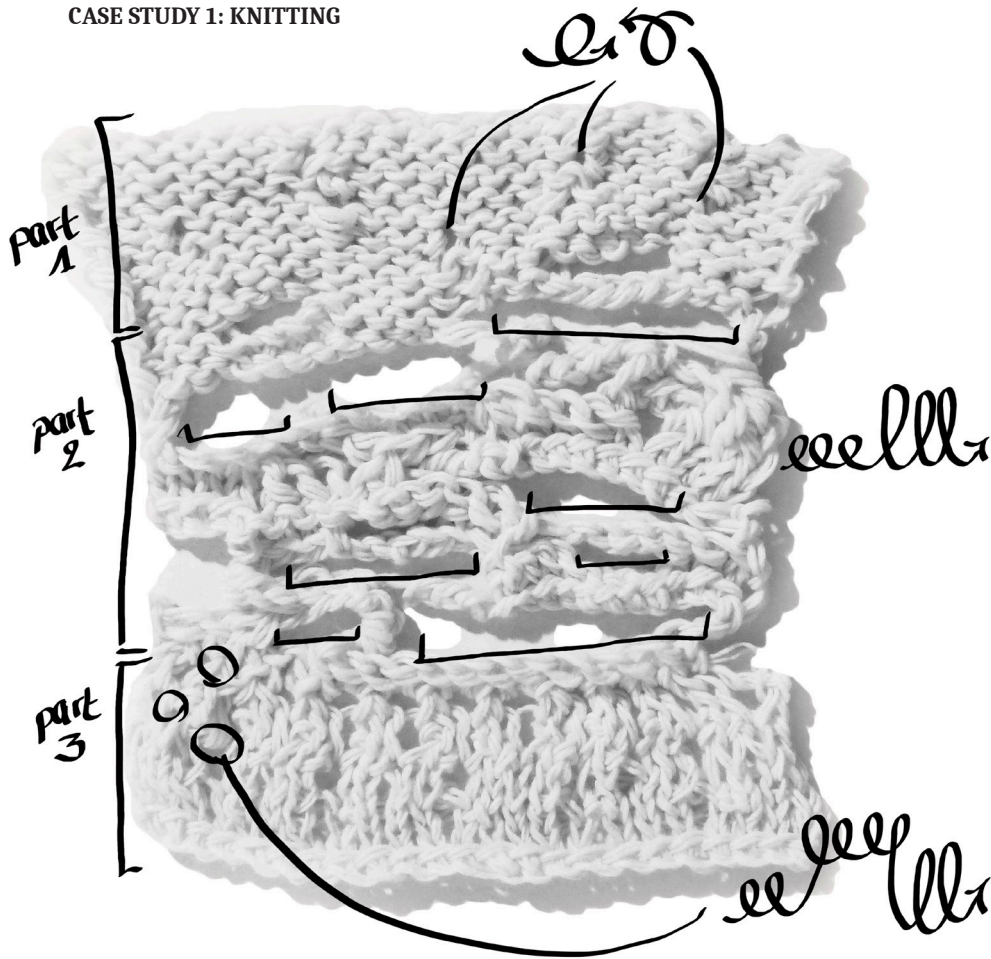
The modified loop



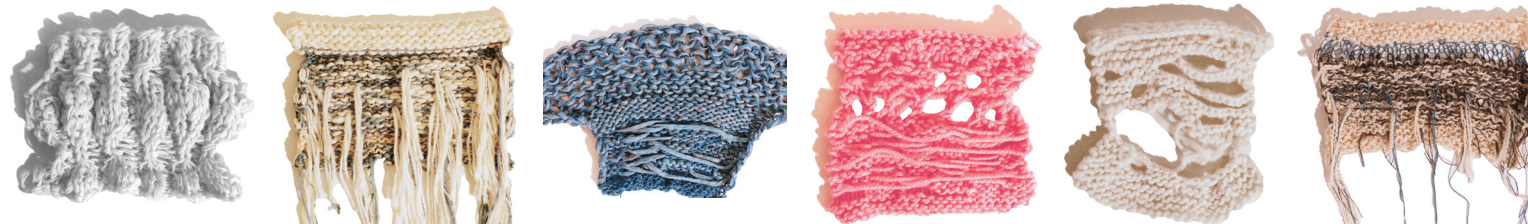
The noisy loop



CASE STUDY 1: KNITTING



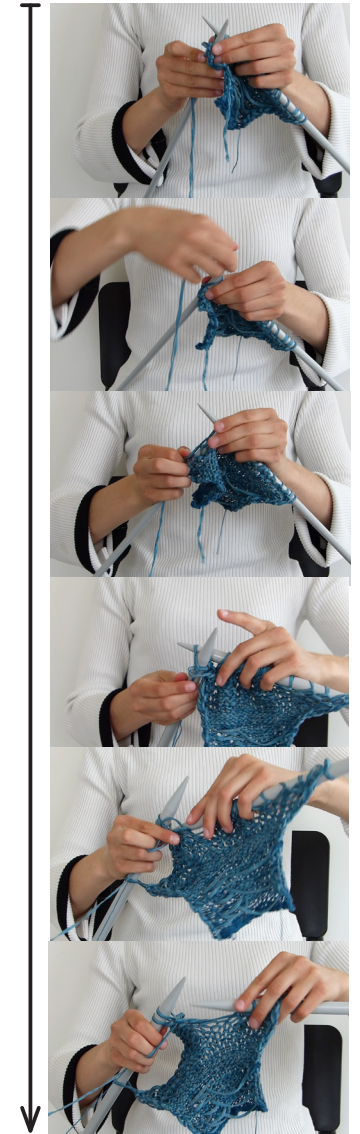
Samples



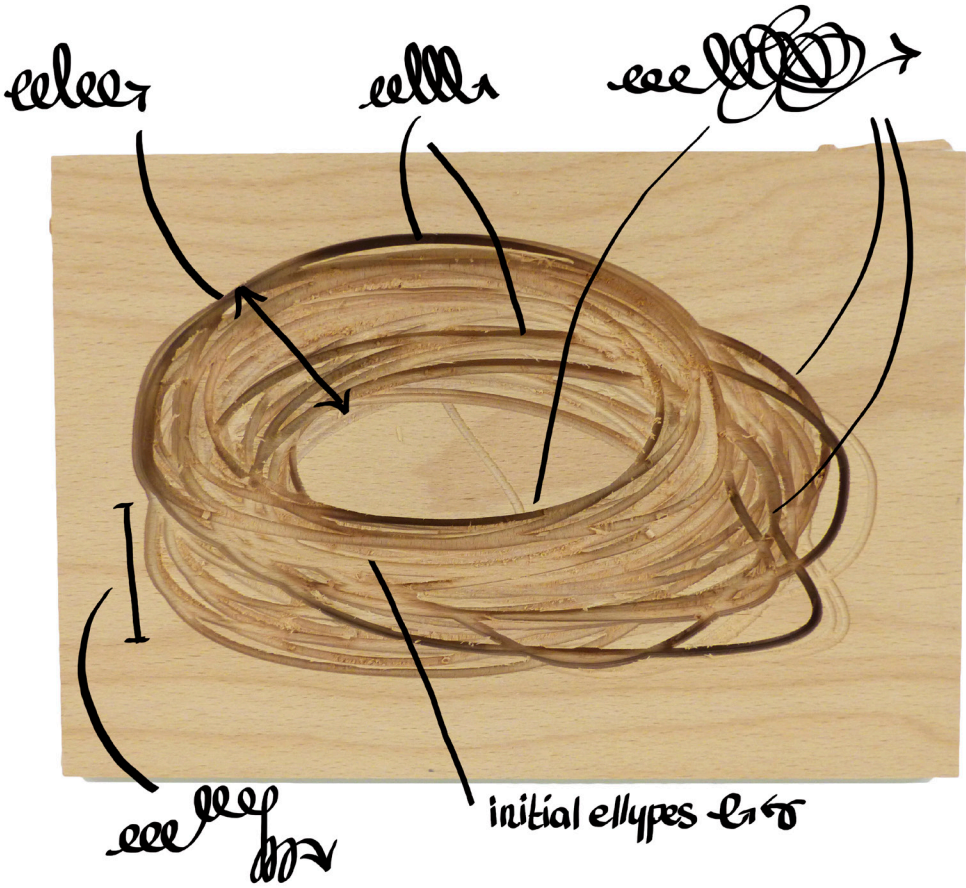
In the first case study, we followed the score by performing the loops in a knitting practice. Our process consists of choreographing ourselves while knitting, following each sequence in each part of the score. The knitting gestures follow a pattern that we repeated forward and backward, where we introduced errors and sustained them, and where we introduced noise and cumulated it. We illustrate hereafter an example of one of the knitting artifacts produced. We can see in the first part small holes where the transitions from forward to backward loops occurred. The backward knitting was performed by turning the work over. We can see in the second part the traces of the errors. We performed them by putting the stitch on the previous one which cancels it creating holes. Going back to the original loop is then done recreating the original stitch on the next line. When such an error is sustained, the hole is larger. Finally, in the third part, we can see how the stitch has been modified when introducing noise and how the mesh is subdivided into three stitches that propagate this noise further.

Performing the score

Time



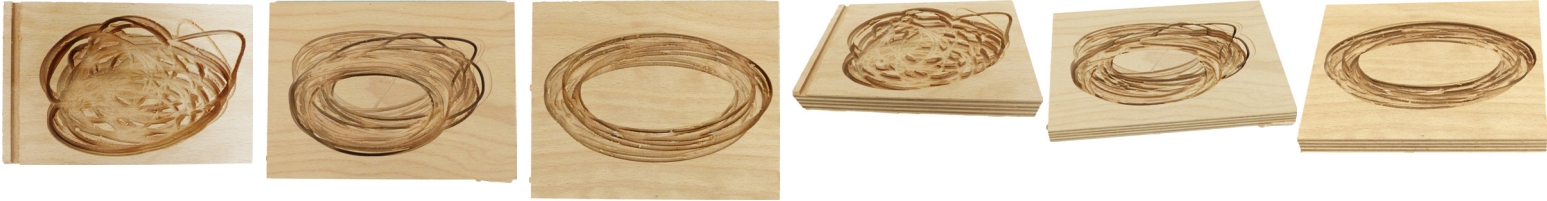
CASE STUDY 2: WOOD WORKING



In the second case study, we programmed a CNC milling machine to follow the score we elaborated by performing the loops in the sequence order. Initially, the CNC machine's movement cannot be predicted; only the resulting pattern can. We hacked the program that controls the machine so that its movement follows the score temporally and in a continuous manner. We cared that the machine performs the loops more than we cared that its result represents them faithfully. We illustrate hereafter an example of one of the wooden artifacts produced based on elliptic loops. We can see in the first part the initial ellipses that are repeated forward and backward. We then see occasional and sustained errors that shift the spindle on the side and in depth. Finally, we see the noise that changes the shape of the ellipses and that cumulates to create waves that do not come back to the starting point.

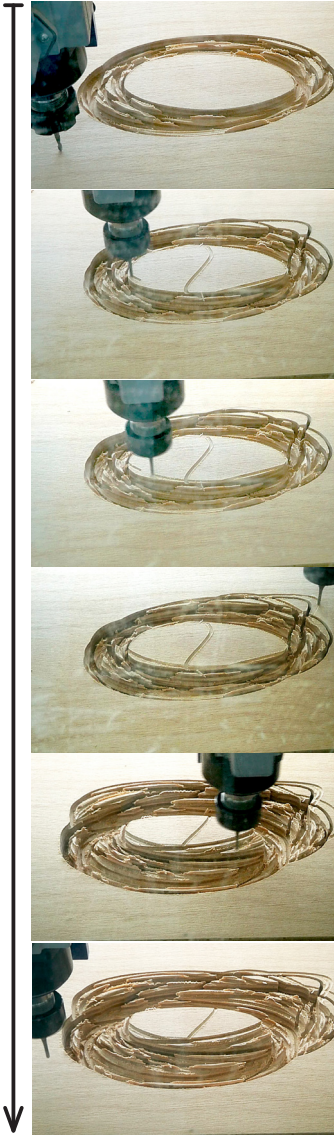


Samples

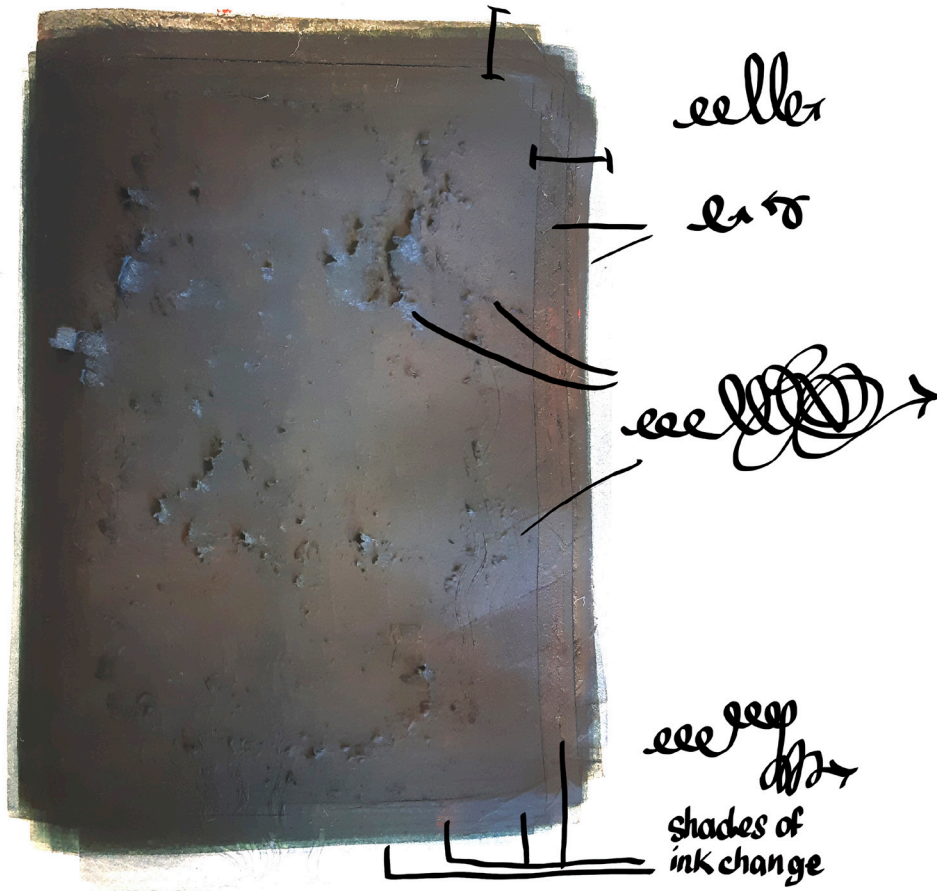


Performing the score

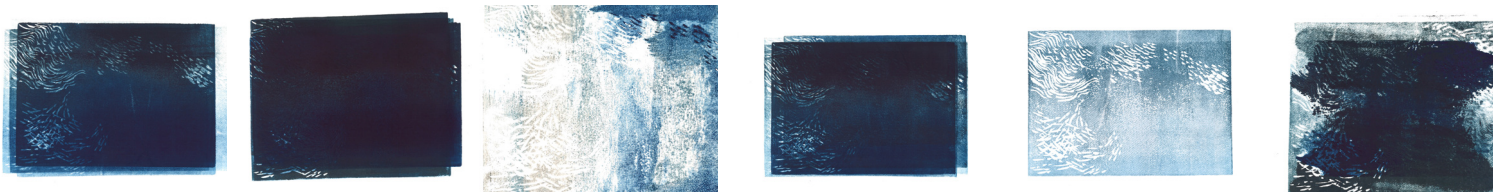
Time



CASE STUDY 3: LINO PRINTING



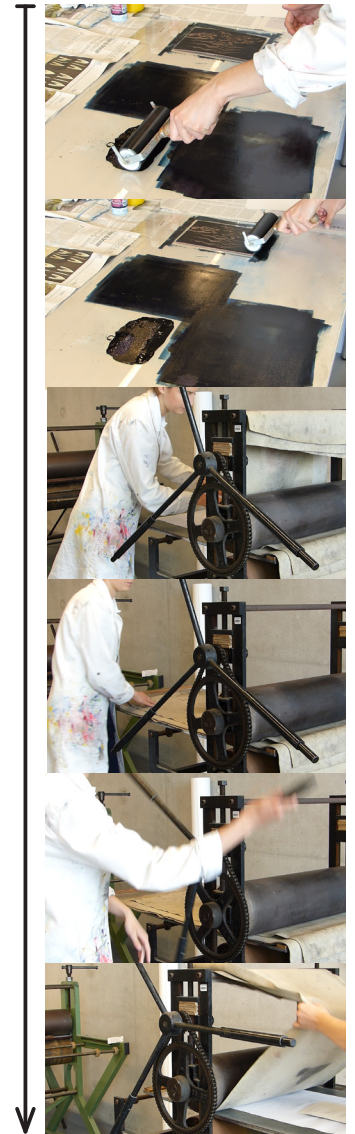
Samples



In this third case study, we followed the score while lino printing. We first engraved the linoleum plate following the sequences of the score. We then choreographed ourselves printing the plate repeatedly, following the score. We repeated the gestures of printing forward and backward. We also introduced errors and sustained them. Finally, we introduced noise and accumulated it. We illustrate hereafter an example of one of the print artifacts produced. It was performed on the same sheet of paper by repeating the printing gesture 100 times. In the first part, the prints are made forward or backward by going back to the previous phase (inking); too much or too little ink is deposited on the paper. Then we add error by moving the plate sideways and sustaining such a shift through a few repetitions. Finally, we include noise that modifies the shade of the print and then cumulates it to alter the paper through disintegration, wrinkling, and corrugation. By performing the printing gesture along with the errors and noises repeatedly, we can see how they mark the paper with the traces of the repetitions.

Performing the score

Time



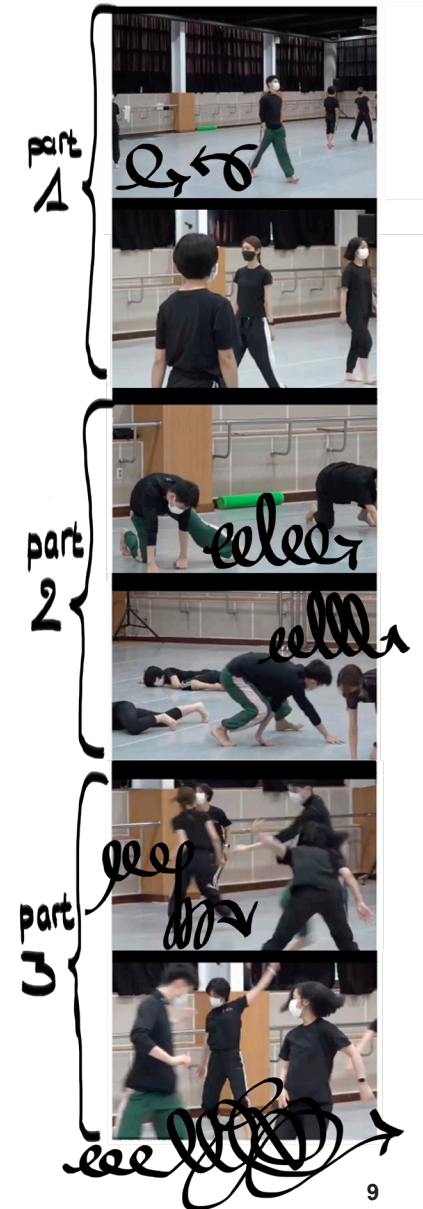
CASE STUDY 4: DANCING



We had the opportunity during our design process to run an online dance class given to students from the university of Hanyang in South Korea through zoom. In agreement with the students, we explored the score that we made choreographically during the class. We gave the score to the students and asked them to produce short performances that embodied the 3 different parts with the sequences of loops. We illustrate hereafter an example of one of the performances produced based on an initial movement inspired by an everyday movement. We can see in the first part how the dancers are performing simple walking patterns repeated forward and backward. We then see occasional and sustained errors bringing the dancers to move on all fours. In the third part, we see how dancers introduce noise and then the chaos that disturbs the trance in which the body is caught when repeating the same movement. This is shown by the images with dynamic changes of rhythm, intensity, and chaotic organization in space.

Performing the score

Time



Samples



REFLECTIONS ON PHYSICALIZING LOOPS

Performing a score, scoring a performance

In physicalizing loops through following a score, we embodied the patterns of the score, or in other words performed them with our body. Thus each artifact crafted results of a sort of micro-performance. And just like each performance is always unique, each one of our artifacts is a new unique representation of the micro-performance and instantiation of the score.

In dance or performance, the body enacts patterns following the structure of a possible score. And as soon as the patterns are performed by the body, they are lost. Thus, the score is the main tangible trace that remains of a performative act that is by essence ephemeral. However, in our design process, we embody the score to produce a physical artifact. Such an artifact becomes a new tangible trace of the previous tangible trace. Thus, our physicalization is a metatheatre where a trace is performed to produce a new trace that can be re-performed to produce a third trace and so on. One can see our design process as a generative score-making where each new score represents the original intention but also opens new interpretations. In his book, *Languages of Art* [14], Nelson Goodman discusses the concept of scores as allowing a stable, repeatable representation of the artwork. It is according to him the way in which a work can be identified and can be repeated. It can also have the function of supporting composition. However, he argues that its primary role remains to identify the work. Our process resulted both in a performance of a score and a scoring of such a performance. Our generative emergent artifacts are new scores because they identify the loop patterns that we initially delineated and because they also support new possible future compositions and micro performances.

Values of embodying materiality of craft

Experimenting with the concept of loops by performing

a score and by crafting materials allowed us to tackle the design process from an embodied perspective. Our process leveraged the tactile and sensorial relationship that we built when manipulating the materials involved in knitting, printing or dancing and on the physical and bodily experiences of performing a score. While our physicalizations relied on a variety of machines and computational systems to support them (we communicated via zoom or used a CNC and printing machines), we saw these systems as mere mediation of the main endeavor, which at its core, consisted of repeating physical gestures to manipulate various physical materials. Although the CNC machine is the one that is moving to carve the wood, we generated an intimate relationship to it as we choreographed it to follow a specific movement. This is similar to the dance students' performances. Mediated by zoom, we choreographed the dancers' movements by instructing them to follow the score and repeat the patterns in a specific way. The same idea is behind how we choreographed ourselves performing the knitting and the printing, this time mediated by a printing machine or knitting needles. Thus, we cultivated a state of embodiment, sensoriality and attunement to the body from noticing loops to performing them regardless of the tools (computational or not) mediating our craft. We embraced such embodied performative play without much thinking, executing the score with the body over and over again in a form of trance that made space for the emergence of unpredictability, ambiguity, surprises, uncertainty, rhythm and play [13].

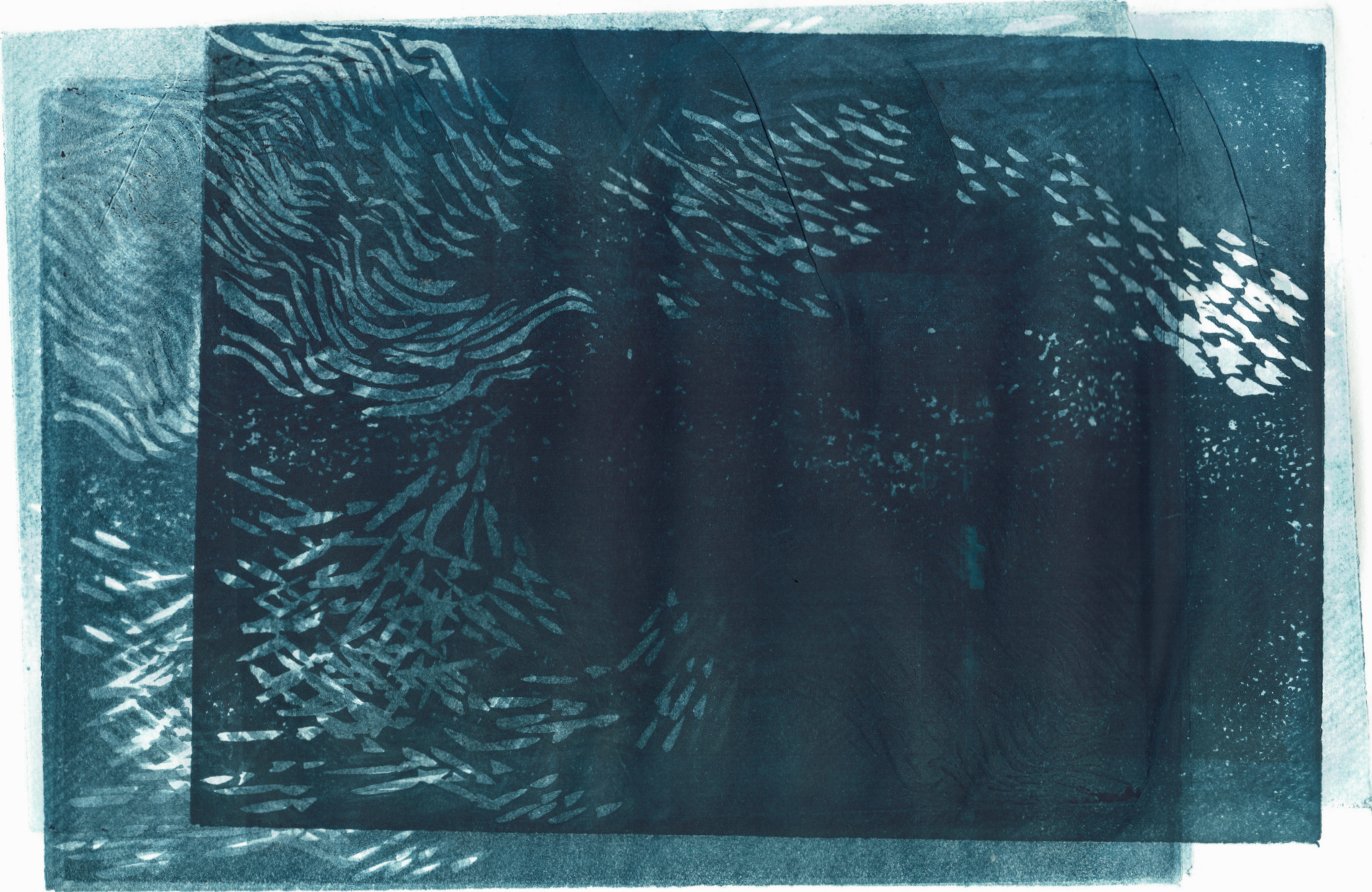
Looking back at the artifacts, we could see how they represent our own gestures, the errors, the hesitations, the pauses and the excitement. They layer stratum of embodied states that can be made visible and tangible. We argue for the cultivation of the experiential qualities made of surprising and ambiguous relationships to materials and craft that can be present in the making process with digital and non-digital fabrication methods.

A personal process that speaks to all

This pictorial presents a project and a process that is based on our personal craft and making. We believe that a broader interaction design audience can learn from such personal endeavors. Our pictorial offers "annotations of realized design exemplars" [12] and an authentic reflexive account of our design and artistic works which we hope will resonate with readers' experiences and reflections on craft and making. The artifacts themselves communicate the whole process and thus provide us with an object that supports our self reflection about what we did, how we did it and why we did it. Therefore, rather than generalizable or replicable findings, we aim to reflect on a design process that would inspire designers that aspire to use craft and fabrication in creative craft-based physicalization [32].

Additionally, our study also shows the potential of a score to be used and shared among different craft domains and fabrication methods [15]. It synthesizes in a simple and abstract way a sequence of actions that can be embodied to craft various types of artifacts. A score structures these actions and transmits them across disciplines. In our pictorial the score structured the 'loop patterns' and allowed us to share this structure among ourselves practitioners, and across our practices.

As designers and artists we were interested in starting with an investigation of our daily surroundings and in allowing ourselves to let a singular design inquiry emerge. We stayed open to inspiration, which led us in a very different route where we choreographed ourselves to craft physical artifacts that explore loops as spatio-temporal patterns that induce an embodied state. This emergent and zigzagging design process allowed us to create artifacts that we did not premeditate [36] and to embrace the importance of the body in material exploration in design.



CONCLUSION

In this pictorial, we explored the concept of loops that we noticed in our everyday life as a design material using an ethnographic design method. We curated a collection of images of loops and created a typology that we instantiated in a score. Our design process consisted of following the score by performing loops while knitting, woodworking, lino printing and performing dance. We contribute in this pictorial with exemplars of artifacts as well as a reflection on the concept of loops through the crafting of these artifacts. Our work proposes an embodied approach to making through scoring and performing.

ACKNOWLEDGMENTS

Typography (titles): Copyright 2012 The Caladea Project Authors (<https://github.com/huertatipografica/Caladea>)

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REFERENCES

- [1] 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 (DIS '22)*, 1581–1596. <https://doi.org/10.1145/3532106.3533499>
- [2] Ronald Beghetto. 2019. Structured Uncertainty: How Creativity Thrives Under Constraints and Uncertainty: Resistive Theories, Practices, and Actions. *10.1007/978-3-319-90272-2_2*.
- [3] Heidi R. Biggs, and Audrey Desjardins. 2020. Crafting an Embodied Speculation: An Account of Prototyping Methods. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference (DIS '20)*, 547–60. <https://doi.org/10.1145/3357236.3395591>.
- [4] David Db Bihanic, et Nicolas Nova. 2015. Design Ethnography?: Towards a Designerly Approach to Field Research. In *Empowering Users through Design Interdisciplinary Studies and Combined Approaches for Technological Products and Services*, 119–28. <https://hal.archives-ouvertes.fr/hal-02950774>.
- [5] Janghee Cho, Laura Devendorf, and Stephen Volda. 2021. From The Art of Reflection to The Art of Noticing: A Shifting View of Self-Tracking Technologies; Role in Supporting Sustainable Food Practices. In *Extended Abstracts of the 2021 CHI Conference on Human Factors (CHI '21)*, 1–7. 298. <https://doi.org/10.1145/3411763.3451838>.
- [6] Anne Teresa De Keersmaecker, et Bojana Cvejić. 2019. *A Choreographer's Score: Fase, Rosas Danst Rosas, Elena's Aria, Bartók (Softcover Edition)*. Mercatorfonds&Rosas.
- [7] Audrey Desjardins, et Timea Tihanyi. 2019. Listeningcups: A Case of Data Tacitility and Data Stories. In *Proceedings of the 2019 on Designing Interactive Systems Conference (DIS '19)*, 147–60. <https://doi.org/10.1145/3322276.3323694>.
- [8] Laura Devendorf, et Chad Di Lauro. 2019. Adapting Double Weaving and Yarn Plying Techniques for Smart Textiles Applications. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '19)*, 77–85. <https://doi.org/10.1145/3294109.3295625>.
- [9] Graham Dove, Michael Mose Biskjaer, Caroline Lundqvist, Jeanette Falk Olesen, and Kim Halskov. 2017. Constraints and Ambiguity: Some Design Strategies for Supporting Small-scale Creativity in the Classroom. In *Proceedings of the European Conference on Cognitive Ergonomics (ECCE '17)*, 69–76. <https://doi.org/10.1145/3121283.3121310>.
- [10] Daniel Favier. 2015. Répétitions. Books on the Move, Repères, cahier de danse, no 35.
- [11] Mikhaila Friske, Jordan Wirfs-Brock, et 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)*, 297–310. <https://doi.org/10.1145/3357236.3395442>.
- [12] 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)*, 937–946. <https://doi.org/10.1145/2207676.2208538>.
- [13] William W. Gaver, Jacob Beaver, et Steve Benford. 2003. Ambiguity as a resource for design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03)*, 233–40. <https://doi.org/10.1145/642611.642653>.
- [14] Nelson Goodman. 1976. *Languages of Art*. Indianapolis, Ind.: Hackett Publishing Co, Inc.
- [15] Bruna Goveia da Rocha, Johannes M. L. van der Kolk, and Kristina Andersen. 2021. Exquisite Fabrication: Exploring Turn-taking between Designers and Digital Fabrication Machines. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21)*, Article 434, 1–9. <https://doi.org/10.1145/3411764.3445236>.
- [16] Lena V Groeger. 2015. On Repeat: How to Use Loops to Explain Anything. ProPublica (blog). 5 juin 2015. Retrieved February 02, 2022 from <https://www.propublica.org/nerds/on-repeat-how-to-use-loops-to-explain-anything?token=mPKNtkPVMg6-T8beodKelct2D2SUi15O>.
- [17] Trevor Hogan, Eva Hornecker, Simon Stusak,

- Yvonne Jansen, Jason Alexander, Andrew Vande Moere, Uta Hinrichs, and Kieran Nolan. 2016. Tangible Data, explorations in data physicalization. In Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '16), 753–56. <https://doi.org/10.1145/2839462.2854112>.
- [18] Kristina Höök, et Jonas Löwgren. 2012. Strong concepts: Intermediate-level knowledge in interaction design research. *ACM Transactions on Computer-Human Interaction* 19 (3): 23:1-23:18. <https://doi.org/10.1145/2362364.2362371>.
- [19] Samuel Huron, Pauline Gourlet, Uta Hinrichs, Trevor Hogan, and Yvonne Jansen. 2017. Let's Get Physical: Promoting Data Physicalization in Workshop Formats. In Proceedings of the 2017 Conference on Designing Interactive Systems (DIS '17), 1409–22. <https://doi.org/10.1145/3064663.3064798>.
- [20] Samuel Huron, Yvonne Jansen, and Sheelagh Carpendale. 2014. Constructing Visual Representations: Investigating the Use of Tangible Tokens. *IEEE Transactions on Visualization and Computer Graphics* 20 (12): 2102–11. <https://doi.org/10.1109/TVCG.2014.2346292>.
- [21] Tim Ingold. 2013. *Une brève histoire des lignes*. Bruxelles: Zones sensibles.
- [22] Yvonne Jansen, Pierre Dragicevic, Petra Isenberg, Jason Alexander, Abhijit Karnik, Johan Kildal, Sriram Subramanian, et Kasper Hornbæk. 2015. Opportunities and Challenges for Data Physicalization. In Proceedings of the 33rd Annual ACM Conference on Human Factors (CHI '15), 3227–36. <https://doi.org/10.1145/2702123.2702180>.
- [23] Szu-Yu (Cyn) Liu, Jen Liu, Kristin Dew, Patrycja Zdziarska, Maya Livio, and Shaowen Bardzell. 2019. Exploring Noticing as Method in Design Research. In Companion Publication of the 2019 on Designing Interactive Systems Conference 2019 Companion (DIS '19 Companion), 377–380. <https://doi.org/10.1145/3301019.3319995>
- [24] Jonas Löwgren, Bill Gaver, et John Bowers. 2013. Annotated portfolios and other forms of intermediate-level knowledge. *interactions* 20: 30–34. <https://doi.org/10.1145/2405716.2405725>.
- [25] Deborah Lupton. 2017. Feeling Your Data: Touch and Making Sense of Personal Digital Data. *New Media & Society* 19 (10): 1599–1614. <https://doi.org/10.1177/1461444817717515>.
- [26] Malcolm McCullough. 1998. *Abstracting craft: The practiced digital hand*. MIT press.
- [27] María Teresa Rodríguez, Sérgio Nunes, et Tiago Devezas. 2015. Telling Stories with Data Visualization. In Proceedings of the 2015 Workshop on Narrative & Hypertext (NHT '15), 7–11. <https://doi.org/10.1145/2804565.2804567>.
- [28] Susan Rosemberg. 2016. *Trisha Brown: Choreography as Visual Art*. Wesleyan University Press
- [29] Daniela K. Rosner. 2012. Craft, computing & culture. In Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work Companion (CSCW '12), 319–22. <https://doi.org/10.1145/2141512.2141610>.
- [30] Daniela K. Rosner, Miwa Ikemiya, et Tim Regan. 2015. Resisting Alignment: Code and Clay. In Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '15), 181–88. <https://doi.org/10.1145/2677199.2680587>.
- [31] Daniela K. Rosner, et Kimiko Ryokai. 2009. Reflections on craft: probing the creative process of everyday knitters. In Proceedings of the seventh ACM conference on Creativity and cognition (C&C '09), 195–204. <https://doi.org/10.1145/1640233.1640264>.
- [32] Anna Ståhl, Vasiliki Tsaknaki, and Madeline Balaam. Validity and rigour in soma design-sketching with the soma. *ACM Transactions on Computer-Human Interaction*, 28(6):1–36, dec 2021. doi: 10.1145/3470132. URL <https://doi.org/10.1145/3470132>.
- [33] Saiganesh Swaminathan, Conglei Shi, Yvonne Jansen, Pierre Dragicevic, Lora A. Oehlberg, et Jean-Daniel Fekete. 2014. Supporting the design and fabrication of physical visualizations. In Proceedings of the SIGCHI Conference on Human Factors (CHI '14), 3845–54. <https://doi.org/10.1145/2556288.2557310>.
- [34] Alice Thudt, Uta Hinrichs, Samuel Huron, et Sheelagh Carpendale. 2018. Self-Reflection and Personal Physicalization Construction. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18), 1–13. <https://doi.org/10.1145/3173574.3173728>.
- [35] Anna Lowenhaupt Tsing. 2015. *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins*. Princeton University Press. Princeton, NJ.
- [36] John Zimmerman, Aaron Steinfeld, Anthony Tomic, and Oscar J. Romero. 2022. Recentering Reframing as an RtD Contribution: The Case of Pivoting from Accessible Web Tables to a Conversational Internet. In Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22), 541, 1–14. <https://doi.org/10.1145/3491102.3517789>.
- [37] John Zimmerman, Erik Stolterman, et Jodi Forlizzi. 2010. An analysis and critique of Research through Design: towards a formalization of a research approach. In Proceedings of the 8th ACM Conference on Designing Interactive Systems 5 (DIS '10), 310–19. <https://doi.org/10.1145/1858171.1858228>.