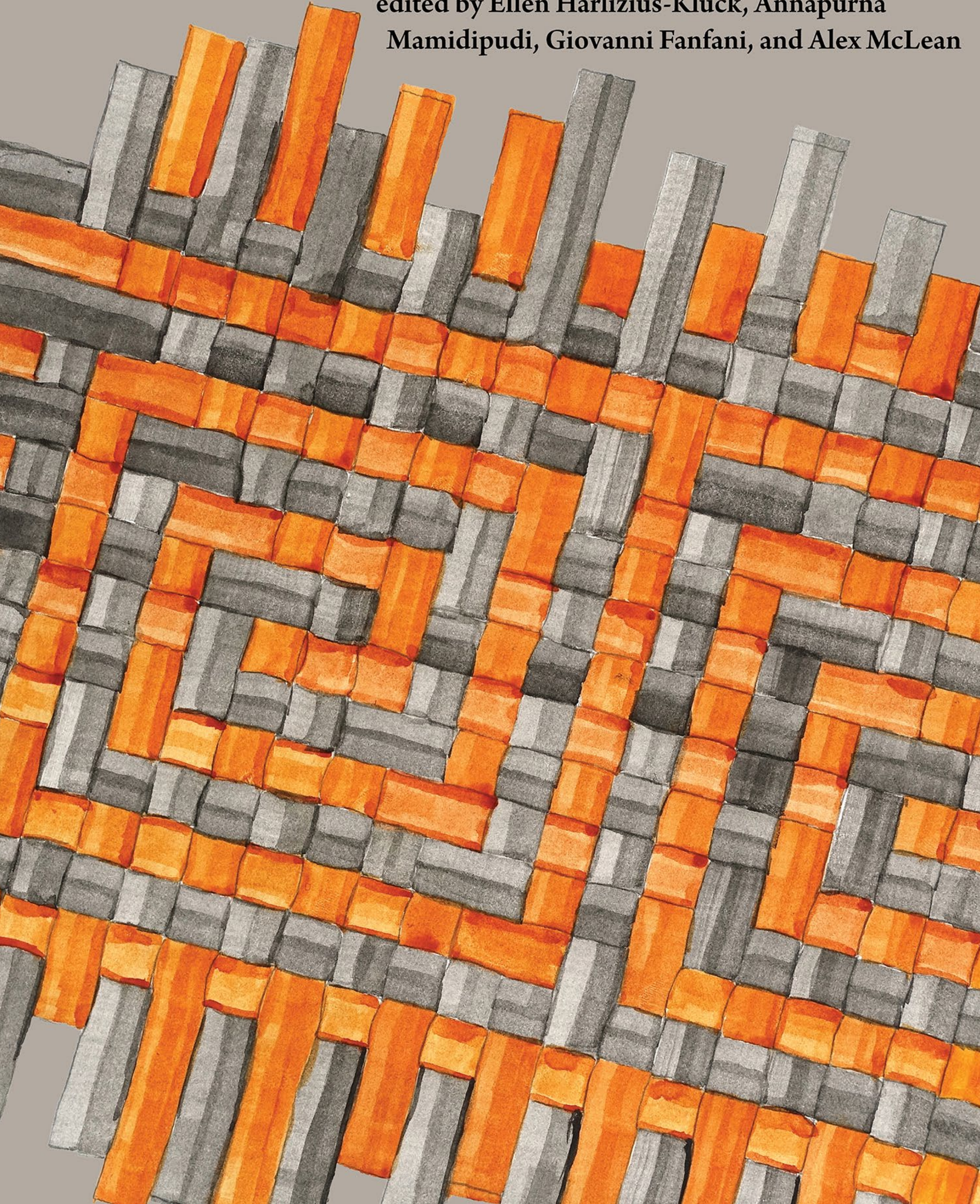
Homo Textor

weaving as (technical) mode of existence

edited by Ellen Harlizius-Klück, Annapurna Mamidipudi, Giovanni Fanfani, and Alex McLean



MATTERING PRESS

Mattering Press is an academic-led Open Access publisher that operates on a not-for-profit basis as a UK registered charity. It is committed to developing new publishing models that can widen the constituency of academic knowledge and provide authors with significant levels of support and feedback. All books are available to download for free or to purchase as hard copies. More at matteringpress.org.

The Press is grateful for the financial support received from our Supporting Libraries, via our partnership with the Open Book Collective. The Press' work has also been supported by: Centre for Invention and Social Process (Goldsmiths, University of London), Copim, European Association for the Study of Science and Technology, Hybrid Publishing Lab, infostreams, Institute for Social Futures (Lancaster University), OpenAIRE, Open Humanities Press, and Tetragon, as well as many other institutions and individuals that have supported individual book projects, both financially and in kind.

We are indebted to the ScholarLed community of Open Access, scholar-led publishers for their companionship and extend a special thanks to Thoth Open Metadata for their ongoing metadata management and dissemination work, as well as the Directory of Open Access Books and Project MUSE for cataloguing our titles.

MAKING THIS BOOK

Books contain multitudes. Mattering Press is keen to render more visible the unseen processes that go into the production of books. We would like to thank Endre Dányi and Michaela Spencer who acted as the Press' coordinating editors for this book, the two reviewers Claire Waterton and Kat Jungnickel, Steven Lovatt for the copy editing and proofreading, Jennifer Horsley and Lukas Franke for production support, Tetragon for the typesetting, and Will Roscoe, Ed Akerboom, and infostreams for their contributions to the html versions of this book.

COVER

	1	2	3	4	5	6	7	8	9	10	11	12
1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	0	1	0	1	0	1	0	1	1
3	1	0	0	1	0	1	0	1	0	1	1	0
4	0	1	0	0	1	0	1	0	1	1	0	1
5	1	0	1	0	0	1	0	1	1	0	1	0
6	0	1	0	1	0	0	1	1	0	1	0	1
7	1	0	1	0	1	1	0	0	1	0	1	0
8	0	1	0	1	1	0	1	0	0	1	0	1
9	1	0	1	1	0	1	0	1	0	0	1	0
10	0	1	1	0	1	0	1	0	1	0	0	1
11	1	1	0	1	0	1	0	1	0	1	0	0
12	1	0	1	0	1	0	1	0	1	0	1	0

Columns 1–11: Spiral A (The full weave code contains 12x12 cells).

The cover presents the construction of a meander fabric from black and terracotta threads based on a binary weaving code, where the figure 1 indicates that the vertical thread (warp) is up and the horizontal thread (weft) crosses under it. A zero indicates that the vertical thread is down and the weft crosses over. The system or algorithm of ones and zeroes (or of crossings) is visible in the area of the x-cross where all warp threads are black and all weft threads are terracotta. The same rule of up and down applies all over the fabric; however, the meander only appears where the colours alternate in warp and weft direction. For the cover we translated the binary code into drawing, guided by the technical mode of existence of weaving (or histomorphism) that provides the topic of this book and the principle of its organisation.

Cover art by Ellen Harlizius-Klück and Julien McHardy

HOMO TEXTOR:

Weaving as a (Technical) Mode of Existence

EDITED BY

ELLEN HARLIZIUS-KLÜCK,

ANNAPURNA MAMIDIPUDI,

GIOVANNI FANFANI

AND

ALEX MCLEAN

Mattering Press

First edition published by Mattering Press, Manchester.

Typesetting and ebook by Tetragon, London

Freely available online at https://www.matteringpress.org/books/homo-textor

ISBN: 978-1-912729-39-5 (pbk)
ISBN: 978-1-912729-40-1 (pdf)
ISBN: 978-1-912729-41-8 (epub)
ISBN: 978-1-912729-42-5 (html)
DOI: http://doi.org/10.28938/9781912729425

This publication is part of the PENELOPE project that has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (Grant agreement No. 682711).

European Research Council
Established by the European Commission

CONTENTS

PART II. EXPLORATIONS OF PATTERNS AS KNOWLEDGE OF ORDER

PART III. ON MISSING AND SEIZING TEXTILE OPPORTUNITIES

LIST OF FIGURES

CONTRIBUTORS

DENISE Y. ARNOLD is an Anglo-Bolivian anthropologist. She has been Leverhulme Research Fellow, ESRC Senior Research Fellow, and Research Professor at Birkbeck, University of London. She directs the Instituto de Lengua y Cultura Aymara, in La Paz, Bolivia, and is Research Fellow (Hon.) at University College London. Her interests include Andean textiles, visual languages, oral tradition and non-verbal systems of communication, including new approaches to Andean iconography. She is currently working on the role of weaving in Andean initiation rituals.

JOSEPH CAPOZZI graduated from the University of Massachusetts, Amherst, in 2020 with a degree in Computer Science. He is currently a graduate student at the Georgia Institute of Technology.

GIOVANNI FANFANI is a Classical philologist who has held postdoctoral positions at the University of Copenhagen and at the Research Institute for the History of Technology and Science of Deutsches Museum, Munich. His research spans Archaic and Classical Greek literature, especially lyric poetry and Pre-Socratic philosophy, around the interaction between textile technology and early Greek thought. Giovanni's current work with Ellen Harlizius-Klück explores the contribution of ancient weaving to the emergence of Greek mathematics.

ADELINE GRAND-CLÉMENT is Professor in Ancient Greek History at the University of Toulouse 2 Jean Jaurès since 2007 and has been a Junior Member of the Institut Universitaire de France (2016–2021). Her main research deals with the role played by colours and the senses in ancient Greece. Since her monograph, entitled *La fabrique des couleurs. Histoire du paysage sensible des Grecs anciens*, was published in 2011, she has focused her enquiries on the sensory dimension of rituals, which is the topic of her most recent book, *Au plaisir des dieux. Expériences du sensible dans les rituels en Grèce ancienne* (Anacharsis, 2023). Her current research interests are in environmental history and the anthropology of nature.

DAVE GRIFFITHS is a founding director of Then Try This, a non-profit research organisation in Cornwall, UK. The organisation's work includes hosting Alex McLean's fellowship on algorithmic patterns, building award winning apps to help farmers measure the nutrient content of their manure, teaching technology to children by making sounds using semiconducting crystals collected from mine waste, sound projects with Aphex Twin and building citizen science games so players can contribute to understanding disease and evolution.

LARS HALLNÄS is professor of Interaction Design at The Swedish School of Textiles, University of Borås. Trained as composer, philosopher and logician, his work in interaction design has focused on the aesthetic foundations of interaction. His current research interests range from the foundations of design aesthetics to textile geometry. He was coordinator for the Marie Skłodowska-Curie action ArcInTex European Training Network (ArcInTexETN) 2015–2018.

ELLEN HARLIZIUS-KLÜCK is Senior Research Fellow at the Institute for the History of Technology and Science, Deutsches Museum, Munich. Trained as a mathematician, artist and philosopher, she explores the impact of ancient weaving technology on the development of science and culture. Recently she conducted *A Study of Weaving as Technical Mode of Existence* in the five-year project PENELOPE together with Alex McLean, Annapurna Mamidipudi, Giovanni Fanfani, and David Griffiths (ERC-CoG-2015, GA Nr. 682711).

EBRU KURBAK is an artist whose research-based practice explores the entanglements between art, technology, culture and politics, with a focus on uncovering hidden values and ideologies in science and technology research. She is currently a Senior Research Fellow at the University of Applied Arts, Vienna. She has held residencies and exhibited her work at key international art and technology institutions and venues, and is a recipient of the LACMA Art + Technology grant.

ANNAPURNA MAMIDIPUDI is a scholar of science, technology, and society studies (STS). She has been awarded a DFG project titled 'Epistemologies of Craft: The Role of Material Innovation in Making Color Expertise' at Technische Universität Berlin. She is a co-editor of *Ownership of Knowledge: Beyond IP*, published by MIT Press. She was previously a postdoctoral researcher at Deutsches Museum working on an ERC project on weaving knowledge in ancient Greece. She is a trustee of the Handloom Futures Trust, which works at the intersection of knowledge and livelihood support for traditional craftspeople in India. Her research interests focus on how craftspeople innovate their material practices and how they make knowledge claims to build value for their work in past and contemporary society.

ALEX MCLEAN is a researcher, musician and technologist at the independent Then Try This studio. He is interested in both contemporary and heritage use of algorithms in pattern-making, particularly in the performing arts, having co-founded the TOPLAP and Algorave live coding movements, and the TidalCycles free/open source live coding system. Since December 2021 he has held a Future Leaders Fellowship titled Algorithmic Pattern, awarded by UK Research and Innovation.

VICTORIA MITCHELL is a Research Fellow at Norwich University of the Arts (UK). She pursues a broad interdisciplinary approach to visual culture and textile practices with reference to intersections between material, making, metaphor and meaning. She has co-edited *The Material Culture of Basketry* (Bloomsbury 2020) and *Pattern and Chaos in Art, Science and Everyday Life* (Intellect Books, 2023).

CINZIA PRESTI is a PhD student specialising in Roman Archaeology at the University of Cincinnati. She received her MA in 2022 from the same institution for her thesis, *Architectural Furnishings as Evidence of Local Intentionality in*

Etruscan Tombs. She has conducted excavation and geospatial work at Poggio Civitate Murlo, the Palace of Nestor Excavations at Pylos, and the Tharros Archaeological Research Project. Her writing primarily centres on architecture, urbanism, and geospatial analysis.

CAROLINE RADCLIFFE is a Reader in Drama and Performance at the University of Birmingham. Before entering academia, Caroline trained as a musician and actor, working as a freelance performer for orchestras and the stage, nationally and internationally. Caroline danced with Pat Tracey's clog group, Camden Clog, between 1992 and 2008, and in 2007 she teamed up with composer and sound artist Sarah Angliss to create 'The Machinery', based on one of Pat's dances. Radcliffe and Angliss were awarded the Dance4/Quake Contemporary Dance Award for the work, followed by Arts Council England and National Heritage Lottery funding to develop it with film maker Jon Harrison. Caroline is also a specialist in Victorian theatre and is currently writing a monograph on Wilkie Collins' dramas.

COLE ADAM REILLY completed their Master's in Computer Science at the University of Massachusetts Amherst in 2021, where they now teach. In between semesters, they work at a number of excavations designing systems to visualise arguments and benefit the archaeological process.

JULIAN ROHRHUBER works in an interdisciplinary field of media theory that combines philosophy, informatics, anthropology and art. His current research is on abstract objects, algorithmic acoustics and fieldwork in philosophy. As a professor at the Robert Schumann Hochschule in Düsseldorf, he develops art as a form of theory as well as teaching as a mode of research. As a programmer, he devises open source systems for experimental programming and electronic music. His recent publications are concerned with topics like patents and algorithms, the history of programming and mathematics, art theory, sonification and documentary film. Recent texts concern theories of time and the citizenship of abstract entities.

KALLIOPE SARRI is an archaeologist specialising in the prehistory of the Aegean. She studied history, archaeology and art history at the University of Athens and at the Institute of Prehistory and Early History at the University of Heidelberg. She is particularly interested in social organisation, burial customs and the development of ancient ceramic and textile technologies. She participates in research programmes on related topics and is co-organiser of activities in the field of experimental archaeology.

ANTHONY TUCK is Professor and Chair of the Department of Classics at the University of Massachusetts, Amherst. He serves as the Director of Excavations at the archaeological site of Poggio Civitate (Murlo), an Etruscan settlement located in central Tuscany. His work spans a range of issues arising from the site, including problems related to emergent aristocracy, the archaeology of narrative, and a consideration of manufacturing and production's relationship to identity.

1

INTRODUCING *HOMO TEXTOR*

Ellen Harlizius-Klück, Annapurna Mamidipudi, Giovanni Fanfani, Alex McLean

ALTHOUGH PENELOPE, WIFE OF ODYSSEUS AND TRICKY WEAVER, IS PROBABLY well known to most readers,[1] we begin our introduction with a quote from Homer's *Odyssey*. The extract presents the complaints of Antinous, the leader of the band of Penelope's suitors, to Telemachus, Penelope's son, about her flaw of being 'crafty above all women'. It is by her craft, Antinous says, that she 'keeps the Achaeans from knowing' how they are being forestalled in their plans to coerce her to marry one of them. Penelope is being forced to choose a suitor, even though she still believes her husband Odysseus will come back from his journey:

> Nay, I tell thee, it is not the Achaean wooers who are anywise at fault, but thine own mother, for she is crafty above all women. For it is now the third year and the fourth will soon pass, since she has been deceiving the hearts of the Achaeans in their breasts. To all she offers hopes, and has promises for each man, sending them messages, but her mind is set on other things. And she devised in her heart this guileful thing also: she set up in her halls a great web, and fell to weaving – fine of thread was the web and very wide; and straightway she spoke among us: 'Young men, my wooers, since goodly Odysseus is dead, be patient, though eager for my marriage, until I finish this robe – I would not that my spinning should come to naught – a shroud

> for the lord Laertes, against the time when the fell fate of grievous death shall strike him down; lest any of the Achaean women in the land should be wroth with me, if he, who had won great possessions, were to lie without a shroud.' So she spoke, and our proud hearts consented. Then day by day she would weave at the great web, but by night would unravel it, when she had let place torches by her. Thus for three years she by her craft kept the Achaeans from knowing, and beguiled them…[2]

What Antinous addresses as Penelope's craft is not just her weaving nor her unweaving, but rather her silent knowledge of the net of responsibilities and duties that even the suitors cannot escape when they want control over Ithaka, the realm of Odysseus; and the shroud she weaves is an important token in that network.[3] In a chapter analysing the connection of Penelope's weaving to Odysseus' position of power and honour (*geras*),[4] Beate Wagner-Hasel writes: 'By undoing at night what she has woven during the day, Penelope effectively halts the passage of time and makes it impossible for the suitors to obtain Odysseus' *geras*, which they hope to gain through marriage to her' (Wagner-Hasel 2020: 234). Penelope uses this knowledge from within her mode of being a weaver to resist the suitors and finally rescue the estate on her husband Odysseus' return. Contrary to *Homo faber*, or man the maker, who is able to control his environment through the use of tools, establishing a monodirectional cause-effect-relation, Penelope instead not only weaves back and forth in a continuous zigzag movement, but even unweaves her fabric at night, accentuating the possibility of re-turns.

Because of this possibility of returns and this knowledge of technical, social and political weaving, Penelope is our most prominent example of *Homo textor*, (wo)man the weaver, and the (technical) mode of existence of weaving that we aim to exemplify with this book.

. . .

By looking at weaving as a mode of existence, we invoke Bruno Latour's *Inquiry into Modes of Existence* (AIME, 2013), a project that is supposed to be a corrective to Western modernity where *Homo faber*,[5] man the maker, employs technology to control his environment by cause-effect relations.[6] Latour wants to move away from such 'first empiricism', namely the modern conviction that the world can be divided into primary and secondary qualities and that this 'naturalism' needs to be maintained (Latour 2011: 2).

As a philosophical category, modes of existence were introduced in 1943 by Etienne Souriau to explore a philosophical ontology with different ways of being (Souriau 2015). Taken up in 1958 by Gilbert Simondon for technical objects (Simondon 2017), these modes of being then attracted the attention of Latour, who had been looking out for a possibility to tell the history of the Moderns in a new way. Latour extends the modes and establishes a Cartesian coordinate system where pairings of modes generate the cells of a grid.

As Simondon shows, problems arise in the case of the technical mode when it is understood as the application of form to matter by a human being who invents and controls tools, i.e., *Homo faber*. This idea of making, conceptualised as hylemorphism[7] or hylemorphic schema, has been arguably established by Aristotle as the way nature acts on matter to bring forms into being (Simondon 2017: 176, 184, 248).

> (T)he attention is given to form and matter, not to the process of taking form as operation. […] The generalized use of the hylomorphic schema in philosophy introduces an obscurity that comes from the insufficiency of this schema as technical basis (Simondon 2017: 248).

For Latour, this specific understanding of production is bound up with the concept of *Homo faber* in the following manner:

> If you succeed in seeing in all technology a preexisting form that it applies to a hitherto inert and formless matter, then you are going to be able, by sleight of hand, to make the material world disappear even while giving the impression that you are populating it with objects whose materiality would have the same phantasmatic character as that of Nature! Here is where *Homo faber* comes on stage, shaping his needs through tools by 'effective action on matter' (Latour 2013: 218–19).

As the reader will learn from this book (chapters 2 and 12) and the meander construction on the cover, the composition principles enacted with the loom do not fit the hylemorphic scheme: the meander is not applied to textile matter but emerges from the composition of two distinct orders: the binary structure of the weave and the arrangement of colours. It is this mode of existence of weaving, termed histomorphism (from Greek *histos,* loom, and *morphê*, form) in our book, that makes weaving a powerful paradigm for complex order transgressing the simplicity of the cause-effect relation. The anthropologist Tim Ingold, who argues that making is less a mode of formation than one of growth, therefore shifts attention to weaving in his enquiry:[8] 'If the basket is an artefact, and if artefacts are made, then weaving must be a modality of making. I want to suggest, to the contrary, that we should understand making as a modality of weaving' (Ingold 2000: 339).

Ingold's use of the term weaving goes beyond (or stops short of) the factual technological import of the word, taking on a rather metaphorical and analogical function (Ingold 2010). In fact, a central claim of this volume is that the potential of weaving as a paradigm for non-hylemorphic and in-formational modes of production mainly follows from understanding and acting with its technological features and material conditions. To be sure, Ingold is aware that the material context of a technology or craft determines what is capable of being composed. For him, making is a process in which different materials unfold their potentials orchestrated by the capacity of the maker, while in Latour's approach, material does not really enter the picture.

Latour's idea is that the modes of existence would be included in diplomatic negotiations that remain true to the respective modes, and focus on relations, transformations and translations as instances of compositions. This 'comparative anthropology' would replace the concept of knowledge and allow the STS researcher to speak for other civilisations, cultures and technologies.[9] As a vision of such a diplomatic encounter, Latour refers to the Panathenaic festival in ancient Athens:[10]

> I have often wondered, contemplating the mutilated frieze of the Parthenon through the black clouds of pollution in Athens or in the room in the British

> Museum housing the marbles stolen by Lord Elgin, what a contemporary Panathenaic procession would look like. Who would be our representatives? How many genres and species would be included? Under what label would they be arrayed? Toward what vast enclosure would they be heading? How many of them would have human form? If they had to speak, swear, or sacrifice in common, what civic or religious rites would be capable of assembling them, and in what agora? If a song had to accompany their march, or a rhythm were to punctuate their long undulations, what sounds would they make, and on what instruments? Can we imagine such Panathenaics? (Latour 2013: 483)

The Panathenaia were the most important events in ancient Athens, publicly celebrating Athena as patron of the city-state by rhapsodic recitations of the Homeric epics, agonistic performances of music and dance, horse races and other athletic competitions in the guise of the Olympics. Compared to other festivals in Greece, the Panathenaics are famous for including women and even

FIG. 1.1 PENELOPE laboratory with model of the Parthenon temple in the Museum for Casts of Classical Sculptures, Munich. Photo by Ellen Harlizius-Klück in 2019

slaves,[11] possibly because these were key to the preparation of the weaving of the *peplos* (a Greek fabric, usually to make a female dress) depicting the founding myth of the city: the battle of gods and giants. Crucially for our argument here (although not mentioned by Latour), the most important part of the festival was a huge procession carrying this *peplos* to the Parthenon, the temple of Athens, through streets crowded with visitors from all over Greece and representatives of other cities – so-called *theôroi*.

> In the traditional practice of *theoria*, an individual (called the *theoros*) made a journey or pilgrimage abroad for the purpose of witnessing certain events and spectacles. In the Classical period, *theoria* took the form of pilgrimages to oracles and religious festivals. In many cases, the *theoros* was sent by his city as an official ambassador: this 'civic' *theoros* journeyed to an oracular center or festival, viewed the events and spectacles there, and returned home with an official eyewitness report (Nightingale 2004: 3).

It is on this notion of *theôria* that Plato builds his idea of theory as a vision of everlasting universal ideas. To him, the depiction of the gigantomachy on the *peplos* is a case of a philosophical theory, albeit a false one that is dragging down universal ideas of gods to the material ground of the giants clad in the myth of a battle and presented on a fabric.[12] While the *theôroi*, as representatives, witness the truth of the woven story for the people in their home cities with their eyes and their physical presence, the theorists invented by Plato only trust everlasting universal ideas that need no body or material to exist.

The Panathenaic festival demonstrates that weaving indeed was once able to compose a common world; the *peplos* is the emblem of the unifying power of the festival. However, the purification of knowledge as science is already on its way when Plato rejects the woven *peplos* of the Panathenaic festival as a case of a 'materialistic' and thus false theory, one in which matter takes part in the genesis of political *kosmos* (or 'order in the state').

The *peplos* escapes the attention of Latour, the scientist. He goes back in time to Greece only as far as the point where the split of culture and technology is already at work, where weaving is either ignored or claimed to be man's work, where numbers and geometry are about to be established as universal immutable mobiles, where the prevalence of idea over matter is already set on track. We contend, in fact, that the way Latour revisits Greece and starts the modernity project anew reinforces the very gestures that established the universality claim of Western metaphysics, the very same categories that blind us to women's work and to alternative approaches to social and cosmic order.

Here is where we depart from Latour's discursive diplomacy, and introduce – with the contributions of this book – a different thematic encounter of several representatives: our *theôria* of weaving. While a Latourian approach suggests that negotiations would do the job of 'teaching the art of speaking well to one's interlocutors about what they are doing – what they are going through, what they are – and what they care about' (Latour 2013: 64), we contend that weaving knowledge resists such discursive negotiations by scholarly representatives. If we take weaving seriously in its material, social and technical specificity, these recourses turn out to be shortcuts that tend to exacerbate the problems they are trying to solve, thus perpetuating phantasies of universality and representation.

FIG. 1.2 Clay weights attached to the warp on the warp-weighted loom (photo by Viktoria Lubomski in 2019)

We further contend that weaving and its technological mode are obliterated not only in Latour's image of the Panathenaic procession, but also in the standard descriptions of the advent of science in ancient Greece (for instance by Jean-Pierre Vernant, see chapter 2) as well as in the discussion establishing modern art theory (by Alois Riegl, see chapter 2). Indeed, we argue that these blind spots that ignore the composition principle of weaving (introduced here as histomorphism), have been and remain constitutive of the development and epistemological trajectory of science and the success of the hylemorphic description of making.

We also insist that it is not sufficient to claim symmetry for the actors involved (be they human or non-human). Arguably established as the most distinctive contribution of STS (representing all agents from their standpoint), symmetry, according to Latour, is imagined as a universal translatability principle for multiple moving frames of reference (Latour 1988). This principle seems to be at work where formulas and diagrams – immutable mobiles in the words of Latour – are employed for the purification and standardisation of practices. However, where Latour detects zigzags, detours and discontinuities – what he terms 'shifting' (2013: 228) or '*technical* FOLDING' (2013: 227; emphasis by Latour) – these cannot be straightforward descriptions of technology. Looking at the weaver and her/his loom as such a technical folding (see chapter 2) of symmetrical agents, Latour would suggest that it is the product that makes the man (and not the man that makes the product, as in *Homo faber*) and abandon the notion of mastery (2013: 230). However, we felt that such a practice would not allow but in fact deny a symmetric negotiation of scholars and master weavers where translatability does not exist per se, since the frames of reference are incommensurable.[13]

This implies, however, a specific difficulty in describing not only the mode of existence of/in weaving but also how it travels across domains. We would submit that it is not possible to capture this mode in diagrams and texts. Not that the weavers deliberately keep others from knowing, but that the knowledge is embedded in the network of threads, weaver and tool established when the weaver is working at the loom.

. . .

The book is the result of two encounters. First there was the project PENELOPE: *A Study of Weaving as Technical Mode of Existence*,[14] conducted by the team of editors and supported by David Griffiths.[15] In the PENELOPE project, we, Ellen Harlizius-Klück (philosopher and mathematician), Giovanni Fanfani (ancient philologist), Alex McLean (live coder) and Annapurna Mamidipudi (historian of technology and science, and handloom activist), aimed to set out the mode of weaving as it travelled across ancient Greece, emphasising its binary character and ordering concept, its atomistic and algorithmic features, its knowledge and artistic approach.

The second encounter was with the participants of a workshop/conference entitled HOMO TEXTOR, who reflected and extended this mixture with their own works and projects. When conducting our research, we came across the works of scholars who stood out for their inspiring approaches to textiles, its role in history and in organising societies. These scholars were also involved in incorporating new technologies and approaches to formalise weaving techniques. We invited these scholars to our PENELOPE laboratory where we practically explored ancient weaving and developed digital tools to make the patterning

FIG. 1.3 PENELOPE laboratory, preparation for the HOMO TEXTOR pre-conference workshop (photo by Viktoria Lubomski in 2019)

and ordering processes accessible (figure 1.3). The encounter consisted not only of presentations in the laboratory but also of talks and small performances. By these means the scholars contributed their own diplomatic encounter on weaving and finally found their way into this book.

For the HOMO TEXTOR encounter, we not only contravened Plato's interdiction against presenting the battle of gods and giants[16] (see figure 1.2) but also his warning to take weaving seriously: 'No one in his right mind would ever consider weaving for its own sake' (*Statesman* 285d). However, to consider weaving for its own sake is precisely what we asked of our contributing authors. We even asked them to try to be speculative about what would result for their fields of enquiry from such a serious look at weaving with regard to its theoretical potential. The idea was to see what happens when weaving, and textile processes and concepts are used as interpretative keys for geometric pottery design, classifications of codes, structures of poems, robot movements, dancing textile workers, patterns in nature, social and environmental organisation, the history of electronics and even mathematics.

The contributions form clusters and socialise around challenges of referencing terminology, technology, and form (part I), explorations of patterns as knowledge of order (part II), and stories about missing and seizing textile opportunities (Part III).

PART I: CHALLENGES OF REFERENCING TECHNOLOGY, TERMINOLOGY AND FORM

In engaging with weaving technology as generative of concepts and notions, the five contributions forming the first thematic subsection of this volume take further issue with well-established paradigms of production and making: the superimposition of form upon matter (hylemorphism), the opposition of (extrinsic) structure and (intrinsic) substance, and the search for exact correspondences between terms and objects. To these models of exploring, grasping, and interpreting processes of creation, weaving poses a radical challenge.

In the chapter following this introduction, Ellen Harlizius-Klück provides a detailed account of the scope and structure of 'The Technical Mode of Existence of Weaving' whose core term is introduced as histomorphism. The paper demonstrates that most of the misunderstandings about weaving stem from the problem of preferring hylemorphic explanations. This hylemorphic bias perpetuates through history and across disciplines an idealistic view of making that does not account for material and technical details and bodily and social embeddedness. The term 'histomorphism' (from Gr. *histos*, for loom or fabric and *morphê*, form) prevents several category errors resulting from such idealistic explanations and provides the necessary knowledge to understand how (ancient) weaving creates order. By shedding light on a misrepresentation of pattern weaving in art theory as based on geometry, Harlizius-Klück clarifies what histomorphism through weaving practice means, and how it proceeds from threads to society and the cosmos in ancient times. By doing this, she situates weaving in ancient Greece as a *technê* capable of integrating culture and

FIG. 1.4 Pre-conference workshop in the PENELOPE laboratory at the Museum for Casts of Classical Sculptures, Munich (photo by Viktoria Lubomski in 2019).

technology, thus providing a paradigm of pattern-generation that goes beyond the hylemorphic model in the sense that it is able to prevent the difficulties and paradoxes of the categories of objective knowledge and material practices. Histomorphism can indeed serve as a counter-model to the matter-form and technology-culture dualisms.

In chapter three 'Merge, Weave, House, Trap: First Steps Towards a Reverse Palaeoanthropology of Identity Concepts', Julian Rohrhuber ponders the hylemorphic paradigm at work in the very different epistemic environment of contemporary programming and computer science, through the opposition of substance (essence/matter) and structure (form), which is addressed and questioned. The chapter explores weaving and merging as means to shape concepts of identity in the field of computer programming, and as intuitions rooted in 'primitive' material practices. Rohrhuber argues that taking such intuitions seriously sheds light on the concepts themselves. Both merging and weaving exhibit a specific explanatory power for making sense of the idea of 'identity'; in merging, the different elements may still be distinguishable at times, but the concept of identity resulting from it is strongly characterised as intrinsic. Identifying something as the result of weaving, on the other hand, means situating its identity extrinsically as a mode of interaction. As Rohrhuber makes explicit, the nature of the reference to weaving is not metaphorical but functional: the explanatory power of weaving rests on the specific structure of the technology, and it is the interaction of elements that gives these their identity – like in the histomorphism of pattern weaving (see chapter 2).

However, the distinction drawn between intrinsic merge and extrinsic weave, which seems to be a subdivision of (intrinsic) substance and (extrinsic) structure/form, proves to be less stable than expected. Rohrhuber refines the opposition by adding reversibility (winkingly pointing to Penelope's unweaving) and irreversibility, which he introduces as dimensions of contingency and which complicate the initial picture by enabling new associations (the reversibly intrinsic and the irreversibly extrinsic) and new categories (housing and trapping).

While Rohrhuber thus proposes a reverse palaeoanthropology of concepts, the fourth chapter goes back to the epistemic landscape of ancient Greece and seeks to lay ground for an archaeology of notions of order rooted in weaving technology. Insecurity in reference and the identification of objects and words is characteristic of a (Classical) philology that cannot approach ancient terms as if they were immediately comprehensible. In 'Lost in Lexicography? *Kaîros* as Concept of Order', Giovanni Fanfani proposes an alternative approach to the 'word excavation' model of much scholarship in textile terminology that aims at matching words to objects or functions. The chapter explores the possibility of grasping notions of order (as core to ancient weaving terms) in two sets of textual material. On the one hand, the notion of 'order at the loom' is investigated through Greek lexicographers' accounts of the elusive word *kaîros*, a *terminus technicus* of weaving technology which ancient lexica and scholia unambiguously connect to a particular operation at the warp-weighted loom. That operation, namely distributing the warp threads in front and behind the shed bar, guarantees the ordered configuration of warp threads which enables weaving. On the other hand, the notion of 'order from the loom' emerges from the way in which the Archaic Greek abstract term *kairós*, an all-important concept of balance, appropriateness, and symmetry in Archaic thought, may have derived part of its semantic range from the weaving term *kaîros*. Fanfani proposes an integrated notion of *kairos* as order: a particular configuration of space and time at the loom which permits the insertion of the weft into the warp.

A lost play by Sophocles tells the disturbing myth of Philomela, Procne, and her husband Tereus where Philomela secretly communicates to her sister Procne that Tereus raped her – by sending a fabric she has woven. Many of the details of the story are lost to us, but Aristotle in his *Poetics* refers to this fabric as a plot device of the play, addressing it in a recognition scene as the 'voice of the shuttle'.

Anthony Tuck is searching for this voice in his paper 'Woven Witness: Philomela, Procne and Visualised Narratives through Textiles'. Following a serendipitous encounter with weavers singing in India and encoding pattern information into songs, Tuck investigates the nature of such encoding. Does it refer to a communication which is pictorial (a scene woven into a fabric), symbolic, or a text written in threads? Or does it refer to a weaving pattern that relates to a specific song – a secret language between women?

A technological tradition of committing pattern-related information to memory and performing it as/in songs seems to have been widespread in the

Indo-European linguistic environment, as passages from the Vedas attest to the connection between weaving and song. Together with Cole Reilly, Cinzia Presti and Joseph Capozzi, Tuck tries to verify the intriguing hypothesis that a reconstruction of the metrical structure of a rhapsodic performance – reflected in the patterns of alternating long and short syllables in each dactylic hexameter – may provide a graphic rendering of metrical sequences exposing the visual appearance of woven patterns. Entertaining the further hypothesis that the patterns of long and short might have communicated pattern-related information to weavers, Tuck and his team have developed an algorithm capable of generating patterns and displaying them as images where each pixel has a 'colour' or grey tone corresponding to the duration (long or short) of each syllable in the sequence of the dactylic hexameters of the Homeric poems. With the experiment allowing for different standardisation of the many combinations with which the Homeric hexameter occur, some of the visual results shown in the chapter's images exhibit a striking resemblance to textile patterns, especially the checkerboard-like designs depicted on funerary ceramic vessels from the Geometric and Archaic period of Greek art.

As this discussion of metrical patterns by Anthony Tuck and his team can demonstrate, an especially rewarding way to approach weaving as an integrated technology is to start from the woven pattern and the structural zigzag composing it. However, in his paper 'The Textile Expression Gap', Lars Hallnäs reminds us that it is not so clear how textiles are defined, nor what the definition and the textile can express. Some years ago, Hallnäs introduced 'Slow Technology' as a turn in the technology perspective. It is 'a search for mastering a technology as means of expressions, as means of expressing' (Hallnäs 2015: 32). Here, if '"function"' refers to what a thing does as we use it, "expression" then refers to what the thing displays as we use it' (Hallnäs 2015: 33). The paradox of a textile definition, a pattern formula, is that this expression is invariant under those transformations, while the textile expression itself is not invariant under transformations of use. Hallnäs proposes a 'near field reading of a textile', referring to an algebraic structure which is applied in the study of geometries. Textiles can then open up a space for definition by use in a very specific manner. While the expression of a formula is by nature abstract, in the case of yarn, material becomes a means of expression. Thus, textile is a theory, a definition, a formula, where its quality of being exact is expressed in the way in which the yarn 'in its places' displays the textile formula, as 'Slow Technology'.

PART II: EXPLORATIONS OF PATTERNS AS KNOWLEDGE OF ORDER

The papers following in part II look at what weavers do and know, and how this knowledge travels to other types of objects and beings as well as their relation to each other, the world in which they live, and how it is ordered. The phenomenology of pattern migration sets the first two contributions in dialogue with chapter 2 on the technical mode of existence of weaving, where Harlizius-Klück tackles the complexity of the relations between weaving technology and the visual representation of textile patterns. This relation is now addressed in different contexts. For investigations into ancient, and even prehistoric weaving, where the lack of material textile remains is compensated by the pervasiveness of textile patterns on pottery in Neolithic art, such pottery can be seen as potential evidence of a consistent practice of craft exchange and of pre-mathematical awareness that indeed has its origin in the woven pattern 'migrating' across different domains and media, and displaying modes of ordering and knowing. The same can be shown for a particular Greek term, namely *poikilia*, a notion that mediates between order in nature and in the craft of weaving. The reader will finally be drawn into the textile concepts of ordering economic, social and ecological routines in India and the Andean region, which demonstrate that the extension of textile concepts across nature and the cosmos is not specific to ancient Greece.

In the first contribution of Part II, 'Modular Patterns: A Survey on the Textile Origin of Neolithic Design and Its Calculational Implications', Kalliope Sarri takes us back to prehistory and offers a detailed account of the emergence and development of geometrical design in pottery as possibly inspired by textile patterns. The central hypothesis of the contribution makes a case for craft transfer – the manipulation and transference of patterns from the three-dimensional reality of textiles to the two-dimensional surface of pottery – and argues for the influence of weaving technology in other artistic and technological media. Due to the way in which symmetry is embedded in woven patterns, and the level of calculational skills required in weaving geometrical motifs, Sarri draws a connection to the operations of counting and manipulating numbers done at the abacus, as well as a three-dimensional binary system featuring a horizontal and a (virtual) vertical axis. The hypothesis animating the chapter proposes a cognitive environment in prehistory where it is possible to detect a connection between a) weaving and the generation of geometrical pattern, b) early forms of mathematical reasoning, and c) the visual outcome of that connection as displayed in visual design in media like pottery. Sarri argues that Neolithic weavers were able to create the geometrical patterns and symmetrical coloured shapes seen in their pottery because of the counting implied in weaving. She further contends that, through this experience, they developed their awareness and knowledge of geometric shapes.

Drawing partly on her own ground-breaking investigation of the ancient Greek notion of *poikilia*, Adeline Grand-Clément makes a robust case for establishing a connection between instances of *poikilia* in nature (namely, in the skin and plumage of two particular animals) and woven patterns in her contribution '*Poikilia:* Geometry and Living Patterns in the Greek Archaic and Classical Mind'. While Harlizius-Klück's contribution introduced the Greek term *poikilos* with reference to order in textile patterns, Grand-Clément takes a deeper look at occurrences that somehow blur the divide between the natural and the crafted world. The two cases discussed as instantiations of *poikilia* are the *iunx* (wryneck) and the snake, both described as being *poikilos* in literary sources. Such *poikilia*, which is primarily referring to the pattern on the plumage and skin of the two animals, is associated with further features which the wryneck and the snake share: the length of the tongue, the mobility of the neck and the sound they emit. By drawing on the characterisation of *poikilia* as *mêtis* (uncanny and deceptive intelligence), a trait that in animals such as the *iunx* and the snake seems to be transferred from their physical *poikilos* appearance to their behaviour, Grand-Clément explores the nature of the common ground that such *poikilia* shares with patterned textiles, as well as the role of geometrical patterns in the connection. When such features of *poikilia* are in turn transferred, via geometrical patterns on fabric, to depictions of humans, we find associations with Oriental/barbarian characters (who in Archaic Greek literature are connected to luxury, splendour and delicacy) as conveying the same traits of 'otherness' and hybridity as the snake.

Annapurna Mamidipudi takes ordering, coding and reading seriously in the context of textile production by hand weaving in India in her contribution 'Epistemic, Social and Material Ordering through Weaving Threads'. To do this, she uses the zigzag movement that always needs at least three nodes: loom – body – concept (for epistemic ordering) or livelihood – community – ecology (for social ordering). Ordering space and time is the work of modern science, but for weavers in India, time and space is ordered through their practices of weaving. Mamidipudi shows how weavers understand time through the example of the dyer nurturing the Indigo vat as one would nurture a child: not just caring for it, but also feeding and stimulating it regularly in order to keep it healthy. Memories are archived in products, like the nine-time dipped Indigo fabric, or into bodies that draw from the past to produce patterns for the future. Bodies are needed to smell colour, to sing the song of the shuttle and to form relationships that make weaving a mode of existence. Like Penelope weaving and unweaving at her loom, the Indian weavers, in keeping their techniques honed, seem to halt time and refuse progress.

Finally, in an event like the weaver festival in Chirala in India in 2018, representatives of different kinds of knowledge met over their looms, and for the festival's duration suspended the hylemorphic shadow that puts weavers into categories of labourers or design implementers, and cast their looms as primitive technology. At the festival, where veridiction of the weavers' knowledge was suddenly graspable because weaving was known to all the participants – exactly like in ancient Greece where everyone could witness the woven battle of Giants and Gods in the Panathenaic festival – weaving knowledge suddenly emerged into existence. Not through the single mirror of universal science, but as a reflection from the multiple perspectives of scholars, coders, designers, sellers, consumers and most importantly, the weavers themselves.

Likewise, for the Andean weaver, according to Denise Arnold, weaving creates a regional sense of identity through the expression of common technical

FIG. 1.5 Denise Y. Arnold and Annapurna Mamidipudi discussing in the PENELOPE laboratory (photo by Viktoria Lubomski in 2019)

values, cultural symbols and ideas. In her 'Comparative Reflections on Andean Weaving as Science', Arnold demonstrates how the threads carry information – as do textiles themselves: the relation between arrangements of threads visually expressing relations between entities in the real world – such as planning and predicting quantities of possible cultigen yields. Weaving becomes a vibrant interface for documenting and disseminating cultural ideas and symbols that express these living processes. The textile is a bodily outcome that carries the record of social, technical, financial and ecological decisions made in a society, disciplined into material order through weaving, passing knowledge from one body to the other, on ordering tasks, on cultivating fields and creating social hierarchies. Yet weaving is knowledge as a means – to a sustainable livelihood, to an interconnected web of practice or a simply to ensuring continuity of life.

PART III: ON MISSING AND SEIZING TEXTILE OPPORTUNITIES

The contributions in this third part bring together chapters demonstrating that not only the textile object as outcome of a textile production process, but also the production process itself (with its social relations and movements), when considered seriously, can open new perspectives not only in art, but also in coding and developing new technologies. The chapter authors provoke alternative views on the role of textiles in the history of electronics and machines, respectively.

In 'The String: Rewiring Women and Electronics', Ebru Kurbak reveals the relationship between textiles and electronics, with a focus on string-as-technology, mapping out the politics of an unrealised past and, in so doing, suggesting a potential textile future for electronics if the gender gap is further overcome.[17] Kurbak focuses on the demonstrable interchangeability between wire and threads. Yet she does not advance a simplistic hypothesis that would posit women as moving from ignorance into technological skill. Neither does she see weavers as supported by the efforts of feminists who use textile work as the type of a gendered activity that establishes woman weavers as metaphors for oppressed and home-bound women (like the usual reading of Penelope). For Kurbak, it is the string itself that presents the opportunity to make the 'strangely familiar' relation between an electrical circuit and a skein of yarn. She proposes that the textile threads and electronic wires that are materially compatible are rendered incompatible through social processes. Gender stereotyping hinders interactions, while crossovers occur due to the archetypical nature of string. Thus, she argues, today with the lifting of these segregating forces, we see current inventions that seem futuristic, but are in fact manifestations of unrealised pasts and lost possibilities.

The second contribution in this part, 'Algorithmic Patterns on the Live Loom' by Alex McLean, takes an auto-ethnographic approach to comparing weaving with computer programming by connecting them into a single, live and embodied system. The usual approach of representing weaving is by code (or formula, as presented by Hallnäs in chapter 6). Here one may invent new

FIG. 1.6 Alex McLean preparing the Live Loom for presentation (photo by Viktoria Lubomski in 2019)

ways to weave or construct fabrics by exploring the code's possibilities (which are claimed to be bigger than the factual possibilities that weavers are able to explore). Instead, one could claim that coding falls short in aspects that weavers do not like to miss, and that addressing this shortfall could enhance our understanding of code's relation to thinking. This possibility was explored by Alex McLean throughout the PENELOPE project, where he developed a language for coding weave-structures on a small rapid prototype of a warp-weighted loom (figure 1.6) for exploring the code and understanding its relation to the resulting weave.[18] Instead of following a pre-designed draft, as is usual with computer-controlled looms, this system allows the weaver to compose the pattern as part of the process of weaving it. The reflections on his practical explorations allow McLean to consider algorithmic patterns and metrics that operate in music as well as weaving, and conclude that notation is no necessary requirement for making and thinking about such algorithmic patterns.

As a result, McLean is able to introduce algorithmic pattern weaving as one of the missed opportunities that Kurbak points to.

Radcliffe's contribution, 'Embodying Patterns of Textile Machinery: A Dialogue' builds a bridge between historical and contemporary technological practices, albeit in the history of Lancashire textile mills during the Industrial Revolution. During the conference discussion, Radcliffe asserted that clog dancing was the 'hip-hop of the nineteenth century' – an incredibly popular working-class dance movement. In a close collaboration with composer and arts technologist Sarah Angliss, she has been staging a particular dance included in a video installation, *The Machinery*, which mimics both the movements and sounds of textile machines. In the form of a dialogue with Alex McLean, her contribution brings out the political aspects of labour and creativity that resonate through this piece of performance art.

In Radcliffe's view, it is not the domesticated woman weavers at home who are oppressed, but the artisan weavers forced into alienated factory work. Yet those factory workers responded to the repetitive noise of the industrial machines by composing clog dancing steps that humanised the machinic patterns. Relating this to the experience of call-centre workers, and home-workers during the COVID19 pandemic, Radcliffe speculates that the clog dancers prove that capitalism can be challenged, and that the human spirit can overcome adversity through creativity. Today the clog dance survives as a codified pattern of the body, as McLean suggests as patterns that are associatively digital.

In the absence of the original context of clog dancing choreography, Radcliffe wonders whether coding the steps into another register would allow the dancer to work with the structure in a new way. Here notation would not be used to stabilise the pattern into stasis, but to create new patterns that operate on another register. This is important for both McLean and Radcliffe, because whether coding algorithms or working in a mill, it is important to realise when the machine has power over you, and when you have power over the machine – when you can challenge the machine through your creative practice.

The last two contributions take the conversation from weaving to the related techniques of braiding. Victoria Mitchell's piece, 'Braiding and Dancing: Embodied Rhythm and the Matter of Pattern' brings together research from anthropology, robotics, textile history, archeology and cognition to explore braidings and the bodily movements which make them. She investigates the successive crisscrossing of braiding and dancing, from the hands dancing when braiding to the synchronised motions of the dancing body, as a basis for social interaction and the formative patterns of thought. The contribution tackles a basic question regarding reciprocity between the manipulation of materials, synchronised dance motions and social interaction, connecting physical acts of braiding or dancing to cognitive systems of relational interaction. Mitchell explores how this works across biological organisms and robots, when the body is not always conscious of what it knows.

Contending that technique is the preserve of collectives as well as individual bodies, Mitchell suggests that braiding's sequential reciprocity has an ordering propensity in respect of perception, conception and cognition. Thus, the finished basket or braid becomes an extension of this ordering, carrying the memory of its coming into being. Bodily movements are involved in braiding and dancing, particularly in the case of maypole dancing, where people interact with one another, sharing the stimulus of rhythmic music, negotiating

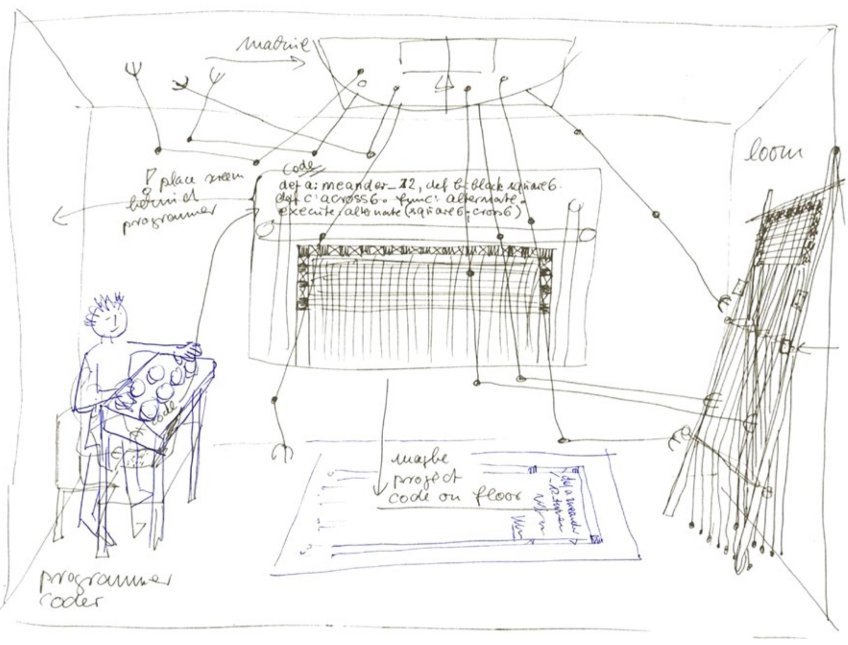


FIG. 1.7 Sketch of live coded warp-weighted loom that guided the PENELOPE project as a vision (drawing by Ellen Harlizius-Klück)

the pattern of the dance. Each moving body is a strand, and the strands are braided together, even as relationships between the dancing partners are made, braiding social coherence. Here again is the performance of social ordering through dancing bodies, like the choral dancing of ancient Greece. Rather than take social braiding as a metaphor, Mitchell shows how braiding lends itself to extension, being carried by the body's actions across and between phenomena of making products, dancing patterns or negotiating social interactions.

David Griffiths also picks up on braid dancing in his contribution 'Untangling knowledge work by maypole weaving with a PENELOPEan robot swarm'. His robots are one answer to the vision of a final PENELOPE project performance (figure 1.7), featuring a demonstration of the weaving process split up into the warp-weighted loom, a live-coding weaver and an arachnoid robot operating

FIG. 1.8 PENELOPEan robots populating the stone floor of the Museum for Casts of Classical Sculptures, Munich (photo by Viktoria Lubomski in 2019)

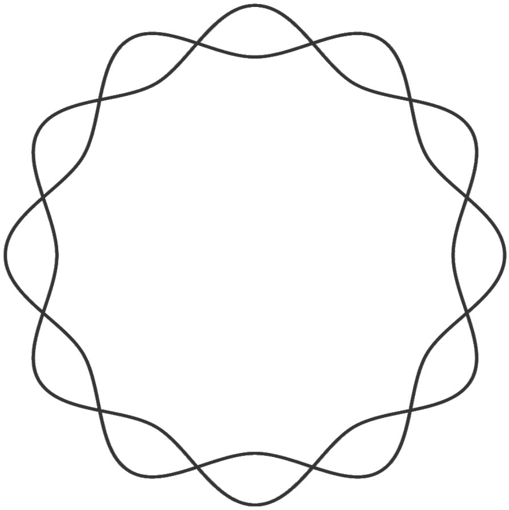


FIG. 1.9 Track for 12 pairs of maypole dancers (graphics by Viktoria Lubomski in 2020)

the loom according to the code that is also made visible to the public by being projected onto the wall or floor.

In Griffiths' approach, our vision found a new form with the robots as choral dancers, with live coded music in time with Homeric recitation.[19] Griffiths takes a trajectory similar to McLean by employing a critical engineering method to reconsider contemporary technology from the perspective of ancient technology. As part of a performance in the PENELOPE laboratory presenting the idea of ancient dancers 'braiding' ribbons stretched from an upright shaft, Griffiths introduced robots to dance around a maypole (figure 1.8). In order to throw light on the human hand in robot technology, the robots themselves are made by tablet-weaving, exposing and exploiting the algorithms underlying such textile craft. Furthermore, the robotic dancers themselves are only able to complete something like a braid with human help, demonstrating how entangled we are with technology, and indeed, always have been (figure 1.9).

. . .

The maypole dancing robots close the circle of the contributions by questioning our understanding of the social and the technical, or the cultural and the technological, as disparate fields. Indeed, the chapters evidence the scope of the (technical) mode of existence of weaving not only with their content, but also in the way they correspond with each other across borders of scientific disciplines. They iterate the story of Penelope, the zigzagging path of the shuttle in weaving as well as unweaving, and thus the technical mode of existence of weaving.

While Latour and Simondon both argue that our times are not able to integrate technology and culture, in Archaic Greek thought – with categories such as nature, culture and technology not yet shaped – weaving not only encompassed all of them, but also provided a pervasive model for the generation, implementation and projection of order in several domains: in craft, in nature, in poetry, dance, the community and even the cosmos. While providing us with a mode of knowledge integrating a series of dichotomies (culture vs nature, human vs non-human) and preceding the split between pure and applied science introduced by Plato and perpetuated by Aristotle, weaving not only in its Archaic Greek incarnation but also as a craft still processed by hand all over the world presents a technical mode of existence that is not yet distorted by loom developments that speed up the production process at the cost of reducing the possibilities of fabric and pattern composition for the weaver. This is why Penelope is our paradigmatic weaver – not only for representing ancient weaving itself, but also its paradoxes. Against the trajectory of technological development, the most primitive looms may yield the most complex fabrics; despite its seemingly geometrical construction, weaving is not well suited for geometric design, but based on arithmetic and properties of numbers; from the beginning it is a digital/binary art and analogue at the same time, discrete (up and down of warp/weft) and continuous (the linear thread) in one and the same object. Ancient weaving and the way it operates as a model of order in archaic communities furthermore enables us to understand similar types of order bound up with non-Western textile technologies.

By explicating weaving as a technique/culture/art, a *technê*, that – from outside the typical Western trajectory of technology[20] – is able to provide order concepts travelling across domains, and eventually even establishing cosmologies (see chapters 2, 4, 8, 9, and 10), this book breaks down the phantasies of immutable mobiles that reign within technocratic narratives of science and technology, and questions the idea that STS researchers may speak for others without being acquainted with their situated practices.

The book reflects the weaving together of the disciplines in our project as well as in the HOMO TEXTOR conference. Moreover, it does so, not as a graph of intersections meeting at a crossing in a cartesian grid, like in the AIME project, but as a non-directional infinite dance of pairs socialising in space and time without being localised at a definite point. Sometimes the chapters correspond historically, sometimes technically, sometimes culturally in a way that reveals something about weaving that remains invisible if presented according to disciplines or chronology.

Woven together, the chapters present interventions in a very Western understanding of technology and its terms and principles, including the assumption that technological logic should be universal and that it travels effortlessly and without loss along chains of translation. Such effortless travel or transformation of modes across domains, graspable and mobilisable by sociologists of science in speaking for others that cannot or do not speak for themselves, is a phantasy we do not subscribe to. Instead, we stay with the material, the processes, the concrete circumstances and the material history of the object or technology in question. As this will not lead to a purified description of weaving, we beg the reader to accept this impurity as a necessary condition to do justice to the various modes of weaving. Although we point to the epistemological value of weaving by addressing the blind spots in scholarly discussion that have been constitutive for science since Plato and Aristotle, we know that we cannot get rid of them by integrating them in a discursive way. Our book instead shows that the weaving mode transgresses boundaries of disciplines, that the idea of immutable mobiles like geometry or diagrams fails (they may stabilise production but they do not stabilise the knowledge of the weaver that needs to be mobile to be productive), that recipes cannot be given, categories fail, and terminology remains unstable.

ENDNOTES

1 Penelope and Odysseus are the main characters of the epos *Odyssey* by the poet Homer (8th century BCE) written down at the turn of the eighth and seventh centuries BCE. When Odysseus did not return from the Trojan war, a crowd of young men gathered in his home in Ithaka and tried to persuade Penelope to marry again. Laertes, for whom Penelope weaves a shroud, is Odysseus father.
2 Homer, *Odyssey*, 2.85–105. Translation by Augustus Murray from http://data.perseus.org/citations/urn:cts:greekLit:tlg0012.tlg002.perseus-eng1:2.84–128. Murray's translation for the Loeb Classical Library was published in 1919 and presents an antiquated language style. However, his translation of this passage shows Penelope as a person of knowledge, craft and wit – not as a housewife doing needlework – which is our reason for choosing his seemingly outdated translation.
3 For the important role of textiles in establishing such networks, see Wagner-Hasel 2020; Weiner 1992.
4 Wagner-Hasel explains that *geras* has 'both a material and an intangible meaning. On the one hand, *geras* denotes the concrete privileges of a high-status leader, a woman skilled in weaving, and a portion at the feast, which give visible expression to his status. On the other hand, *geras* can be understood as the ability to store or memorise social norms and knowledge and to use these stores of wisdom in counsel and decision-making.' Wagner-Hasel 2020: 244; see also chapter 4.3, 232–45.
5 According to François Sigaut, the concept of *Homo faber* arose from discussions, debates, and protest against the exclusion of technology from culture and education, and was introduced by Henri Bergson to claim that technique is an integral part of human nature (Bergson 1959: 88; Sigaut 2018: 18). In anthropology it is employed to distinguish modern man as active changer of his environment from his forerunners who produced for necessity and ceased work when their needs were fulfilled.
6 See http://modesofexistence.org/, last accessed 8 February 2024.
7 In this contribution, we use the spelling 'hylemorphic'. English publications usually refer to this concept as hylomorphism; however, both spellings are possible. See Manning 2012: 1, note 2.
8 Ingold on the art of inquiry: 2013: 6–8.
9 See http://modesofexistence.org/, last accessed 8 February 2024.
10 Latour speaks of his 'odd dream of doing for contemporary collectives what had been done – on the Elgin marbles – for the Panathenaic festival' (Latour 2010: 607).
11 'The Great Panathenaia, held every four years, is generally taken to be Athens' attempt to rival panhellenic festivals such as the Olympic games. In this festival, the procession included not only male Athenian citizens, but also Athenian maidens and priestesses, metics (male and female), freed slaves and non-Greeks living in Attica.'

Nightingale 2004: 55. The time of the founding of the celebration is unknown. An earlier rite, known as the Arrhephoria, where young girls prepared the beginning of the weave of the *peplos*, had been introduced already in the twelfth century BCE (Burkert 2001: 38). Peisistratos formalised the Panathenaic festival in 566 BCE. The Elgin Marbles from the Parthenon, to which Latour refers for his vision, were created under the reign of Perikles and probably erected around 433 BCE.

12 'And indeed, there seems to be a battle like that of the gods and the giants going on among them, because of their disagreement about existence. … Some of them drag down everything from heaven and the invisible to earth, actually grasping rocks and trees with their hands; for they lay their hands on all such things and maintain stoutly that that alone exists which can be touched and handled; for they define existence and body, or matter, as identical, and if anyone says that anything else, which has no body, exists, they despise him utterly, and will not listen to any other theory than their own.' Plato, *Sophist* 246b–c after Plato in Twelve Volumes, Vol. 12 translated by Harold N. Fowler (Cambridge, MA, Harvard University Press; London, William Heinemann Ltd. 1921).

13 Ganaele Langlois, in a recent book on textile as medium of communication, speaks of 'incommensurable worlds and modes of being' (Langlois 2024: 154; see also 61, 118).

14 The PENELOPE project has received funding from the European Commission under the HORIZON 2020 Research and Development Programme (Grant Agreement No 682711).

15 Dave provided digital tools and support for the experimental parts of our project with his company FoAM Kernow, later turned into ThenTryThis, see https://thentrythis.org/.

16 The PENELOPE laboratory was placed right next to the Parthenon Model showing the battle on its east side. The famous model was made around 1888 in Paris by Adolphe Jolly and Charles Chipiez and is now in the Museum for Casts of Classical Sculptures in Munich. It also shows the Elgin Marbles with the procession admired by Latour, and the dedication of the *peplos* right above the entrance to the temple.

17 This potential can be seen clearly in Kurbak's own work, for example within her *Stitching Worlds* project (see Kurbak 2018).

18 In the PENELOPE project, we call it a prototype, because some important features of the warp-weighted loom are missing, namely the starting and framing borders that pre-organise the pattern possibilities.

19 See https://zenodo.org/records/3246038, accessed 8 February 2024.

20 The warp-weighted loom that Penelope and her time employed for weaving fabrics is hardly ever mentioned in histories of textile technology. And the cases where it is mentioned reveal specific misunderstandings caused by modern categories of labour, market and the idea of gaining time by technological progress. We thus contend that ancient weaving on the warp-weighted loom is as alien to the common understanding of technology as traditional weaving in, for instance, South-America, Laos or Ladakh.

REFERENCES

Bergson, H., *L'évolution créatrice* (Paris: Les presses universitaires de France, 1959).

Burkert, W., 'The Legend of Kekrop's Daughters and the Arrhephoria: From Initiation Ritual to Panathenaic Festival', in W. Burkert, *Savage Energies: Lessons of Myth and Ritual in Ancient Greece* (Chicago: University of Chicago Press, 2001), 37–63, 38.

Hallnäs, L., 'On the Philosophy of Slow Technology', *Acta Univ. Sapientiae, Social Analysis*, 5.1(2015): 29–39.

Ingold, T., *The Perception of the Environment: Essays in Livelihood, Dwelling and Skill* (London and New York: Routledge, 2000).

Ingold, T., 'The Textility of Making', *Cambridge Journal of Economics,* 34 (2010): 91–102. doi:10.1093/cje/bep042.

Ingold, T., *Making: Anthropology, Archaeology, Art and Architecture* (London and New York: Routledge, 2013).

Kurbak, E., ed., *Stitching Worlds: Exploring Textiles and Electronics* (Berlin: Revolver Publishing, 2018).

Langlois, G., *How Textile Communicates: From Codes to Cosmotechnics* (London: Bloomsbury, 2024.

Latour, B., 'Reflections on Etienne Souriau's Les différents modes d'existence', in G. Harman, L. Bryant and N. Srnicek, eds, *The Speculative Turn: Continental Materialism and Realism,* (re.press 2011) 304–33. https://hal-sciencespo.archives-ouvertes.fr/hal-01054002.

Latour, B., 'Coming out as a Philosopher', *Social Studies of Science* 40.4 (2010): 599–608, https://www.jstor.org/stable/25746348, accessed 10 October 2022.

Latour, B., *An Inquiry into Modes of Existence: An Anthropology of the Moderns* (Cambridge: Harvard University Press, 2013).

Latour, B., 'Drawing Things Together', in M. Lynch and S. Woolgar, eds, *Representation in Scientific Practice* (Cambridge and London: MIT Press, 1990), pp. 19–68.

Latour, B., 'The Netz-Works of Greek Deductions', *Social Studies of Science* 38.3 (2008): 441–59.

Manning, G., 'Three Biased Reminders about Hylomorphism in Early Modern Science and Philosophy', in G. Manning, ed., *Matter and Form in Early Modern Sciences and Philosophy* (Leiden: Brill 2012), pp. 1–32).

Murray, A. T., *Homer: Odyssey*, London: Loeb Classical Library, 1919.

Sigaut, F., 'Die *Homo faber*-Kontroverse' *Zeitschrift für Kulturwissenschaften* 2 (2018): 17–33.

Nightingale, A. W., *Spectacles of Truth in Classical Greek Philosophy: Theoria in its Cultural Context* (Cambridge: Cambridge University Press, 2004).

Simondon, G., *On the Mode of Existence of Technical Objects* (Minneapolis: Univocal, 2017).

Souriau, É., *Les différents modes d'existence* (Paris: PUF, 1943).

Souriau, É., *The Different Modes of Existence* (Minneapolis: Univocal Publishing LLC, 2015).

Wagner-Hasel, B., *The Fabric of Gifts: Culture and Politics of Giving and Exchange in Archaic Greece* (Lincoln, Nebraska: Zea Books, 2020).

Weiner, A. B., and Schneider, J., *Cloth and Human Experience* (Washington: Smithsonian Books, 1989).

Weiner, A. B., *Inalienable Possessions: The Paradox of Keeping-While-Giving* (Berkeley: University of California Press, 1992).

PART I

CHALLENGES OF REFERENCING TECHNOLOGY, TERMINOLOGY AND FORM

2

THE TECHNICAL MODE OF EXISTENCE OF WEAVING: INTRODUCING HISTOMORPHISM

Ellen Harlizius-Klück

THIS CHAPTER CONCENTRATES ON CRUCIAL NOTIONS OF ANCIENT WEAVING as a technology establishing order far beyond the borders of a fabric, thus claiming weaving to be a technological basis for a whole culture, integrated into its mode to calculate, to explain stunning patterns in nature and to understand the order of the cosmos. The chapter introduces the technical mode of order and generation in pattern weaving (which I call histomorphism) and explicates how that ordering principle and process travels into other domains like painting (on pottery and frescoes), natural history (bird feather and snake skin patterns), arithmetic (how number features behave when numbers are combined) and atomism (how elements constitute the cosmos).

In this contribution, I strongly distinguish between the travel or transfer of form (which can be described by hylemorphism) and the transfer of its principle of production or creation in weaving (which asks for histomorphism). This does not mean that the principles are opposed to each other. However, while hylemorphism splits idea or form from matter, this is not possible in histomorphism where they are cognates in the process of making.

Because of the back and forth as well as up and down movements of the weft and shuttle in weaving, histomorphism partakes in a major feature listed by Bruno Latour for any technology, namely that the technical mode of existence[1] is characterised by a specific deviation: the technical or technological labyrinth (Latour 2013: 223). Latour employs several terms to indicate this defining feature: 'ingenious detour' (2013: 223), '*technical* FOLDING' (2013: 227; emphasis by Latour), 'technical zigzag' (2013: 216–18, 227). This detour is also addressed as *mêtis*, a Greek term for a specific type of intelligence that seizes opportunities and does not follow pre-established plans. It is often attributed to Odysseus or Penelope, both capable of technical ruses. In undoing her weave by night, in undoing the patterned fictions created the day before, Penelope insists on weaving as a mode of existence rather than a design practice: she persists in weaving as a zigzag path between doing and undoing, and retains the social order that textiles establish in Archaic Greece. [2]

Also, the productive way of ordering in weaving itself – for example, the repeated introduction of the weft by a shuttle – includes a zigzag movement that is, however, commonly understood as futile labour replaced in the course of the history of technology by machines. The productive order of the zigzag movement thus no longer contains the creative aspect of fabric making which is nowadays located in the design process.[3] It is exactly the 'ancient' zigzag of production and its intellectual implications that I want to put (back) into the heart of the technological mode of weaving by explicating it along the paradigmatic case of the meander pattern (figure 2.9). With reference to this mode, the term 'ancient' has two meanings; first, it indicates the zigzag that contemporary weavers still do with their hands all over the world,[4] a movement that genealogically predates loom developments that speed up the production process at the cost of the possibilities of fabric and pattern construction for the weavers.[5] Secondly, it literally indicates the weaving of ancient Greece, which is based on a warp-weighted loom and for which the meander poses specific problems, as we shall see. But why do I go back as far as ancient Greece?

To Latour, it is a key question why our type of science, which had its advent in ancient Greece, makes it so difficult to grasp modes of thinking that differ from objective knowledge (Latour 2013: XXV). That arguably new type of reasoning in ancient Greece is a stumbling block for scholarship, in constant need of explanation.[6] Jean-Pierre Vernant describes the innovative change in the following way: 'a new thought sought to base the order of the world on relations of symmetry, equilibrium, and equality among the various elements that made up the cosmos' (Vernant 1982: 11). With regard to the Greek city-states, Vernant asks, further, how a community can be founded on contradictory elements, or, 'to apply the Orphics' formula, how, on the social level, could one emerge from many and many from one?' (Vernant 1982: 45). It is here that histomorphism, the concept of entangling elements by the zigzagging and dialectical movement of weaving that is based on a binary order of up and down, can provide a unique model of explanation. This idea of entangling elements in the dialectical movement of weaving is demonstrated not only by the Panathenaic festival – which celebrated a fabric woven by girls and women of the city of Athens and was dedicated to the city-patron and mythical founder Athena (see chapter 1) – but also the Orphics' text corpus, brought up by Vernant himself. The Orphic cosmogonist Pherecydes[7] introduced the cosmos as an intricate fabric woven by the God *Zas* (Zeus). Here, weaving is able to present a clear idea of how order comes into the world from many single elements.[8]

Some Pre-Socratic philosophers described the cosmos as an entanglement of uncut elements (atoms) and void, ordered by weight and movement – just like threads on a warp-weighted loom. I contend that Aristotle, in opposing his concept of hylemorphism to the atomistic idea of the order of the cosmos, especially rejected a mode of existence that was strongly connected to the technical mode of weaving on a warp-weighted-loom. Aristotle criticises atomistic ideas as materialistic while claiming that only ideas and forms are universal and eternal and should therefore be regarded as primary 'elements' of the cosmos.[9] In the course of this text we will see how investigations of textile concepts will fall prey to this dichotomy of materialism and idealism in which geometry, as an inscription of universal ideas of order, plays a key role – a role that Latour reassessed (and actually reinforced) as a practice establishing 'immutable mobiles' (1990).

This investigation will proceed in four steps:

A) I first revisit the debate among art historians as to whether textile art was the beginning of art itself, an argument initiated by the art theorist and architect Gottfried Semper. This discussion reveals a fundamental misunderstanding of woven forms as geometric and establishes the value of art with reference to geometry, thereby connecting the beginning of art to the scientific revolution in ancient Greece where geometry was established as science. Although this seems to be a scholarly discussion, political conditions of the perception of textile work inflect it as a battle between materialism and idealism in a German context in times of revolution, a battle in which weaving played a crucial role.

B) To clarify the role of geometry for textiles, I then look at how patterns are transferred to other surfaces, and how they shed light on the discretisation of planes by geometrical grids. Here, we not only encounter ways to reproduce patterns, but also stunning ways to express meaning through patterns that exceed their decorative function and raise the riddle of their construction.

C) By looking into ancient descriptions of patterns – especially the Greek term *poikilos* (multi-coloured, variegated) in its various forms – it is possible to show how weaving presents cosmic generation. Discussed as a technology of enchantment, we encounter some explanations of how weaving prefigures atomism in the description of colour mixtures. Here, we revisit Aristotle and the earliest conflict between materialism and idealism that gave rise to the hylemorphic scheme in which principles of construction are not relevant.

D) Finally, I will look at practices of weaving in ancient Greece, clarifying features that are specific for weaving on a warp-weighted loom, but also presenting some basic principles of pattern weaving in general. We will not only encounter the loom, but also its 'arithmetic' or visual algebra at work, and the concept of mixing threads to 'forms' and 'fictions'[10] like the meander, including the constructive aspect. From here, we can finally delineate histomorphism as the mode of existence that travels across the archaic world.

Weaving will be presented here as a *technê* in its ancient meaning, where nature and technology are not opposed but able to explain each other.[11] The ancient mode of existence of weaving is not only technical[12] but extends into the realms and fields of religion, cosmology and natural philosophy, thus being an encompassing mode of existence that bridges technology, culture and nature.

MISUNDERSTANDING WOVEN FORMS: THE ROLE OF GEOMETRY

'In the beginning was the textile art' – with these words, Gottfried Semper (1803–1879), the famous German architect and art theorist, liked to introduce his lectures on ornamentation.[13] The phrasing provocatively alludes to the Gospel of John, where the word functions as a principle of cosmic genesis.[14] Semper triggered a fierce discussion among art historians as to whether art is founded on such a technological basis.

Semper claimed technological features to be responsible for the first principles of style in art, and he lists four technical classes to consider: textiles, ceramics, tectonics (carpentry) and stereotomy (masonry etc.). Addressing the question of which technique was primary, he goes on to say:

> It is hard to establish which of the technical branches listed in the previous chapter was practiced first in the natural course of human development, and ultimately there is little point in knowing this. But there can be no doubt that in the first two branches – textiles and ceramics – we find the first efforts to embellish functional objects through a conscious choice of form and decoration. Of these two arts, textiles should undoubtedly take precedence because they can be seen, as it were, as the primeval art form from which all other arts – *not excepting ceramics* – borrowed their types and symbols, whereas it itself seems quite independent in this respect. Textile types evolved within the art itself or were borrowed directly from nature. (Semper 2004: 113; emphasis by Semper).

Semper concludes: 'There can be no doubt that the first principles of style are bound up with this earliest of artistic techniques'"

Semper was obviously aware that ceramics would have been favoured as the first technology by most of his colleagues. And indeed, his idea was taken up by the archaeologist Alexander Conze (1831–1914) who placed geometric pottery at the beginning of style development:

> Semper correctly says that the details of forms and the whole characteristics of the ornaments of these vases are of technical origin and point to the technique of weaving, possibly also to plaiting and embroidery; the rectangular crossing of threads is responsible for the linear character and the straight and angular forms. The fact that even the execution with brushes constrains itself to these forms that are rooted in a completely different technique seems to prove that a time and population where weaving, embroidery, plaiting, particularly executed by women and above all being the most important branch of art, left its traces here. (Conze 1870: 522; my translation)

Opposed to both Semper and Conze, the Austrian art historian Alois Riegl (1858–1905) fervently rejected this idea as 'materialistic', instead introducing the 'will to art' (*Kunstwollen*). Riegl held this to be an aesthetic disposition, innate to human beings by nature,[15] that is the main driver of style development. He then founded modern art history as the history of such style.[16] Riegl especially objected to the idea that the characteristics of geometric vase decoration were grounded in textile patterns (Riegl 1985: 9). To Riegl, not the specific constraints of textile technology were responsible for the geometric style, but rather artistic laws that were universally true and independent of technique and material – like the laws of geometry (Riegl 1985: 3).

Riegl's objection became the standard argument against any effort to give textile technology a paradigmatic position for the beginning of art.[17] In 1969, the archaeologist Bernhard Schweitzer (1892–1966) described ornamentation on Archaic pottery as a grammar[18] operating on the elements of point, line, straight line and angular line, and observed:

> [I]t is not by accident that these are the axioms of geometry: the point that generates the one-dimensional line when it moves; the straight line that leads to the area of a rectangle when crossed, and the angle that in the end leads to the image of the triangle and lozenge by crossing.

And he summarises: 'Here we have, for the very first time, an inquiry into the essence of geometry – what it is by its very nature – and from the elements of geometry a great and abstract artistic language is built up with mathematical precision' (Schweitzer, 1969: 15; my translation). Schweitzer thus aligns with Riegl regarding the independence of geometric ornaments from technical or material origins:

> In relation to nature, these beginnings of Greek art are not sensual, but eminently intellectual. Intuitive foreboding of a geometric-mathematical structure of the cosmos – cosmos in the not accidental threefold meaning of decoration, ornament and universe – seeks and finds its purest reflection in the first ornamentation that the Greeks produced: the geometric.[19]

The attempt to value textile techniques by connecting them to geometry (though well-intended by Conze), ended up in subordinating them to the intellectual pre-conception of geometry as a universal mathematical subject by early pottery painters. While it could be then claimed for painters that they employ an intellectual activity in transposing geometric shapes to surfaces, weavers remain the slaves of a geometric grid that produces geometry as a natural result of technology with no participation of the intellect. Their 'design' is a matter of technical constraints, not an artistic invention or *disegno*.

Revisited from the twenty-first century, this might appear a marginal discussion. However, it reflects not only the unease of intellectuals with the decoration of new industrial products, but also the uproar induced by industrialisation all over Europe.[20] The German revolution of 1848 followed on a series of weaver revolts, the most famous being the revolt of Silesian linen weavers in 1844. The Prussian officials did not fear the workers but saw great danger in the intellectuals (in those days called *Literaten*[21]) taking up the case and giving momentum to the debates following the revolt (Beck 1992). Semper, professor at the University of Dresden since 1834, took part in the fighting in Dresden in early May 1849 (together with the composer Richard Wagner), even enhancing the construction of the barricades. From that month on, Semper was wanted by the Silesian police on a warrant, and was forced to flee from Saxony.

He went to London, where he worked on the Great Exhibition in the Crystal Palace in 1851 and taught at the Government School of Design (today the Royal College of Art) together with Owen Jones. The Crystal Palace was a technical building of steel and glass, exposing a transparency that emphasised the rich decoration of the exposed Western objects that exhibited ornaments copied from the past. The Great Exhibition induced a long discussion of the role of ornaments for industrial production. While Jones explored the inner laws of ornamentation, published as *Grammar of Ornament* in 1856, Semper went to Switzerland where he got a lifetime professorship in Zurich in 1855, and wrote and published *Style* (1860), which included his 'materialistic' thesis of textile techniques being the origin of art (while still being wanted by the Saxony police until 1863).

Meanwhile, Karl Marx developed his concept of (historical) materialism: the way in which people organise material production (and reproduction) is the basis of all social organisation. Marx offered materialism as an explanation better suited to describe the social and economic situation than idealism. However, one idealist scholar compared the harm that materialistic ideas would do to society with the breakdown of cosmic order due to the loss of the force by which planets are bound to the sun.[22] Playing out the opposition of cosmic/universal ideas and technological matter is a repeating motif in the discussion between materialism and idealism. Connecting the beginning of art to geometric pottery (and not textiles) as an intellectual and intuitive notion of a pure mathematics ordering the universe should be seen within this wider political and social situation where 'textiles' would have called to mind the weavers' uprisings and the revolution that followed in its footsteps.[23] Another consequence was the discussion on ornamentation which found its fever pitch in the essay 'Ornament and Crime' by the architect Adolf Loos.[24]

At the end of the discussions between art historians and archaeologists, the beginning of art is connected to the beginning of science in ancient Greece: the axiomatic foundation of geometry and the birth of pure mathematics in Euclid's *Elements*, written around the turn of the fourth century BCE (and thus much younger than any geometric pottery or textile patterns). As a result, for art theorists such as Schweitzer and Riegl, it is clear that only abstract geometry can provide a reference for a work of art to the order of the world or the cosmos, but never the interweaving of threads in textile ornamentation.

In the words of Latour, the scholarly debate is decided by the possibility of inscription: the immutable mobile (geometry) wins over the technical mode of weaving that no one in the debate actually ever tried to investigate.

TRANSFERRING TEXTILE PATTERNS

At first glance, it indeed looks like weavers work with geometry. In addition, the connections between geometry and textile production extend right into the names of the materials and equipment: both, the English 'line' and Latin *linea*, derive from the same Latin word *linum* for linen. On the ancient loom, the rod used to create patterns is called *kanôn* (Greek) and *regula* (Latin), both denoting the ruler or straight-edge. The linguistic relationship is not surprising considering that threads and cords were essential tools of early field measurement. However, at the loom, the parallel thread lines and right-angled thread crossings are not the result of applied geometry. They follow the laws of physics (gravitation, tension), which exert their effect on the loom and its elements within an order that is determined by rhythms and numbers, not by measurements.[25] Neither a trace of the movement of the hand[26] nor the line of the thread generates the line of the pattern: it emerges through a technically complex operation, the zigzag, the technical labyrinth of weaving, or histomorphism, executed on and with 'linear' threads.

Still, painters of a vase or fresco who transfer textile patterns onto other surfaces indeed need to grasp the pattern by geometry. They need to identify its form and symmetries, and need to transform it into shapes and areas. To this degree it is correct to say that the geometry of such depictions of textile patterns does not derive from textile techniques as such; however, it is exactly the case of textile pattern depiction, where geometry becomes important and sometimes indispensable.

Let us look at an example of such textile pattern transfer onto a vase-like surface, namely the marble leg of the sculpture of Paris from the west tympanon of the Aphaia temple at Aegina, dated to the fifth century BCE and executed as a reconstruction by the team of Vinzenz Brinkmann (figure 2.1; see also Brinkmann 2003, Brinkmann and Koch-Brinkmann 2003).

FIG. 2.1 Reconstruction of painting on the leg of the Paris statue of the Aphaia Temple by Vinzenz Brinkmann and his team (photo by Ellen Harlizius-Klück in September 2019)

As photographs with sidelight showed, the marble legs had a complex zigzag pattern that the Brinkmann team first tried to paint freehand on the marble-reconstruction – yielding an unsatisfying result (see Brinkmann 2003: 91–92). In another attempt, they applied a rectangular grid to the surface into which the pattern was then filled, yielding the result presented in the final reconstruction. Such grids are employed by artists to transfer and enlarge motifs between surfaces, e.g. from draft to canvas. Such regular perpendicular grids connected to Euclidean geometry and Renaissance perspective[27] are, however, not the best choice for a transformation of the visible forms of an original three-dimensional curved fabric to the similarly curved sculpture. Depending on the form of the motif to be transferred, the grids sometimes have a lozenge form and thus diagonal lines. As the zigzag pattern suggests, and a textile reconstruction of the trousers by Dagmar Drinkler confirms, a diagonal grid would have helped to represent the pattern perfectly[28] (figure 2.2). The insistence on a rectangular grid as standard seems particularly inappropriate for reconstructing the pattern

FIG. 2.2 Plaster cast of Paris sculpture with reconstruction in sprang-technique by Dagmar Drinkler (photo by Ellen Harlizius-Klück in 2019)

on the arms of the sculpture, where a skewed or oblique grid as would have been provided by the plaited fabric already presents the perfect lozenge grid by itself.[29]

The original marble sculpture from the Aphaia Temple shows no physical traces of such a grid, although such supports for depicting textile patterns had been in use in Archaic times and are known from frescoes of Knossos and Mycenae (ca. 1,500 BCE), i.e. already one millennium earlier. Sometimes, this grid is termed

FIG. 2.3 Detail of pattern with artist grid from the skirt of a goddess at the Villa in Ayia Triada, Rodenwaldt 1919: 104[31]

FIG. 2.4 Detail of fresco from Aya Triada with patterned skirt, Halbherr 1903, p. 10, https://doi.org/10.11588/diglit.9310#0216

‘incised’, and some call it ‘impressed’.[30] On the occasion of a description of the frescoes of Mycenae in 1919, Gerhart Rodenwaldt explains that a net was pressed into the plaster (Rodenwaldt 1919: 96, note 1, see figure 2.3).

The earliest evidence of this method, called ‘artist’s grid’ by Maria Shaw, stems from Crete, namely from the island of Pseira and the site Aya Triada, where the pattern of a women skirt has been constructed in such a way (figures 2.3 and 2.4; Shaw 2010: 316). The textile pattern appears almost identical to a ceiling ornament in Egypt, prompting Rodenwaldt to argue that textiles were traded across borders and that such a pattern was imitated here (see figures 10 and 11 in Rodenwaldt 1919: 104).

Shaw and Murray present several such pattern depictions from Mycenaean frescoes. It is striking that they do not reflect the body of the wearer at all (see figure 2.5). About the scale pattern of the cupbearers on the fresco at Ayia Triada, Murray writes: ‘It would appear that maintaining the integrity and clarity of the rapport design was a greater priority than visual naturalism’ (Murray 2016: 55). She continues: ‘The fact that the dress has a fancy weave is more important to record than how it fits and moves as clothing. It is as if the artist conceived of the fabric as the original bolt straight from the loom.’

FIG. 2.5 Two examples of textiles worn by cupbearers, depicted with the help of rectangular artist grids. Palace of Minos in Knossos, details from procession fresco, Archaeological museum of Heraklion, Crete, Greece (Photo made in 2015, Public Domain)

According to Shaw, only grids made by vertical and horizontal lines are 'the true artist's grid' (Shaw 2010: 318, note 10). She sharply distinguishes such grids from the ones that go diagonally, correspond to the pattern repeat (Shaw 2016: 194), and are applied to the depiction of wall-hangings.[32]

But why did the painter depict the textile pattern, that is usually always stretched and squeezed by the body, in such an unrealistic way? Why did they aim at this high pattern precision? Such minutely constructed patterns, when presented flat and not depicted as bending through the body of the wearer, are even irritating for the eye and claim an attention that works against the overall composition; perfection in textile pattern geometry does not appear as realistic or natural, but stands out: 'The visual effect of this room must have been stunning', says Murray (Murray 2016: 55). There are reasons to assume that this was exactly the aim of the artist.

Rodenwaldt avers that the rooms in which the patterns were discovered 'must have had a very special meaning. However, any further clue is missing to determine more precisely what this meaning was, whether we have to recognise a room of similar purpose as the smaller Tirynther Megaron or perhaps the chapel of the palace' (Rodenwaldt 1919: 106; my translation). Shaw and Murray also point to such a cultic meaning of the rooms where artist's grids are employed to depict textiles:

> In cases where a sufficient amount of a fresco composition is preserved to suggest a context, scenes in which elaborately patterned textiles or decorated garments are worn often have a ritual context, as they depict richly dressed goddesses, priestesses, or other ministrants engaged in activities of epiphany, adoration, offering, or initiation. (Murray 2016: 44; see also Shaw 2010: 316)

However, the fact that elaborate patterns may indicate a cultic meaning is not considered in the discussion of the textiles that are denoted as 'examples of luxury clothing', 'haute couture', 'striking fashions', or 'extravagant textiles 'and thus considered part of a luxury discourse and not as part of major social, political or religious events (see Murray 2016: 44, 46, 47, and 516) like the Panathenaic festival or the funeral of Penelope's father-in-law, Laertes.

ON THE FORM OF THE COSMOS: WEAVING AS COSMIC MODE OF BEING?

Let us go back to the trousers of Paris to get a better understanding of the perception of textile patterns in ancient times. In a satyr play of Euripides, Helen's head was turned by the prince's trousers:

> She saw the parti-colored breeches on the man's legs and the gold necklace around his neck and went all aflutter after them, leaving behind that fine little man Menelaus[33]

What is of interest here is the problem of understanding the core term *poikilos* within the phrase *tous thylákous tous poikílous* (τοὺς θυλάκους τοὺς ποικίλους) as expressing the specific attraction and seductive power of the patterned textile, badly translated as 'parti-colored' (or 'embroidered breeches' by Coleridge[34]). Adeline Grand-Clément, in trying to get to the specific meaning of this term and the pattern it denotes, describes the *poikilia* pattern effect as 'an entrapment of the eye caused by the interplay of chromatic contrasts animating the patterns' (Grand-Clément 2015: 413). Such effects appear especially when ornaments show strict symmetries and strong colour contrasts.

> This visual trick is what gives the observer an impression of animation, what intrigues and fascinates him. The captive gaze tries to unravel the mathematical and geometrical rules of the design's construction. But the search is endless … (Grand-Clément 2015: 412).

Grand-Clément, referring to Alfred Gell's discussion of the 'technology of enchantment', states that the attraction is a result of the aim to unravel the secret of its production, as the viewer knows well that there is order and rule behind the complexity.[35] In the case of depicted textiles, this attraction is indeed stronger: even when we understand the geometric transfer by the painter, we still do not know how the real fabric pattern was composed. Grand-Clément summarises thus:

> [T]he *poikilia* are the result of perfectly mastered craftsmanship, based on the inlaying and juxtaposition of varied materials, the organizing of patterns, or the meshing of colored threads. *Poikilia* thus refers to several techniques that share a common objective: to obtain a varied, glistening, and durable radiance – that is, to turn out what the Greeks called *agalmata*, valuables fit to delight the gods and men (Grand-Clément 2015: 410).

I suggest that this is what the precise pattern depictions in the ritual spaces are meant to achieve: they seem to illustrate a cosmic order that is best represented by textiles.[36] However, this representation of order is not achieved by a sort of depiction like in the cosmic textiles, mentioned for example by Plutarch, Euripides or Pherecydes, that depict golden stars, the moon or the signs of the zodiac.[37] What the term *poikillô* emphasises is the technical mode of generation: the elements that are combined do not actually merge. Grand-Clément quotes an observation made by Anne Wersinger that: 'the effect is not one of mixing that would immediately neutralize the diversity but rather one of juxtaposition, as for weaving with coloured thread, to which the painters' brushstrokes or the mosaic tesserae correspond'.[38] This is said to be characteristic of Archaic aesthetics and implies order, beauty and harmony, concepts that come together in the term *kosmos* (Grand-Clément 2015: 410). As for the production/construction of *poikilia*, Grand-Clément states that, 'it lies in bringing heterogeneous elements together, as a unified whole, while they retain their own nature and keep interacting in a dynamic fashion.' (Grand-Clément 2015: 415)

The decisive point in this description is the mode of blending that is typical for textiles: not a homogenous physical mixture[39] but a sort of optical mixture that Democritus is said to have described first.[40] Alexander of Aphrodisias writes:

> Democritus, then, thinks that what is termed blending occurs by juxtaposition of bodies, with the constituents being divided into corpuscules and forming themselves into a mixture by their positioning beside one another; he says that they are not at all blended in reality, but that the apparent blend is a juxtaposition of bodies with one another where each preserves in corpuscular form its own nature, which they had even before the mixture. These

> bodies seem to be blended since perception is unable to grasp a single one of them because of the minuteness of the juxtaposed bodies. A lover of truth and a philosopher, he did not shrink from stating the consequence for those who say that blends occur in this way.[41]

In the *Metamorphoses*, Ovid describes how the famous weaver Arachne employs this type of mixing colours for weaving. He compares it with the rainbow, in which a thousand colours seem to shine.[42] Grand-Clément quotes the fragments of Pherecydes, one of the earliest (if not the earliest) prose texts in Greek literature, dealing with cosmological questions, as an example of the meaning of *poikillô* as cosmogonic activity. Here, cosmic order indeed comes into existence as a fabric on a loom.[43] The order of the world is generated by Zas as a weave that shows not only the signs of the zodiac, but also *ôkeanos*, the river that surrounds the world like the meander surrounds a cloak. The fragment says: 'And on the third day of the wedding Zas makes a great and fair cloth and on it he decorates (*poikillei*) Ge and Ogenos and the halls of Ogenos …' (Kirk/Raven/Schofield 1983: 61)

As before, the word *poikillei* in the original fragment is translated as decoration and therefore alludes to a hylemorphic scheme where the fabric is made first and then decorated by some sort of surface design. Robert Eisler, investigating the motif of the cosmic mantle,[44] argues that, 'Because weaving is a uniform type of work that gives no room for creative freedom, the greater magic of δαιδάλεον ποίκιλμα [*daidaleon poikilma*], the figure building multicoloured embroidery, needs to be added.' (Eisler 1910: 248; my translation)

We are back, again, among the representatives of the primacy of form putting forward the prejudice of the simplicity of weaving that calls for additional techniques of surface design. Instead, in the term *poikilos* as we can reconstruct it from the sources with respect to textile technology, we see nature, craft and mathematics intertwined. Although the order of the pattern is mostly addressed as geometric, the importance of the concept of mixture without blending points to a calculated order by composition that, as in the Pythagorean idea of the cosmos,[45] depends on the arithmetical relation of elements that do not change in themselves but, when put into relation, generate a third instance by in(ter)ference. While the result of merging two different fluids cannot usually be reversed, the *poikilos* mixture of weaving can be undone and presents a view where one can still tell apart each element, just by looking close enough to detect where elements shift in and out – as Ingold did in the case of the Navajo blanket; when writing the chapter *Traces, Threads and Surfaces* for his book on *Lines* Ingold gives an account of his looking at a blanket made by a Navajo weaver:

> What is most striking about the Navajo blanket, however, is that, while the colored designs on its surface are strongly linear, these lines are not themselves threads. Nor are they really traces. Indeed when we look for the line in the blanket, however closely, we find only differences – namely, variations in the colour of the threads, and row-by-row displacements in the locking position of the weft for each colour. We could say that the line on the blanket exists not as a composite of the threads of which it is made, but as an ordered system of differences among them (Ingold 2007: 63–64).

We need to have a closer look at the composition of such patterns.

PATTERNING TEXTILES, OR, FORM AS NUMBER AND SONG

To weave means to order. Nothing messes up more easily than threads, which have a natural tendency to entangle. Because of this predisposition, a huge part of textile art is to prepare the necessary arrangement of threads for work, and to decide on the correct form for transport from one stage of production to the next in order to keep this arrangement. It therefore comes as no surprise that the word 'order' relates to a Latin verb *ordior*, denoting the action of setting up the warp threads on the loom. Let us consider the ancient weavers' practice to understand this specific mode of production.

The most significant difference between present day and ancient weaving is the way in which weaving begins. Fabrics from the warp-weighted loom in use in Greek times (see figure 2.6) employ a starting-border: a band that carries the warp threads for the fabric and later remains attached to it. Due to this border,

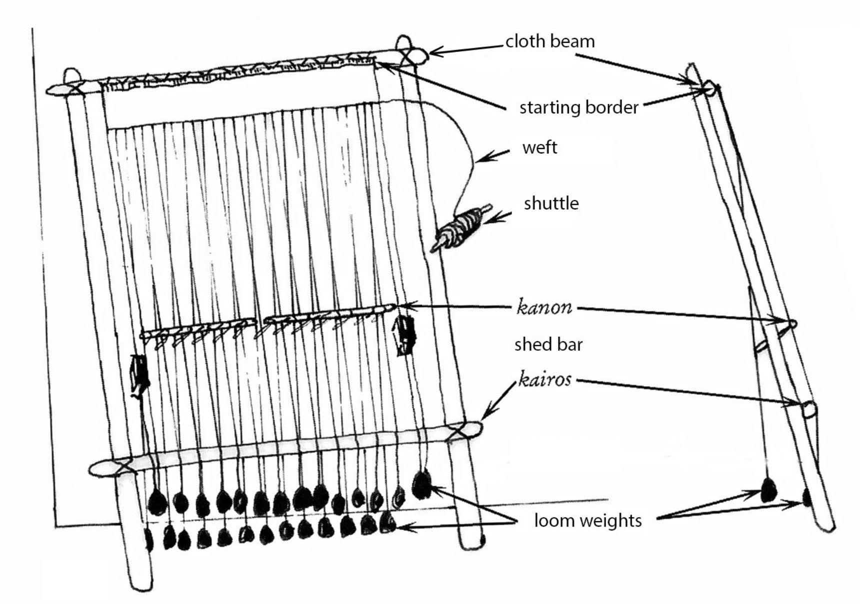


FIG. 2.6 Diagram of warp-weighted loom with side view of natural and artificial shed (drawing by Ellen Harlizius-Klück in 2020)

the warp is not connected to the loom but only to the fabric, and no cut into the warp is required to take the fabric from the loom.

Furthermore, due to this type of beginning, whatever pattern the weaver wants to establish on their fabric needs to fit into the arrangement of threads provided by this pre-woven border. For a pattern like the meander displayed by the famous painter Exekias as a fabric pattern on a funerary plate (figure 2.9, detail on the right) and reconstructed in the PENELOPE laboratory, the number of warp threads needs to be a multiple of the number of threads in the pattern unit (twelve in my example); or to put it another way, the thread-count of the pattern needs to be a factor of the number of warp ends. If this were a prime number, no repeat would ever fit, because a prime has no factors beyond one and itself.

When the weaver sets up her loom, the threads coming from the starting border are distributed evenly across the shed bar or *kaîros*;[46] every thread with even numbers goes behind the bar and the odd ones in front (or vice versa). This provides a natural shed that is always open for inserting the horizontal weft. In order to make the countershed to insert the next weft, all the threads behind the *kaîros* will then be knitted onto a heddle rod (called a *kanôn*) which allows half of the warp to be pulled in front of the other half.[47] Thus *kaîros* and *kanôn* open the shed (void) that allows insertion of the weft and composes the elements to make a fabric.

The weaver starts in front of those perpendicular threads that are kept in order by the starting border and by the weights attached to the lower end of the threads. She then gradually inserts weft threads perpendicular to these lines.[48] The fabric and its patterns are generated by rhythmical and algorithmic picks of selected warp threads. When every second thread is picked up and this system is set off by one in the next row,[49] a tabby is produced: the simplest type of weave. If both thread systems have the same colour, a uniform colour shows on the fabric. When all warp threads are black and the weft threads white, a tiny check pattern shows but the fabric appears grey from a distance. This effect of white and black threads intertwining into optical grey is employed in the case of check patterns that generate squares of three colours from two different thread colours: the third colour is an optical mixture or merge of the other two (figure 2.7) – like the 'grey' in the previous example.[50] When groups of colours,

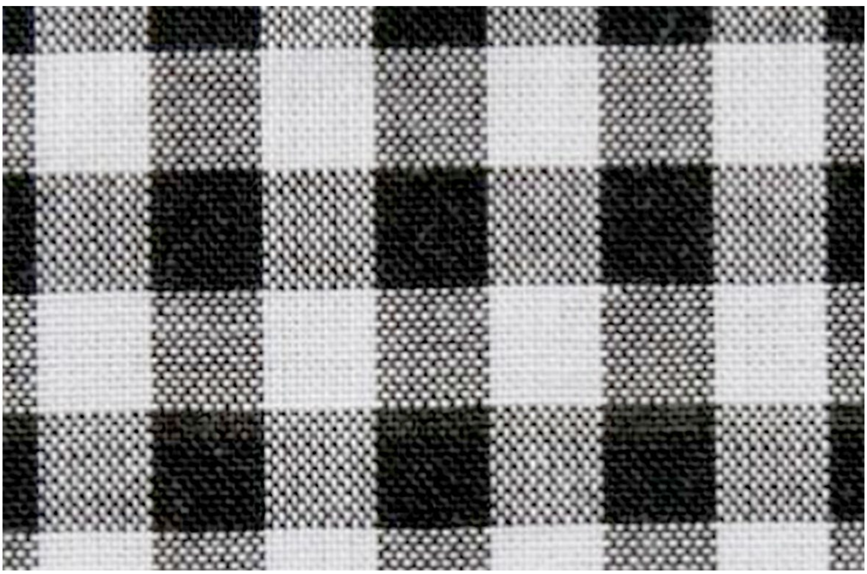


FIG. 2.7 Fabric made by interlacing groups of black and white threads alternating in warp and weft and producing a check pattern (photo by Ellen Harlizius-Klück)

like black and white, alternate in warp and weft direction, there will be a black square where the black threads cross, a white square where white threads cross, and 'grey' squares where black and white threads cross. The number of 'grey' squares equals the sum of black and white squares. All three examples have the same algorithm of weaving, namely just up and down; it is only the change in thread colour that produces the different visual patterns.

Depending on the weave structure, the field of mixed or 'entangled' colour ('grey' in the examples above) can show pattern elements that add up with the plain-coloured parts to a bigger pattern unit and often generate the form of a swastika-like cross. A lot of pattern depictions from Crete, Mycenae and Egypt show such interlock patterns, where the ornament seems to be the result of interlocking forms (see figure 2.8).

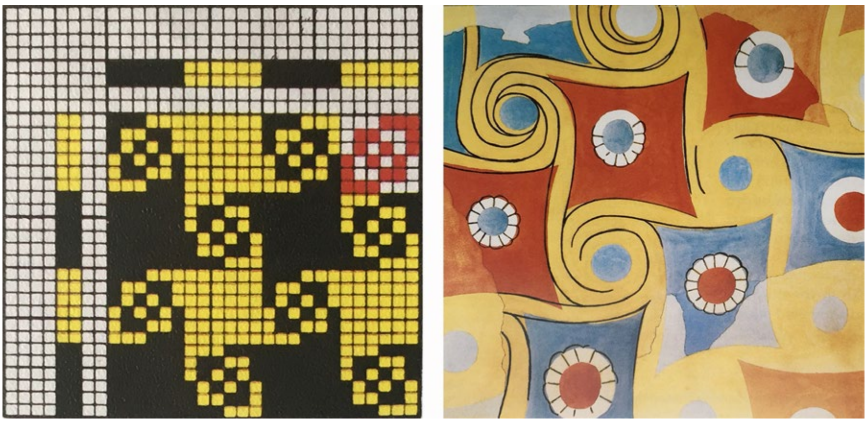


FIG. 2.8 Draft for colour-effect pattern with picking scheme in black and white (hand draft from weaving student, private archive Ellen Harlizius-Klück), and detail of fresco from Knossos (Karetsu 2000: 242)

There are more possibilities to pattern a textile, like inserting a coloured supplementary weft that runs along the whole width of the fabric. Complex weave structures have not been found in ancient Greece so far, and most textile finds show tabby, i.e. the basic up and down structure we know from canvasses, often with higher density of the weft, resulting in hidden warp threads.[51] This also applies to tapestries, where the colour sometimes only runs as far as the motif and thus is closer to the principles of executing forms in drawing or painting than other weaving techniques. To weave geometric patterns in tapestry (like on a Navajo blanket) is not easier or more difficult than, for example, weaving birds or fishes, horses or human beings. The freedom here is not a result of the freedom of depicting a shape or a form being filled, but of stacking layers of zigzagging weft threads that finally present a visible result: a form or an image.

But aside from tapestry and similar techniques, patterns in weaving, including floral motifs, are subject to technical constraints and rules that contradict the hylemorphic concept of design where one proceeds from drafting a motif to its execution. The meander, for example, escapes the idea that all geometric pottery paintings are *based* on geometry, because an elementary geometric construction is not at hand. Schweitzer, having explained why ornaments on geometric vases were independent of technical origins, was nevertheless forced to conclude that, 'The prehistory of the meander in the 10th century can probably not be explained without the hypothesis of a textile origin.'[52]

Likewise, Elisabeth Barber argues for a textile origin of the meander, in this case based on her own weaving experiments. When trying to weave the spiral ornament frequently encountered in Greek art, she tried as many techniques as possible, and finally realised that most of them force the weaver to create angular spirals and thus meanders. The technique that worked best was double weave, whereas the running spiral was easiest to weave with a supplementary weft (Barber 1991: 370, Note 10).

Based on practical experiments, I explored variations of the weaving techniques described above – known as colour-and-weave effect patterning – to achieve an all over meander pattern as depicted on a funerary plaque by Exekias (5th century BCE). Figure 2.9 presents the respective fragment on the right-hand side, the motif that is repeated in the middle, and the instruction for lifting the warp threads to the left. Juxtaposed like this, the difference to usual sketching techniques in art is obvious and the difficulty in understanding the process lies open: How could a non-weaver understand how the labyrinthine outcome, the meander, arises from such an instruction (the red-white scheme of lifting threads to the left) that does not present any maze-like feature?

What happens is that the red-white binary scheme is executed as an algorithm on two systems of continuous threads, vertical warp and horizontal weft,

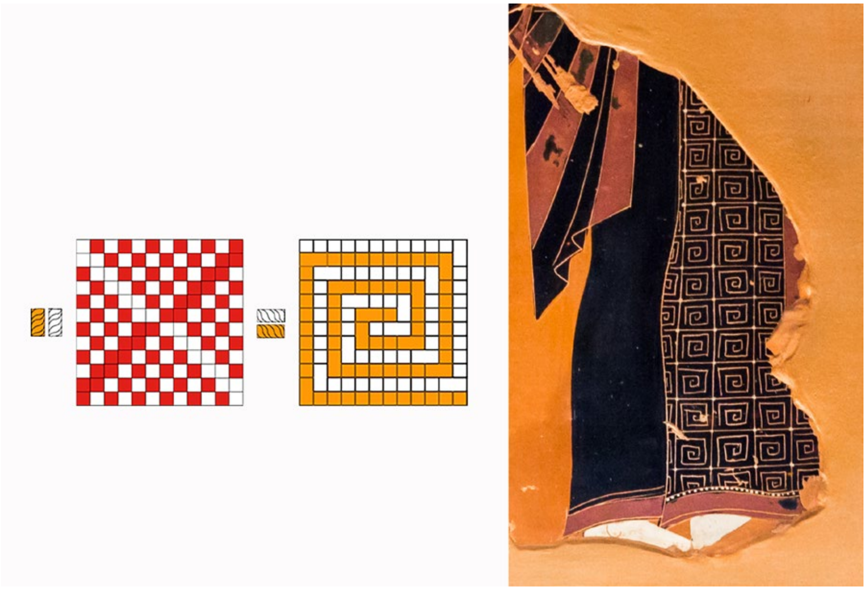


FIG. 2.9 Left: draft, or instruction scheme for lifting warp-threads (part of patron or draft); centre: sketch of result; right: fragment of funerary plate by Exekias. Diagram by Ellen Harlizius-Klück

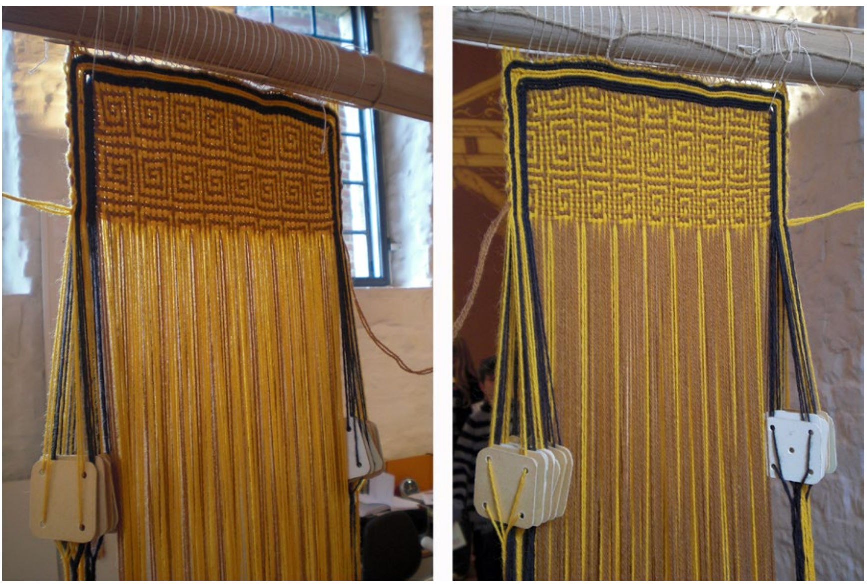


FIG. 2.10 Meander fabric reconstructed by Ellen Harlizius-Klück on the warp-weighed loom, recto and verso side. Photo by Ellen Harlizius-Klück in 2009

in alternating colours of ochre and white. However, the relation between binary action and outcome remains unpredictable for non-weavers.

Such drafts are not known from ancient times and are associated with modern looms with shafts and treadles. Still, they can help to understand the principles of patterning that every weaver has to follow, especially because they show the pattern as a result of two interfering structures. These structures are, first, the system of crossings denoted as a binary grid of red or white squares indicating the up and down of the warp (that we refer to as 'binding' or 'weave', and that are of many kinds) and, second, the arrangement of threads of specific colour that make the meander motif appear to the eyes of beholders. It is this stunning generation process, zigzagging across the loom by following a binary logic imposed on two independent systems (thread order and colour order) that I address as histomorphism: a scheme of composition indicating how a form (*morphê*) is produced in a weave (*histos*) or on a loom (*histos*).

Within the rival concept of hylemorphism, the squared spiral of the meander would be the initial form in the mind of the weaver, being only then imposed on the fabric as its material. This would only work as a concept for embroidery or painting on textiles where the form we see indicates the movement that the hand of the craftsperson has to follow. The line of the woven meander, however, is not such a trace of a movement.

Armed with some insight into the complexity that the weaver needs to master when s/he generates a pattern emerging from structured elements, we can now see why the hylemorphic scheme fails for understanding the genesis of patterns. Aristotle, to whom Simondon and Ingold refer as the origin of the hylemorphic scheme,[53] did not aim to establish a theory of making, but to reject the ideas of atomists like Democritus, for whom change is a rearrangement of tiny material elements (atoms or *stoicheia*). Both Plato and Aristotle discarded such concepts as materialistic, a qualification that did not exist in Pre-Socratic times. The opposition of materialism and idealism, which we saw already as a driving and splitting force in the discussion of textiles as origin of art, does not only refer to the question of what reality really consists in, but also how it originated. To atomists like Leucippus and Democritus, all that exists is an entanglement of matter and void. To speak of matter as an entanglement of elements is opposed to the idea that matter is a continuous substance capable of taking many forms.

It is here that the similarity of the rejected atomism to the construction of fabrics by weaving is most striking. We can easily read the claims of the atomists as saying: all that exists is an entanglement of elements or threads (matter) with interstitches: the void opened by *kaîros* and *kanôn* allows the filaments to compose a three-dimensional structure. The ordered arrangement of discrete elements, namely the threads, is also what generates optical mixtures of colour in a fabric: not a merging of different colours as in painting, but a particular mixture where each component retains its nature, and the optical effect is the result of a pattern, its emergence on the fabric collapsing the distinction between form (design) and material that nevertheless persists in the perception of the pattern as (fictive) 'form'. The interaction of connection and separation with the alternation of order and position as we see it in the histomorphic principle precisely reflects how Democritus, quoted (and rejected) by Aristotle, describes the generation of colour 'by virtue of turning' as understood by the atomists:

> But Democritus and Leucippus, by positing shapes (*ta schemata*), explain alteration and generation on the basis of these: generation and destruction by dissociation (*diakrisis*) and association (*sunkrisis*), alteration by order and position. [...] And that is why he [Democritus] says that colour does not exist: for coloration happens by virtue of turning (*tropê gar chrōmatizesthai*).[54]

Aristotle's concept of hylemorphism deserves a detailed analysis which we cannot deliver here.[55] It seems that the current idea of hylemorphism is a misrepresentation of his initial notion, which does not refer to man-made objects at all. His scheme is clearly brought up against atomistic ideas that were gaining popularity in Aristotle's times. Considering the frequent use that atomists make of textile and weaving terms for explaining how elements organise into bigger wholes, it is no surprise that any rejection of atomism also affects the concept of weaving that travels with those theories of cosmic order and their textile terms and concepts. A glimpse of this important role of weaving as a mediator of atomistic principles is perceivable when the late atomist Lucretius, who frequently employs weaving metaphors, feels obliged to claim that weaving originates from male hands in concert with the invention of iron. In his view, weaving was only later passed to female hands because male hands had more important things to do.[56]

. . .

As this chapter has demonstrated, the operation of pattern weaving itself does not employ geometry, but rather arithmetic, even when the fabric shows squares and triangles. When we see a geometric form on a woven fabric, a weaver who wants to imitate such a pattern does not need knowledge of geometry. Instead, s/he needs to identify (1) the technique (weaving, plaiting, double weave, supplementary weft etc.), (2) the colours of the threads (not the colours of the pattern!) and (3) the distribution and the relation or ratio of numbers/bundles of the coloured threads. Concerning the numbers, it is not so much their amount that is important but rather the relation, ratio or proportion contained in the pattern. This ratio was called *logos* in antiquity and points to 'the group or bundle of numbers that are contained in a thing and by which this thing can be described as well as reproduced.'[57] A traditional weaver from Afghanistan, asked how she translates an image into patterns, responded: 'I don't see it as a picture. I see it as numbers and I make it a song.'[58]

The woven order best explains the atomistic concept of mixture without blending, a calculated order that, as in the Pythagorean idea of numbers constituting the cosmos,[59] depends on the arithmetical relation of elements that do not change in themselves but generate a third instance by a sort of interference. Such a process of generation (here described as histomorphism) where the weaver, as *Homo textor*, is capable of ordering elements into balanced structures bearing forms as emergent compositions of entanglements, can indeed function as a cosmogonic principle and extend to elements in nature, like the scales of a snake or the cross-breeding of plants, or extend to elements of social communities, like husband and wife or citizens and guests, and their relation.

With regard to the question of what it is that travels with the technical mode of weaving, neither the poetic answer given by the weaver from Afghanistan nor the concept of histomorphism presented here are easily accessible for non-weavers.

One can argue that people in antiquity knew the technology well enough to understand how it orchestrates all those seemingly diverse ideas like number, rhythm, entanglement, colour mixture or the quality of being *poikillô*. Changes in the loom during history, especially when they constrain the possibilities of the weaver in orchestrating the entanglement at the loom, make this work appear to be labour only. These changes will finally make the transfer of the technical mode inaccessible and turn textile terminology into mere metaphor.

ENDNOTES

1 The phrase 'technical mode of existence' goes back to Gilbert Simondon (2017), who takes up a concept presented by Etienne Souriau (2015, 1943), related to modes of things like being tough, tender, imaginary, virtual and so on. Bruno Latour in his *Inquiry* refers to both Souriau and Simondon in building up a network of such modes including technology, religion, fiction and reference. In this chapter, I loosely refer to Simondon and Latour (2013). To determine exactly how the technical mode of weaving relates to those endeavors would require a longer philosophical investigation.

2 Homer, *Odyssey* 2.85–2.105, see also chapter 1 'Introducing *Homo textor*', of this book.

3 Our contemporary term 'design' derives from It. *disegno*, in which art history has its own notion of hylemorphism: of an idea applied to matter. *Disegno* is one of the major concepts of the Renaissance theory of art, where it means both design and project, outline and intention, idea in the speculative sense as well as in the sense of invention (Cassin et al. 2014: 224). Where this concept of art-making rules, textile ornaments are conceived of as a design on a sort of canvas, a material surface on which an idea takes form by painting, printing, drawing or embroidery.

4 More common in areas like Bolivia, Guatemala, India, Indonesia for example, but also still alive as craft in the United States and Europe.

5 The development of looms instead has advantages for designers who begin with an idea or form, since looms increase the possibilities for drafting methods that are not concerned with the technical details of fabric construction.

6 For a recent discussion, including an overview of former explanations of the beginning of science, see Makarov 2023; see also Snell 1982 (1953).

7 Pherecydes of Syros was born around 584–581 BCE. Further details of his life are unknown.

8 However, when Vernant refers to the work of Pherecydes, he resumes: 'The myth does not ask how an ordered world could arise out of chaos…' (Vernant 1982: 113). Indeed, Vernant in his investigation focuses on the seemingly typical techno-materials iron, stone and wood. His accounts of economic transformations (71–72), lists of traded products (72), and of transformations in the areas of agriculture and craft (73) illustrate a fundamental neglect of textiles: wool, flax, clothes and textile production are absent from these accounts.

9 Simondon explicates this opposition of atomism and hylemorphism in his thesis (Simondon 1995: 21–22).

10 In the meaning those terms have in Latour's *Inquiry*, especially 2013: chapter 9, 233–57.

11 For the relation of metaphor and technology, as well as nature and culture, as presented in the ancient term *technê* see Harlizius-Klück and Fanfani (2016): 62–64. See also Blumenberg (2015); Schadewaldt (2014) makes a strong case for the peculiar kind of integration between nature, te*chnê* and culture in Archaic Greek thought by exploring the terms/concepts *physis* and *technê*.

12 The concept of a technical mode of existence as introduced by Simondon was meant as an alternative to the idea of hylemorphism that reduces the process of making to the execution of an idea in matter. Into this bilateral but monodirectional concept, Simondon introduces energy as an important condition (Simondon 1995: 43–44) while Tim Ingold, who was the first to describe the process of making as a modality of weaving, aims to establish a field of forces (Ingold 2010: 91–92, 97, 100) as a condition of making, especially in art and craft.

13 Fischbach 1883: VII. My translation.

14 See 'In the beginning was the word …' *John* 1.1.

15 Riegl 1985: 20. Similarly, the art critic George Kubler refers to the individual who creates art as an artisan with a calling: he 'belongs to a distinct human grouping as *homo faber*, whose calling is to evoke a perpetual renewal of form in matter' (Kubler 1962: 10).

16 Riegl 1985. On the history of the beginning of art history, see Vasold 2015.

17 Semper's claim was taken up by two exhibitions in the year 2013 in Germany. *Textiles Open Letter* in Mönchengladbach aimed at presenting a comprehensive reconsideration of the textile medium (Frank and Watson 2015). *Kunst & Textil* in Wolfsburg promised to present textile patterns and structures as a new paradigm for the development of art (Arlt 2014). Both approaches have been criticised by Regine Prange (2015) as the 'Renaissance of the carpet-paradigm' a term borrowed from Joseph Masheck who takes the carpet as a flat, patterned surface directed against the Renaissance ideal of the painting as window on to the world (Masheck 2010). The Department for Art History and Visual Studies of the University of Lund announced in 2012 a publication entitled 'Reconsidering the Carpet Paradigm'. This was published in 2014 as a special issue of the *Konsthistorisk Tidskrift* (3/83) and explicitly referred to Masheck's concept as an attempt at a new foundation of modern art and art theory.

18 The term 'grammar' in this discussion points to the famous and influential *Grammar of Ornament*, published by Owen Jones in 1856.

19 Schweitzer 1969: 28; my translation. Indeed, the Greek word *kosmos* has a wide range of meanings that are difficult for us today to hold together: it can refer to patterned textiles and elaborate bracelets as well as to the order of the stars or of patterns in nature.

20 Germany as a nation state did not even exist. The Prussia-led confederation of northern German regions turned into the German Empire only in 1871.

21 The term could be translated as 'men of letters.' It was used in the late nineteenth and early twentieth centuries to denote what we today would call 'intellectuals.'

22 'Wenn die Lehren des Materialismus in der modernen Gesellschaft zur Herrschaft kommen würden, so würde etwas Aehnliches mit ihr geschehen, wie wenn aus dem Himmel jene geheimnisvolle Kraft verschwinden würde, durch welche die Planeten and die Sonne gebunden sind und ihre Elemente in ihrem Mittelpunkt zusammengefaßt werden'. Haffner 1865: 3–4.

23 Vasold, who concentrates his account of the discussion of Semper's idea on Riegl and Vienna (Austria), does not mention this background. Vasold 2015.

24 There is some confusion about the date of the essay. Probably written in late 1909, it was first published in French in 1913, but the usual publication date is rendered as 1908. See Long 2009.

25 On concepts of order in antiquity and their connection to specific properties of the warp-weighted loom see Harlizius-Klück and Fanfani 2016. For a more detailed analysis of the arithmetical parts of Euclid's elements and their possible relation to ancient patterns and their calculation see Fanfani and Harlizius-Klück, forthcoming.

26 … as later claimed by modern artists like Paul Klee in 'Beiträge zur Bildnerischen Formlehre': the pictorial form in general begins with the point that sets itself in motion and creates a line, see http://www.kleegestaltungslehre.zpk.org/ee/ZPK/BF/ pages 5–6.

27 The most famous demonstration of the use of a grid of threads for constructing perspective is Albrecht Dürer's woodcut depicting the drawing of a woman. *Instruction on Measurement* from 1525.

28 See Drinkler 2009. The team around Brinkmann did not ask for a possible textile construction of the original fabric (apart from some knitting experiments for publicity). Drinkler is textile conservator at the Bayerisches Nationalmuseum and felt challenged by this neglect. She made an example of a textile reconstruction of the trousers in a braiding technique called 'sprang'. Her reconstruction has two colours instead of the five assumed by Brinkmann and his team. Indeed, the available data point to no more than two colours. (Oral information provided by the conservator of the State

Collections of Antiquities, Catharina Blänsdorf, during an interview at the Deutsches Museum, Munich on 22 February 2018).

29 See Brinkmann and Wünsche 2003: 23–30 for the development of the rectangular grid. The authors claim that this grid is an indispensable condition for both the original painting and the reconstruction (23). They give no reason why the grid needs to be rectangular. In fact, the grid-like structure of the textiles probably supported the transfer of form as a discretisation tool before geometry.

30 Murray 2016: 50. Maria Shaw, investigating a fragment of plaster in Pseira, Crete, says that a thin thread is stretched and snapped against the wet plaster where it leaves an impression. See Shaw 2010: 315, note 3; see also Lang 1969: 10 and 11.

31 University Library Heidelberg, https://doi.org/10.11588/diglit.44573#0125 (accessed 9 November 2023).

32 It remains unclear why this distinction should be important as it does not make any difference for the rest of her investigation. In this context it is interesting to see that Shaw, in order to represent the pattern on the skirt of the goddess from the royal villa of Ayia Triada, rotates the drawing by 45° so that the formerly oblique grid becomes a perpendicular one. Obviously, she assumes that the pattern was rotated for depiction and speaks of an 'obliquely placed pattern' (Shaw 2016: 191). As a result, the grid now belongs to her category of artist's grids (and no longer to the repeating patterns) and can be treated in the respective section (see Shaw 2016: 189–198).

33 Euripides, *Cyclops*, 182–85; after Kovacs, http://data.perseus.org/citations/urn:cts:greekLit:tlg0006.tlg001.perseus-eng1:175–202.

34 Euripides, *Cyclops*, 182–85; after Coleridge, http://classics.mit.edu/Euripides/cyclops.html.

35 See Grand-Clément 2015: 413; Gell 1992.

36 There are icons in the orthodox church where the patterns of the clothes of the presented saints are depicted in just the same flat manner. Looking at the icon, the viewer or person in devotion is mesmerised as by a picture puzzle.

37 Plutarch describes the cosmic mantle of Demetrius Poliorketes (Plut. *Dem*. 41.4); Euripides describes the tent of Xerxes (Eurip. *Ion* 1143); Pherecydes presents Zas/Zeus as weaving a fabric for Ge/Gaia (Kirk/Raven/Schofield 1983: 61).

38 Wersinger 2001: 38; quoted after Grand-Clément 2015: 409.

39 Aristotle, *peri geneseôs kai phthoras,* 328a. On the problem of mixing colours see Gage 1993: 30–32.

40 Gage 1993: 31. The idea of a mixture as an interlacement of elements that do not lose their properties when mixed, is the reason why Plato says the statesman should be a weaver who weaves the brave and the tempered citizens as strong warp and soft weft together to achieve a harmonic state (*Politikos* 311c).

41 Alexander of Aphrodisias, *On Mixture and Growth*, 214.18, after Todd 1976: 111.

42 Ovid, *Metamorphoses*, 6.61–67. See also Harich-Schwarzbauer 2016: 150–56.
43 See Grand-Clément 2015: 408. On the interpretation of the fragments of Pherecydes and weaving as comogenesis see Harlizius-Klück 2004: 155–64.
44 The idea of the heaven or cosmos as weave or mantle recurs through ancient times. Euripides presents the priest *Ion* setting up a tent consisting of fabrics with cosmic motifs (Euripides, *Ion*, 1143–58), Plato presents the idea of a band, keeping the cosmos together (*Politeia*, X, 616c). The statue of the Roman Emperor Trajan wears a mantle with rosettes meant as stars (Brinkmann 2003: 121–215).
45 For a detailed investigation of the Pythagorean idea of numbers constituting order in the cosmos, see Harlizius-Klück and Fanfani, forthcoming.
46 For the meanings of the word *kaîros* see Fanfani, Chapter 4.
47 It is important to be aware that the 'halves' of the warp distribute across the whole width of the loom. There is no split in the middle.
48 There is no focusing on the right angle between warp and weft while weaving, contrary to the suggestion by Richard Sennett (2008: 278). Instead, because the weft needs to go up and down along the warp, the inserted thread needs to be longer than the fabric width, and it needs leeway to pass into the third dimension. Therefore, it is either inlaid diagonally or in the form of a curve.
49 This is the rhythm considered from the perspective of the one picking. Thought along the perspective of the thread itself, there is a constant up-down rhythm that extends beyond the borders and turning points of the weft: a stable double zigzag.
50 A checked pattern, a Madras or Tartan, is a simple colour effect pattern. Variants that are more complex are shepherd's check or Glencheck and similar patterns that are the result of an interference of structure and colour that is not easy to understand for laymen. A true checkerboard pattern is impossible to weave in simple tabby. It affords complex weave structures like double cloth or Taqueté.
51 Spantidaki writes: 'Every extant textile dated from the seventeenth century BCE up to the tapestry of Vergina in the fourth century BC is a tabby' (Spantidaki 2016: 55).
52 Schweitzer 1996: 31; my translation. Schweitzer refers to the 10th century BCE.
53 Simondon 2017: 184; Ingold 2010: 92. However, without detailed reference. The main source for the concept is Aristotle, *Physics* i 7, but several other works refer to the same idea.
54 Aristotle's *On Generation and Corruption*, 315a34–b9 and 315b33–316a2. I thank Giovanni Fanfani for pointing me to this source.
55 For a detailed discussion see Kelsey 2010; see also Fratzl et al. 2021: 7.
56 'Clothing made from materials tied together / came before woven garments, woven clothes / came after iron, for cloth is made with iron – / that is the only way men can turn out / such fine, smooth heddles and spindles, shuttles, / and rattling yard-beams. Nature forced the males / to work with the wool before the females, /

for the male sex far excels in skill and is / much more inventive, until tough farmers / scorned weaving, and then the men were willing / to let the women do that kind of work / and to share equally among themselves / in hard labour, strengthening hands and limbs / with heavy tasks.' Lucretius, *De Rerum Natura / On the Nature of Things*, V.1350–60. Lucretius is a Roman author who lived in the first century BCE while the Greek atomists, of whom we only have fragmentary texts, were active in the second half of the fifth century BCE.

57 See von Fritz 1971: 83. For a more detailed investigation of numbers and weaving in Archaic Greece see Fanfani and Harlizius-Klück, forthcoming.

58 Postrel 2020: 84. See also chapter Five by Anthony Tuck et al.

59 For a detailed investigation of the Pythagorean idea of numbers constituting order in the cosmos, see Harlizius-Klück and Fanfani, forthcoming.

REFERENCES

Arlt, P., 'Ikonologie der Textilmuster in der Kunst', *Ossietzky: Zweiwochenschrift für Politik / Kultur / Wirtschaft* 3 (2014). http://www.ossietzky.net/3-2014&textfile=2559 (accessed 3 January 2021).

Barber, E. J. W., *Prehistoric Textiles: The Development of Cloth in the Neolithic and Bronze Ages* (Princeton: Princeton University Press, 1991).

Beck, H., 'State and Society in Pre-March Prussia: The Weavers' Uprising, the Bureaucracy, and the Association for the Welfare of Workers', *Central European History*, 25.3 (1992): 303–31.

Blumenberg, H., *Schriften zur Technik*, ed. by A. Schmitz and B. Stiegler (Frankfurt: Suhrkamp, 2015).

Brinkmann, V., 'Der Prinz und die Göttin: Die wiederentdeckte Farbigkeit der Giebelskulpturen des Aphaia-Tempels', in V. Brinkmann and R. Wünsche, eds, *Bunte Götter: Die Farbigkeit antiker Skulptur* (Munich: Glyptothek, 2003), pp. 84–113.

Brinkmann, V., and U. Koch-Brinkmann, *Der prächtige Prinz* (Munich: Biering & Brinkmann, 2003).

Brinkmann, V. and Wünsche, R., eds, *Bunte Götter: Die Farbigkeit antiker Skulptur*, München: Glyptothek, 2003.

Cassin, B., and others, eds, *Dictionary of Untranslatables: A Philosophical Lexikon* (Princeton: Princeton University Press, 2014) https://www.jstor.org/stable/j.ctt5hhntn (accessed 5 November 2023).

Conze, A., 'Zur Geschichte der Anfänge griechischer Kunst', *Sitzungsberichte der Akademie Wien, philosophisch-historische Klasse* (1870): 505–38.

Drinkler, D., 'Tight-Fitting Clothes in Antiquity: Experimental Reconstruction', *Archaeological Textiles Newsletter* 49 (2009): 11–15.

Eisler, R., *Weltenmantel und Himmelszelt: Religionsgeschichtliche Untersuchungen zur Urgeschichte des antiken Weltbildes*. Vol. I. (München: Beck, 1910).

Fanfani, G., E. Harlizius-Klück, and A. Mamidipudi, 'Anchoring in *tekhnê*. Weaving and Plato's Distinction of Pure and Applied Knowledge', in M. Flohr, S. Mols, and T. Tieleman, eds, *Anchoring Technology in Greco-Roman World* (Leiden: Brill, 2025), pp. 257–283.

Fanfani, G., and E. Harlizius-Klück, 'Pattern Weaving as Knowledge in Early Greek Thought', in R. Hahn, and A. Herda, eds, *Knowledge in Archaic Greece: What Counted as 'Knowledge' Both Before and During the Origins of Philosophy in the 6th century BCE Ionia?* (forthcoming).

Fischbach, F., *Geschichte der Textilkunst nebst Text zu den 160 Tafeln des Werkes Ornamente der Gewebe* (Hanau: Alberti, 1883).

Frank, R., and G. Watson, eds, *Textiles Open Letter* (Vienna: Sternberg, 2015).

von Fritz, K., 'Die APXAI in der griechischen Mathematik', in K. von Fritz, ed., *Grundprobleme der Geschichte der antiken Wissenschaft* (Berlin: de Gruyter, 1971), pp. 334–429.

Fratzl, P., M. Friedman, K. Krauthausen, and W. Schäffner, eds, *Active Materials*, Berlin/Boston: de Gruyter, 2021.

Gage, J., *Color and Culture: Practice and Meaning from Antiquity to Abstraction* (London: Thames and Hudson, 1993).

Gell, A., 'The Technology of Enchantment and the Enchantment of Technology', in J. Coote and A. Shelton, eds., *Anthropology, Arts and Aesthetics* (Oxford: Clarendon Press, 1992), pp. 40–67.

Grand-Clément, A., 'Poikilia', in P. Destrée and P. Murray, eds, *A Companion to Ancient Aesthetics* (Oxford, MA 2015), pp. 406–21.

Haffner, P. L., *Der moderne Materialismus* (Frankfurt: Verlag für Kunst und Wissenschaft: 1865).

Halbherr, F., *Resti dell'età micenea: scoperti ad haghia triada presso phaestos* (Roma: Accademia dei Lincei, 1903).

Harich-Schwarzbauer, H., 'Over the Rainbow'': Arachne und Araneola – Figuren der Transgression', in H. Harich-Schwarzbauer, ed., *Weben und Gewebe in der Antike: Materialität – Repräsentation – Episteme – Metapoetik. Text and Textiles in the Ancient World: Materiality – Representation – Episteme – Metapoetics* (Oxford: Oxbow, 2016), pp. 147–163.

Harlizius-Klück, E., *Weberei als episteme und die Genese der deduktiven Mathematik* (Berlin: Ebersbach, 2004).

Harlizius-Klück, E., and G. Fanfani, '(B)orders in Ancient Weaving and Archaic Greek Poetry', in G. Fanfani, M. Harlow, and M.-L. Nosch, eds, *Spinning Fates and Song of the Loom: The Use of Textiles, Clothing and Cloth Production as*

Metaphor, Symbol and Narrative Device in Greek and Latin Literature (Oxford: Oxbow 2016), pp. 61–99.

Harlizius-Klück, E., and G. Fanfani, 'Weaving the Double Square: An (Im-)material Contribution to early Greek Mathematics', in W. and R. Hahn, eds, *Materia Philosophiae: Material Dimensions of Ancient Philosophy* (Leiden: Brill 2025), pp. 267–309.

Ingold, T., *Making. Anthropology, Archaeology, Art and Architecture* (London and New York: Routledge, 2013).

Ingold, T., *The Perception of the Environment: Essays in Livelihood, Dwelling and Skill* (London and New York: Routledge, 2000).

Ingold, T., *Lines: A Brief History* (London and New York: Routledge, 2007).

Ingold, T., 'The Textility of Making', *Cambridge Journal of Economics,* 34 (2010): 91–102. doi:10.1093/cje/bep042 (accessed 20 November 2023).

Jones, O., *The Grammar of Ornament: A Visual Reference of Form and Colour in Architecture and the Decorative Arts* (Princeton: Princeton University Press, 2016 (1856)).

Kader, I., *Penelope rekonstruiert: Geschichte und Deutung einer Frauenfigur* (Munich: Museum für Abgüsse Klassischer Bildwerke, 2006).

Karetsu, A., ed., *ΚΡΗΤΗ-ΑΙΓΥΠΤΟΣ. Πολιτισμικοί δεσμοί τριών χιλιετιών.* Cataloque Archaeological Museum Heraklion 21 November 1999 – 21 September 2000; (Heraklion: Hellenic Ministry of Culture, 2000).

Kelsey, S., 'Hylomorphism in Aristotle's Physics', *Ancient Philosophy* 30 (2010): 107–24.

Kirk, G. S., J.E. Raven and M. Schofield, eds, *The Presocratic Philosophers* (Cambridge University Press, 1983).

Kubler, G., *The Shape of Time: On the History of Things* (New Haven: Yale University Press, 1962).

Kunstmuseum Wolfsburg, ed., *Kunst & Textil. Stoff als Idee und Material in der Moderne von Klimt bis heute* (Ostfildern 2013).

Lang, M. L., ed., *The Palace of Nestor at Pylos in Western Messenia*, Vol. II: The Frescoes, (Princeton University Press, 1969).

Latour, B., *An Inquiry into Modes of Existence: An Anthropology of the Moderns* (Cambridge MA: Harvard University Press, 2013).

Latour, B., 'Reflections on Etienne Souriau's Les différents modes d'existence', in G. Harman, L. Bryant, and N. Srnicek, eds., *The Speculative Turn: Continental Materialism and Realism* (re.press, 2011), pp. 304–33, https://hal-sciencespo.archives-ouvertes.fr/hal-01054002 (accessed 19 February 224).

Latour, B., 'Drawing Things Together', in M. Lynch and S. Woolgar, eds, *Representation in Scientific Practice* (Cambridge, MA, and London: MIT Press), pp. 19–68.

Long, C., 'The Origins and Context of Adolf Loos's "Ornament and Crime"', *Journal of the Society of Architectural Historians*, 68.2 (June 2009): 200–23. https://www.jstor.org/stable/10.1525/jsah.2009.68.2.200.

Loos, A., *Ornament and Crime* (London: Penguin, 2019).

Makarov, Z., and T. Radzyniak, 'On the Problem of Origin of Science: The Antiquity Context', *Filosofija. Sociologija*, 34.3 (2023): 300–9. https://doi.org/10.6001/fil-soc.2023.34.3.10

Masheck, J., *The Carpet Paradigm: Integral Flatness from Decorative to Fine Art* (New York: Edgewise 2010).

Murray, S. P., 'Patterned Textiles as Costume in Aegean Art', in M. C. Shaw and A. P. Chapin, eds, *Woven Threads: Patterned Textiles of the Aegean Bronze Age* (Oxford & Philadelphia: Oxbow 2016), pp. 43–103.

Postrel, V., *The Fabric of Civilization: How Textiles Made the World* (New York: Basic Books 2020).

Prange, R., 'Die Wiederkehr des Teppichparadigmas: Anmerkungen zur zeitgenössischen „Welt-Kunstgeschichte"', in A. Tietenberg, ed., *Muster im Transfer: Ein Modell transkultureller Verflechtung?* (Cologne and Vienna: Böhlau, 2015), pp. 21–36.

Riegl, A., *Stilfragen: Grundlegungen zu einer Geschichte der Ornamentik* (Darmstadt: Wissenschaftliche Buchgesellschaft, 1985) (Reprint of first edition 1893).

Rodenwaldt, G., 'Mykenische Studien I', *Jahrbuch des Deutschen Archäologischen Instituts* 34 (1919): 87–106.

Schadewaldt, W., 'The Concepts of "Nature" and "Technique" according to the Greeks', in R. Scharff and V. Dusek, eds, *Philosophy of Technology. The Technological Condition: An Anthology* (Hoboken NJ: Wiley-Blackwell, 2014), pp. 25–32.

Schweitzer, Bernhard. *Die geometrische Kunst Griechenlands: Frühe Formenwelt im Zeitalter Homers,* Köln: DuMont Schauberg, 1969.

Semper, G., *Style in the Technical and Tectonic Arts: Or, Practical Aesthetics* (Los Angeles: Getty Publications, 2004).

Semper, G., *Der Stil in den technischen und tektonischen Künsten. Vol. 1: Die Textile Kunst* (Frankfurt: Verlag für Kunst und Wissenschaft, 1860).

Sennett, R., *The Craftsman* (New Haven: Yale University Press, 2008).

Shaw, M. C., 'A Fresco of a Textile Pattern at Pylos: the Importation of a Minoan Artistic Technique', *British School at Athens Studies* 18, Cretan Offerings: Studies in honour of Peter Warren (2010): 315–320.

Shaw, M. C., 'String Lines, the Artist's Grid, and the Representation of Textiles in Fresco', in M. C. Shaw and A. P. Chapin, eds, *Woven Threads: Patterned Textiles of the Aegean Bronze Age* (Oxford & Philadelphia: Oxbow 2016): 183–204.

Shaw, M. C. and Chapin, A. P., eds., *Woven Threads: Patterned Textiles of the Aegean Bronze Age* (Oxford & Philadelphia: Oxbow 2016).

Sigaut, François. 'Die Homo faber-Kontroverse', *Zeitschrift für Kulturwissenschaften* 2 (2018): 17–33.

Simondon, G., *L'individu et sa genèse physico-biologique* (Grenoble: Millon, 1995).

Simondon, G., *On the Mode of Existence of Technical Objects* (Minneapolis: Univocal, 2017).

Snell, B., *The Discovery of the Mind: The Greek Origins of European Thought* (New York: Dover, 1982) (1953).

Souriau, É., *Les différents modes d'existence* (Paris: PUF, 1943).

Souriau, É., *The Different Modes of Existence* (Minneapolis: Univocal Publishing LLC, 2015).

Spantidaki, S., *Textile Production in Classical Athens* (Oxford & Philadelphia: Oxbow, 2016).

Todd, R. B., ed., *Alexander of Aphrodisias on Stoic Physics* (Leiden: Brill, 1976).

Vasold, G., 'Woven Thinking: Textile Art and the Advent of Modern Art Scholarship', in R. Frank and G. Watson, eds, *Textiles Open Letter* (Vienna: Sternberg, 2015), pp. 166–79.

Vernant, J.-P., *The Origins of Greek Thought* (Ithaka and New York: Cornell University Press, 1982).

Wersinger, A. G., *Platon et la dysharmonie: Recherches sur la forme musicale* (Paris: Librairie philosophique, 2001).

3

MERGE, WEAVE, HOUSE, TRAP: FIRST STEPS TOWARDS A REVERSE PALAEOANTHROPOLOGY OF IDENTITY CONCEPTS

Julian Rohrhuber

A PALAEOANTHROPOLOGY OF CONCEPTS

PERHAPS A PALAEOANTHROPOLOGY OF CONCEPTS IS A LOST CAUSE – HOW should we learn, even barely conjecture, how people thought many thousands of years ago, even before they could have left traces of written artefacts? It would be a very narrow understanding of reasoning, however, to reduce thought to language. Nonverbal traces may testify agency and thinking (Gell 1998: 13f), and technology may coordinate practice just as language does (Newen and others 2018). Material conditions determine what is thinkable. But it is not always easy to see how cognition is embedded in material artefacts and bodies. Do concepts exist in other media than language, and may therefore predate language? There are various theories which unfold such an idea (Gamble 2007: 87; Renfrew and Scarre 1998). But even though it is necessary for archaeologists to infer cognitive processes from prehistoric artefacts, a properly synchronic (pre-)historiography is a speculative activity nonetheless.

While no less speculative, this chapter reverses the perspective. Its objective is not to reconstruct palaeolithic thought, but to question contemporary 'primitive' intuitions, which are embodied in low-tech and high-tech in much the same way. Because computers occupy an intersection between formal and material culture, we pay special attention to programming as a field for a 'reverse palaeoanthropology'. Taking intuitions seriously, and taking them as shadows of material practices like weaving or merging, will allow us to displace and open them to alternative readings. Thus, the perspective of this chapter is neither synchronic (suspending the present in favour of the past) nor anachronic (searching for the present in the past), but it follows an ideal of what may be called 'heterochronic description' (doubly offset, both from past and present) (Rohrhuber and Kamensky 2015). If in doubt, we will pretend to have just met, an old palaeolithic philosopher friend and I, and we'll live up to the occasion to embark on a heterochronic analysis of concepts together. We have decided that our focus will be on the concept of identity.

MERGE AND WEAVE

After a sunny day, the heat sleeps in the stone. A cold hand feels warm. The mouth's fog joins the hazy air, just like rain that falls onto the stream, which in turn joins the lake. A yellow and a grey piece of clay completely merge when kneaded together, while the new pale colour still bears the traces of its constituents. Similarly does dough preserve some of the flavours of its ingredients, so that we can taste the sweetness of honey in it as well as the bitterness of powdered seeds. It is in speech that one most distinctly hears the tiredness of the speaker.

While not all, much of matter invites merging. It is a process that can be easily observed and many things can be reasonably explained as being its outcome. It seems to occur naturally where aspects mingle, in breeding plants and animals, in cooking and singing. In painting (body or rock), the contours of the surface and the contours of the pigments may become inseparable in the image. Family resemblances are possible because the related members are mixes. Even if something is identical to itself and carries its identity with it in space and time, we can explain it as a merging of all its aspects with each other, and their merging into locatable permanence. These aspects sometimes stand out from the mixture, making it their backdrop; sometimes they disappear in it, leaving only the assurance that they have entered, not left.

Arising with and engrained in these processes is a particular concept of identity. In many cases, thinking about identity and thinking through identity takes recourse to the explanatory power of merging.

. . .

Without looking back, we jump as far as possible. Another concept of identity is just as credible, but is of a very different character. It arises with the processes of loose combination and gains its stability from the impact of its texture. A trace in sand depends on it. A collection of berries, roots, bones, or branches may gain a collective identity through its amount alone. But moreover, collections may be arranged – they may attain a function through the mutual order of what they bring together. This mutual relation makes up the thing. As we all know, a small house may be built from large bones by interlocking them, a fence from bamboo twigs, hair may be plaited and wattled. Who we are changes depending on whether we walk with our parents, or with a group of friends.

Such identity is not merged into the parts, it is a structural identity that arises from the relations parts have with each other. The identity of a fabric is its pattern, which arises out of an interaction between the materiality of the threads, their mutual tension and order. It is impossible to oversee the variety of possible paths of threads and the placing of members. Again, our reference to weaving is not meant metaphorically, but functionally. Because the constitution of a fabric works the way it does, interweaving becomes a reason for something to be as it is. This type of intuition of identity is predicated upon the explanatory power of weaving.

IDENTITY CONCEPTS IN PROGRAMMING

Merging and weaving are two concepts of identity that have a strong anchor in material culture. Let's reconsider them in programming languages, where materiality is confronted less directly, or in a different way. Our computer programs are an intermediary between a symbolic expression (usually written strings of characters) and a physical process (usually electric currents). Here, what functions as one form of identity in one system may function differently in another. The bit representations and operations are a good example: as electric states, they implement computations on the machine level, but on the level of the programming language, they appear as very different computational entities, such as numbers, symbols, objects and processes. On the one hand, bit patterns are mere constellations of possible states whose identity arises extrinsically from context alone. On the other hand, for a given program, an entity implemented in such a bit pattern is a primitive element. It has properties intrinsically bound to it, irrespective of how it is implemented. But again, at this level in turn, such primitive entities can be used in contexts where nothing counts but their mutual relation, and so on.

Despite this relativity, we find concepts of identity at each level of such a system; they determine the situation at this level; they determine compatibility; and despite differences between languages, it is possible (accepting a bit of distortion) to talk about them quite generally. So let's look at some examples.

The idea of different attributes densely merged in an entity is ubiquitous in computer programming where specific values are at play, and in particular numerical values. Computing enacts number concepts, unrolls and situates them. A test if a number is larger than a limit, a test if a number is divisible by another one, the incrementally growing sum of an account, operations like doubling, tripling, negation. Even though they relate several numbers, these operations tacitly assume a number to have intrinsic properties. And while a name is just a name given through convention, when used to address a value, name and value practically share identity: the only way to have one is to have the other. We found all kinds of strategies for passing values around a system that maintain their connection. Searching a string for a pattern takes this pattern to be an intrinsic attribute of the string. Searching a dataset for certain values takes this dataset to have these values, it owns them as personal property, so to say. Assigning types to variables or values not only stabilises their identity, but also builds on the intrinsic identity of the types themselves. Similarly, internal attributes of objects (such as coordinates in points) identify the object as that which has them, and affiliate it with all those which have similar ones. There are many such ways of identification, which we may generally call intrinsic identifications.

The opposite mode of identification is just as important, however. A number can be just taken for a Boolean truth value, for a letter, an integer for a real, a large number for two smaller numbers; many programming languages reinterpret one datum for one thing or another, dependent on the situation. The same number may play the role both of a counter and an index, for example. More generally, the result of applying an operator depends on its arguments. Even the actual operation behind the operator is often chosen to match the arguments. One function relies on a network of other functions, and even the function call itself may be completely defined in terms of function calls, recursively. Where variables can be reassigned to a new value over the course of the calculation, the variable names are provisional, so that their identity is established only some time later. And of course, a language is interpreted by an algorithm and therefore its meaning depends on it. In such a way, programming languages identify their subject matter extrinsically – a program is woven from elements, insofar as they gain identity only through their relation to and interaction with each other.

DISSOCIATION OF CONCEPTS

The two concepts of identity are as common as they are simple. When considered in the context of contemporary programming, we see how readily they fall into place with the opposition of structure (or form) against essence (or substance) – a historically notorious theme, which became particularly dominant through twentieth-century structuralism. In particular, with the rise of computer science, programming has been treated en par with formal logic, which has helped to cultivate the idea of a purely structural mode of identification – more or less in line with the idea that 'everything is merely zeroes and ones'. And arguably, this move has left a sediment of equally pure essentialist identifications, in line with an idea of a universal horizon of concrete elementary operations or basic elements.

Despite all this, something seems a little forced about the characterisation of purely intrinsic merge and purely extrinsic weave. They combine in ways not compatible with this picture: we find that entities travel around and may claim their changing identities as their own as they enter new constellations. In programming, the subject matter is rarely up to a free combination; not everything is compatible with everything else; there is resistance against recasting of identity. The nomadic is not purely combinatorial. On the other hand, it is not always possible to completely fix identity. As we watch systems grow over time, to provide compatibility, identity has to be contextually negotiated again and again. We encounter tricksters, character changes, double lives. As it seems, the pure merge and the pure weave are particular moments rather than exhaustive concepts.

Again, we use these concepts of identity not as analogies or conventional metaphors, where for instance we would speak of a structure as something 'like a texture', or 'as if woven'. Intuitions are stabilised by situations, which thereby enact a conceptual force. Reconsidering merging and weaving as material practices may help to clarify what is wrong with the use of these concepts as we try to divide and cover a terrain. At least it could be that how the divide between form and substance is usually envisioned limits our understanding, and that taking the intuitions seriously may open a shift in their use.

In the beginning, we saw that to identify something as the result of a merging process is a way of accounting for a differentiated but intrinsic identity. To identify something as a result of weaving is to attribute its identity extrinsically to a mode of interaction. There are implicit assumptions in these two pictures which we can now make explicit. A structure, once put together, can be undone again, recovering the original unrelated elements from the outside. Structures are taken to be somehow loose and reversible. And what has been completely merged cannot be taken apart again, its parts having become essential aspects of the autonomous mixture. It is irreversible. Due to our familiarity with a number of typical material situations in which texture is reversible and mixture is not, we have pairwise identified two dimensions with each other, a time-like and a space-like one.

merge	weave
irreversible + intrinsic	reversible + extrinsic

FIG. 3.1

This identification seems to be a good explanation for the common intuitive understanding of the multiple as loose, light and contingent, and unity as solid, heavy and necessary. Structure is accidental and essence is necessary. As far as a foundational ontology goes, adherents and opponents of the respective paradigm seem to share this intuition. Arguments for intrinsic identity are criticised as dogmatic and eternalist ('conservative'), arguments for extrinsic identity as shallow and opportunist ('liberal'). But all this notwithstanding, we would like to note that reversibility and irreversibility are both dimensions of contingency. This is easy to overlook, so we need to explain what we mean. It is because it is irreversible that one has to accept something as a contingent given: nothing is harder to unravel than a pure coincidence. It determines our situation without accessible reason. But also, the reversible is contingent in the sense that, in order for something to be reversible, it must be possible that it could have been different than it is. So, it has no inherent necessity. Technology fixes rationality in a particular way, so that it works reliably within reason, but this setup is artificial or contingent: it always could have been fixed differently (Deuber-Mankowski 2013).

With this in mind, let's return to the world of artefacts and primitive technologies. Do we know of other practices that constitute a different intuition? Yes, these practices exist and their relevance is easy to see. But first, let's disentangle the two dimensions and make space for an extended concept of identity.

	intrinsic	extrinsic
irreversible	merge	
reversible		weave

FIG. 3.2

THE REVERSIBLY INTRINSIC

This table opens two new fields of enquiry. The first concerns those kinds of identity which are intrinsic, but do not have the irreversibility of a mixture. What are such things, that can carry their identity within themselves, but reversibly so? It helps us to remember that the intuition about the intrinsic-extrinsic distinction has a spatial or at least space-like quality. That is, something is merged, insofar as it shares the very same place, and something is woven, insofar as its parts meet while running past each other. Extrinsic identity is heteronomous. It is secured from the outside of what is identified. Intrinsic identity, by contrast, is insulated from its outside, it is autonomous and stays the same over travel.

So, what is in fact missing in this quadrant seems to be some kind of reversible inclusion, an autonomy that is closed, but can be disassembled. It is easy to see that vessels, covers and containers precisely fulfil this function. A filled vessel or a covered body have autonomy, but can be emptied or uncovered. A mask is such a cover; it is an exemplary technology of exchangeable and temporary identity. Spirits exist as masks, but masks can be taken on and off like any other hat. Perhaps in this group we should also include more diverse artefacts that bestow a specific role to their users. All kinds of instruments have this transformative potential (Gamble 2007; Latour 1999; Schüttpelz 2021). The capacity to enclose is fundamental in the form of bodily, material and social situations (Gell 1998; Strathern 2004). Perhaps the richest technologies of this kind are dwellings like caves, houses and tents. This is why we propose here to use the concept of *house* (as a verb, like merge and weave) to name the concept of identity that is reversibly intrinsic.

Within programming, housing is ubiquitous. Don't we enter a program like a room or a tent? Export data from one, so we can import it to the other? Programs, and their parts, recursively, seem to be internally populated and to be animated from the inside. Many of the cases of intrinsic identification (merge) that we have already touched upon, turn out to be structured like containers as soon as they become mutable. For example, the intrinsic characterisation of an entity like a point by its dimensions becomes reversible when its coordinates can be replaced, or when they can be left unknown until later. Then such an entity becomes hollow, and something else can live in it and inspire its identity. This is why a point object acts like a container of its coordinates.

Or a very different case: deduction is a process that rests on logical 'inclusion', and types can be inferred from other types in such a way. This inclusion is reversible in so far as the types automatically change as the program is rewritten with different presuppositions. More generally, variables have a strong architectural role to play. Not only do variables enclose values, but also there are values that play the role of variables, traveling through a system as a movable indirection. As such objects enter new contexts, their identity stays the same. Pointers or references may pass around the point of access to a specific memory location, for example. Above, we discussed those instruments that bestow identity in use. In programming, we find them as specific operations: operations which may combine with other operations to form new composed operations that subsequently enclose their functionality, like a skilled person and a tool, when joined, that become a professional. From a functional point of view, this modularity is an enclosing. So it is no accident that those structures which keep variables accessible that were accessible in the context where they were defined have been named *closures*.

THE IRREVERSIBLY EXTRINSIC

As it has been so easy to fill the first gap of the reversibly intrinsic, we are looking forward to finding cases for the structural opposite, the irreversibly extrinsic. Again, we have to brush intuition against the fur just a little bit; the usual cases of an extrinsic identity seem to be reversible, if simply for the fact that what is external may be replaced. But just as what is internal may be replaced (e.g. in a container), that which is external may be structured in such a way that it doesn't provide for disassembly. As it happens, in computing, we didn't have to search long for cases of irreversible procedures. Algorithms that have an inverse are indeed very rare, and for a given algorithm the so called 'adjoint code', which reverses it, is difficult to construct (Bennett 1973; Landauer 1961). While in some way closures are containers, which carry with them their enclosed state, this state is usually no longer accessible, and remains irreversibly hidden. Closures function by irreversibility. So a container is often a one-way street. But in what way are these irreversible processes *extrinsic* and not intrinsic?

In fact, extrinsic identity is just as common as its irreversibility. Algorithms, while irreversible, are radically 'generous' (Staal 2007): they are hackable, amenable to be used in ways they were not intended to be used, intentionally or not. Operations are often implemented so as to make them completely dependent on the context in which they are called, or on the arguments passed. In such a way, all the most mundane entities of computing turn out to be of our last kind, identified as irreversibly extrinsic. They cannot be disentangled, but are not self-determined nevertheless. Is the irreversibility of a program part and parcel of its generality or merely the result of our lack of knowledge? At least there is one case where programs function through irreversibility, not despite it. In encryption procedures, identity is completely extrinsic (all that matters is the matching of key and lock), while their trustworthiness is a function of their irreversibility. For the more general case, we will leave open the question whether every rule-based process is reversible in principle.

. . .

A house that identifies irreversibly is a prison. We capture with knots that cannot be undone. Too dense to be reversible, but still extrinsic and structural, the irreversibly extrinsic identification is both a ubiquitous technology and a constant challenge to our alertness, as potential prey and of responsibility, as potential agent. The technology of traps is probably as old as most other technologies, and probably one of the most varied. Traps are models of the prey's body and behaviour, 'lethal parodies of the animal's Umwelt' (Gell 1999: 200–1). But they are also models of the hunter, automata left behind in well hidden places, their prime mover being their first victim. And perhaps nothing is more extrinsic and plainly irreversible than death. But it is too quick a conclusion to be carried away with danger, with the destructive transformation initiated by those traps that kill. The focus on danger may blind us to the numerous traps that we *have to* fall prey to in order to transform, and those we have to set in order to permit transformation. If we look at how traps work, they are a kind of palaeolithic program, a reified future process (Rohrhuber 2008). A trap is a physical prophecy. Hans Blumenberg wrote in his posthumously published manuscripts:

> The trap is an action in absence of the prey, as well as, shifted temporally, of the hunter. The trap acts for the hunter in the moment in which he is absent,

> while the construction of the trap shows the opposite state of affairs. It is expectation that has become a thing. In so far, the trap is the first triumph of the concept. (Blumenberg 2007: 13f, our translation)

Traps function as material concepts because they enable and require us to account for what is absent. They are extrinsic in a temporal sense, and doubly so, because the prey is absent when the hunter is present and vice versa. They are also extrinsic to the prey's cognition. And finally, the close relation between concept and trap alerts us to the irreversible and extrinsic character of the process of learning. In the moment of learning, we cannot know what it is that we will have learned. Once we have understood, it is hard to even imagine why it may have been difficult to decipher. Try and search for some orientation in a seemingly random pattern; before any specific order is detected, the pattern is perceivable in many different ways. Once found, there is no way back. Again, paradise lost. Once we have conceptually understood something, the conditions of experience have become separated from experience. Here we find both function and limitation of concepts condensed: they capture mutually extrinsic aspects, but once in place are hard to escape. We can now be content to have filled in the missing entries of our little diagram.

	intrinsic	extrinsic
irreversible	merge	trap
reversible	house	weave

FIG. 3.3

RECOVERY

This could have been a good ending. After all, we have exhausted the space of possibilities opened by the crossing between the reversible and intrinsic together with their respective opposites, the irreversible and the extrinsic. The bounds of the classical opposition between substance and structure now seem much less severe than expected. And while the conceptual system dissects the intuition of identity, giving way to a much wider space of what is thinkable as identity, it also reframes it in a fresh conceptual trap. Is there anything in the centre of the diagram, or is it absolutely uninhabitable? We've had some serious discussions about this last point.

REFERENCES

Bennett, C. H., 'Logical Reversibility of Computation', *Computer Science*, 17.6 (1973): 525–32.

Blumenberg, H., *Theorie der Unbegrifflichkeit* (Frankfurt/M.: Suhrkamp, 2007).

Deuber-Mankowski, A., 'Der geistige Automat: Das Technische und das Lebendige als Problem einer möglichen Medienphilosophie', in L. Engell, F. Hartmann, and C. Voss, eds, *Körper des Denkens: Neue Positionen in der Medienphilosophie* (Munich: Fink, 2013), pp. 49–68.

Gamble, C., *Origins and Revolutions: Human Identity in Earliest Prehistory* (Cambridge: Cambridge University Press, 2007).

Gell, A., *Art and Agency: An Anthropological Theory* (New York: Oxford University Press, 1998).

Gell, A., 'Vogel's Net', *The Art of Anthropology: Essays and Diagrams* (LSE Monographs on Social Anthropology) (London: Berg Publishers, 1999): 187–214.

Landauer, R., 'Irreversibility and Heat Generation in the Computing Process', *IBM Journal of Research and Development*, 3.5 (1961): 183–91.

Latour, B., *Pandora's Hope* (Cambridge, MA: Harvard University Press, 1999).

Newen, A., L. de Bruin, and S. Gallagher, eds, *The Oxford Handbook of 4E Cognition* (Oxford: Oxford University Press, 2018) (4th ed.).

Renfrew, C., and C. Scarre, eds, *Cognition and Material Culture: The Archaeology of Symbolic Storage* (Oxford: Oxbow, 1998).

Rohrhuber, J., 'Implications of Unfolding', in U. Seifert, J. Hyun Kim, and A. Moore, eds, *Paradoxes of Interactivity: Perspectives for Media Theory, Human-Computer Interaction, and Artistic Investigations* (Bielefeld: Transcript, 2008), pp. 174–91.

Rohrhuber, J., and V. Kamensky, 'Heterochrone Töne: Zur Frage der Historiographie im Dokuentarfilm ALLES WAS WIR HABEN', *Nach dem Film: Audio History* 14 (2015), online: https://www.nachdemfilm.de/index.php/issues/text/heterochrone-toene [accessed 30 October 2023].

Schüttpelz, E., 'Vom Werkzeug zum Behälter, vom Behälter zum Medium: Die Ausweitungen des Körpers', in N. Engelhardt, and J. F. M. Schick, eds, *Erfinden, Schöpfen, Machen* (Bielefeld: Transcript, 2021), pp. 25–72.

Staal, F., 'The Generosity of Artificial Languages.' *IIAS* 44 (2007). Online: https://hdl.handle.net/1887/12527 [accessed 27 October 2023].

Strathern, M., *Partial Connections* (Walnut Creek, Lanham, New York, Toronto, Oxford: AltaMira Press, 2004).

4

LOST IN LEXICOGRAPHY? KAÎROS AS CONCEPT OF ORDER

Giovanni Fanfani

INTRODUCTION

'WORDS SURVIVE BETTER THAN CLOTH' (BARBER 1991: 260): ELIZABETH Barber's introductory motto to her exploration of the Greek terminology for textile technology holds generally true for her purpose of providing a consistent vocabulary for the *chaîne operatoire* of ancient weaving.[1] But what can then be the purpose and scope of reframing the concept of 'word excavation' in cases when, in fact, words do *not* survive in the Greek literary record – and nor do, in terms of archaeological remains and iconographic sources, their material counterparts in weaving technology? My concern here is with the term and concept *kaîros* (καῖρος),[2] unattested as such in the corpus of Archaic, Classical and Hellenistic literature, and only known from the later lexicographical tradition.[3] The lexicographers' accounts, prompted by the occurrence of a few (rather obscure) words apparently derived from *kaîros* in Homer and Callimachus, unambiguously connect the term with the mechanics and technology of the warp-weighted loom. More specifically, the definitions offered by ancient lexicography clearly situate *kaîros* within a constellation of terms pointing to a core operation of weaving on the warp-weighted loom, one that embodies order as both its condition and its result, namely, the setup and distribution of the warp in front of and behind the loom's two horizontal bars: woven into a starting border, warp threads are arranged into two sets of alternating (even and odd) layers, their disposition on the bars generating the sheds and determining, through the mechanism of heddling, features of the pattern-to-be.[4] A first aspect to reflect upon when pursuing the project of rethinking the category of 'word excavation' has to do with the nature of our textual sources for *kaîros*, which in turn seems to respond to the degree of (techno)logical engagement that certain operations at the loom afford and display. Where weaving as site of ordering is at its most apparent – as in the fabrication of the starting border and in the setup of the warp on the loom – language seems to defy its denotative power,[5] lacking the clarity of an exact correspondence between object (or action, or process) and term. The dossier of *kaîros* represents, in this and other respects, a case in point: while the term may have eschewed the register of literature for its excessive technicality,[6] its early currency is guaranteed by an elusive Homeric line (*Od.* 7.107). This means that *kaîros* (καῖρος) circulated alongside, or is at least as old as, the homograph and abstract *kairós* (καιρός), a concept ('due measure', 'appropriateness', 'right time') of significant ethical, aesthetic, and normative import in Archaic Greek thought.[7] In fact, the intriguing hypothesis has been entertained by a few scholars that *kaîros* (καῖρος) and *kairós* (καιρός) may originally have been one and the same word, the different accentuation marking the development of two ramifications of sense (concrete and abstract),[8] a further possibility being that the abstract concept of καιρός derives its broad semantic palette from the functions of the weaving device καῖρος.[9]

Notwithstanding other rewarding ways of investigating the semantics of *kairós*,[10] this contribution seeks to look at the unitary concept of *kairos* (encompassing both καῖρος and, with due specifications and constrains, καιρός) as instantiating a mode of knowing *through* and *as* order that originates in the logic of weaving at the warp-weighted loom, and that, in different areas of Archaic Greek thought, shapes ways of engaging with *kosmos* and *technē* – i.e. with complex structures and patterns in nature and craft.[11]

The argument falls into two parts: in the first, which constitutes the bulk of the contribution, a survey of ancient lexicographical accounts of *kaîros* in context (including a few elusive καῖρος-related words in poetic passages) situates the term within a group of nouns and verbs associated with the crucial ordering operation of distributing the warp threads on the warp-weighted loom; the second part brings the term *kairós* into the discussion, and explores areas of its semantics in Archaic Greek poetry where an emerging notion of 'order' seems to connect the term to the homograph *kaîros* and, thus, to weaving technology. The conclusive remarks argue for an approach to the study of the concept of Archaic *kairos* (καῖρος *and* καιρός) that, transcending the remit of an archaeo-linguistics of 'word excavation', contributes a chapter in some sort of 'archaeology of concepts of order' in early Greek thought.

KAÎROS AS SHED BAR: MODERN SCHOLARSHIP VS. ANCIENT LEXICA?

Barber's (1991: 270–73) discussion of the Greek terminology for the warp-weighted loom and its parts draws on a reference article by Grace Crowfoot where iconography (especially vase painting), ethnographical data, and literary references are productively integrated with considerations of mechanical functionality.[12] One such 'technological' remark, triggered by a comparative analysis of Greek depictions of warp-weighted looms, concerns the pictorial representation of two rods crossing the loom – providing the 'natural' and the 'artificial' shed for the insertion of the weft into alternating crossings of warp threads – and the related question of the evidence for the existence and use of heddles.[13] A particular case, though problematic in its representation of shedding, is the sixth-century BCE lekythos attributed to the Amasis painter,[14] which has the lower and thicker rod, in the description by Crowfoot, 'lashed to the side beams' and having 'cross ties along it over the warp threads'.[15] Just this type of shed rod, 'with its well-ordered warp threads' crossed by ties to keep them in place, is the implement that Crowfoot matches with the term *kaîros*, providing in the notes two fairly vague references to lexicographical sources.[16] In adopting this same identification, Barber specifies that *kaîros*, as shed bar, 'serves also to regulate the warp', and is 'normally bound to every thread in the front half of the warp by a continuous spacer cord, as is so clearly shown by the row of X's on the shed bar on the Metropolitan vase'.[17] Although not unproblematic, the collocation '*kaîros* = shed bar *cum* bindings/ties keeping the warp threads in order' may be seen as an attempt, economical and even elegant, at accommodating evidence from iconography and technological functionality – although, again, not in the fashion depicted on the Amasis vase, which fails to account for the alternating (odd-even, in front of-behind the shed bar) layers of warp threads; it furthermore would seem to incorporate at least a portion of the explanations that ancient lexicographers collected on the term καῖρος.

We find, in fact, just a single reference to *kaîros* as bar/rod in the entire lexicographical dossier of the term: Eustathius of Thessalonica (a major Byzantine intellectual of the twelfth century AD, collector of the Greek lexicographical tradition and commentator of Homer) informs us that 'it is reported in a lexicon of rhetoric that, of the [loom] bars, the one that is attached [to the loom] under the *kanōn* is (the one which is) called *kaîros*'.[18] On the other side, the notion of some binding/tie of the warp threads preventing their entanglement features prominently across textual sources (lexica, scholia, *commentaria*) on *kaîros*: it might well be the single most distinctive trait characterising the device – to the extent that καῖρος is often associated by lexicography with other bindings/ties/cords (heddles, starting border) at work in weaving on the warp-weighted loom. A synthetic review of our written evidence will eventually produce a few hypotheses about just how the warp-threads may have been interlaced to the *kaîros* – and why the term so often seems to overlap with those denoting the heddle-leashes and the starting border.

OBSCURE *LEMMATA*: REMNANTS OF *KAÎROS* IN HOMER AND CALLIMACHUS

At the origin of the lexicographical tradition's engagement with the technical term *kaîros* lies a line in Homer's *Odyssey* (7.107). Framing the verse, in the wider context of the presentation of the blessed life of the Phaeacians in Scheria, is a passage praising the excellence of Phaeacian women in female virtues: they are 'skilled at the loom' (ἱστῶν τεχνῆσσαι, line 110), and have been gifted by Athena with 'knowledge (*epistasthai*) of fair handiwork, and with understanding minds' (line 111).[19] A few lines before, following a detailed description (lines 86–102) of the technological marvels on display in Alcinous' palace, household economy is introduced as we are met with fifty handmaids, some of whom 'weave fabrics' and 'twirl yarns while seating' (105–6); the narrator offers then a glimpse of a further stage of textile production: 'from the *kaîros*-woven linen fabrics, moist olive oil drips down' (καιροσέων δ᾽ ὀθονέων ἀπολείβεται ὑγρὸν ἔλαιον, line 107).[20] The adjective *kairoseōn* (from the otherwise unattested *kairoeis,* as Eustathius notes) is perplexing on many levels,[21] and its precise meaning seemingly opaque already for Greek lexicographers: whatever its sense in the Homeric line, the term represents a crucial pathway into *kaîros*. In fact, what lexica do is to provide fairly general explanations or paraphrases of *kairoseōn*, trace the term to the domain of weaving by clarifying its derivation from *kaîros,* and collect a number of technical descriptions of the weaving device καῖρος – the last being the material that concerns us the most here.

The Homeric term *kairoseōn* is glossed by lexica, scholia and *etymologica* as corresponding to 'skillfully woven' (εὖ ὑφασμένων and εὐυφῶν), in turn a paraphrasis of 'skillfully *kaîros*-made' (εὖ κεκαιρωμένων, participle of the denominative verb καιρόω and thus, on its own, of little help in determining the sense of καιροσέων) and of the allegedly synonymic 'skillfully *mitos*-made' (μεμιτωμένων, participle of the denominative μιτόομαι, from μίτος 'heddle-leashes').[22] The logic of the *interpretamentum* – the obscure *kairoseōn* is to be connected to *kaîros,* which anchors it in the domain of weaving and, in turn, attracts the term *mitos*, perceived as equivalent in meaning – seems to imply that the erudite Greek lexicographical tradition, from Hellenistic to Byzantine times, had problems making sense of the semantic relation between the adjective *kairoeis* (from which the genitive plural feminine *kairoseōn*) and *kaîros*. Callimachus' sophisticated allusion to the Homeric *kairoseōn* in his *Victoria Berenices* (*Aitia* book 3 fr. 383.13 Pf., where the adjective is *kairōtous*), all but confirms the linguistic idiosyncrasy and semantic opacity of the original term: picking up a single-usage word (*hapax legomenon*) in Homer is entirely within the archaeological-antiquarian practice of intertextuality that Callimachean poetics claims for itself.[23] Interestingly, two more καῖρος-derived words are found in Callimachus:[24] in these cases, too, lexicographers seem to suggest that poetic words etymologically rooted in *kaîros* are to be treated as semantically equivalent to plain *hyph*-derived terminology,[25] i.e., as referring to weaving (*hyphainein* in Greek) in general. If not a case of generalisation or banalisation on the part of the compilers of lexica, this semantic stretch of *kaîros*-derivatives in poetic diction could be tentatively explained as pertaining to the domain of tropes: a sort of synecdoche, in this specific case, where a part stands for, or refers to the whole (*pars pro toto*).

There is, however, a further hypothesis that might be able to account for the fact that Homer's καιροσέων (and Callimachus' καιρωτούς) seem to associate the quality of what is 'the product of *kaîros*' – or what is produced 'according to *kaîros*' – with the notion of 'well woven'; this has to do with the possibility that *kaîros* may indicate, rather than a specific device or function, a crucial arrangement of space and time at the loom, one that enables the very possibility of (skillfully) weaving: the specific configuration of the sheds, with the crossing of the two layers (odd and even) of warp threads, at the moment of the insertion of the weft, when a physical and temporal opening is graspable. The gloss 'skillfully *mitos*-made' (μεμιτωμένων), collected by Hesychius as a synonym of *kairoseōn*, might be making a comparable point: a fabric is 'well woven' when regulated by the function of *mitos*, the ensemble of heddle-leashes looped around individual warp-threads and attached to the heddle rod (κανών) to produce the 'artificial shed' and, when the *kanōn* is pulled forward, provide the opening for the insertion of the weft.[26] While the hypothesis of seeing *kaîros* as also a spatio-temporal configuration will resurface in the course of the argument, so much for the semantically opaque sample of *kaîros*-rooted terms in Greek poetry.

BINDING, SEPARATING, ORDERING: *KAÎROS* IN THE GREEK LEXICOGRAPHICAL TRADITION

Things, in fact, become more intriguing when lexicography engages with the weaving device *kaîros*, offering revealing glimpses of ancient weaving technology and interesting details about how order is instantiated at the warp-weighted loom. The attempt to make sense of the descriptions of what καῖρος *is* and what *functions* it performs in the mechanics of the loom will show that the glosses of lexicographers seem just to conflate the two elements (object and function), often assimilating *kaîros* to other implements of weaving technology on the ground of functionality considerations.

One possible approach (among many others) to the lexicographical material, notwithstanding the impossibility of drawing any consistent and stable picture of καῖρος from the – often contradictory – *interpretamenta,* would be to order the glosses around three categories: a) nature of the device called *kaîros,* b) functions of the device, and c) cases where καῖρος is identified with other devices (often, as expected, bindings/ties or cords themselves).

A degree of oscillation between a few variants of the term (*kaîros, kairōma, kairōsis,* all equivalent in meaning)[27] and between singular and plural forms (in particular *kairōmata*) – the plural underlying an emphasis on the individual bindings/ties interwoven to the warp threads, the singular on the thread/cord that contains them – is to be accounted for, and not only in regard to *kaîros*. Other recurring terms waving between singular and plural form are *stēmōn, stēmones* (with the first, a collective singular for 'warp threads', more frequent) and the cluster of terms for 'binding/tie' (*diaplokē, diaplegma, plegma, syndesis*) that ancient lexica so often identify with καῖρος.[28] A further methodological caveat before listing and discussing the lexicographical material: given that much of the terminology at stake here only occurs in the glosses of late lexica, and these refer with various degrees of precision to technological *realia,*[29] any rendering of the relevant Greek terms into English will be only tentative – the tool of semantic comparison with literary texts is severely limited, as we have seen for the term *kaîros*.

Starting from category a) above, the glosses of lexicographers define *kaîros* as:

> some kind of cord or string (Gr. *seira* σειρά): 'a cord (σειρά) in the loom through which the warp threads are inserted (διείρονται)';[30] 'a cord through which the warp-threads are stretched down/descend (καθίενται)';[31]
>
> some kind of binding(s)/tie(s)/interweaving(s) (Gr. διαπλοκή, πλοκή, (τὸ) διαπλεκομένον, διάπλεγμα, πλέγματα, σύνδεσις): 'the interweaving (*diaplokē*) in the *diasma* in which the warp threads are stretched down/

descend';[32] 'the interweaving/binding (*diaplegma*) that prevents the warp threads from entangling';[33] '*kairōsis* is to be called the binding together (of the warp threads)';[34] '*kairōmata* are the bindings that keep the warp threads separated';[35] '*kairōma* is the interweaving in the warp along/parallel to the heddle-leashes (*mitos*) so as to prevent the warp threads from entangling';[36]

a bar: 'it is reported in a lexicon of rhetoric that, of the [loom] bars, the one that is attached [to the loom] under the *kanōn* is (the one which is) called *kaîros*'.[37]

As for category b), the functions assigned to *kaîros* by our lexicographical sources can be ultimately integrated into the fundamental one of *ordering* the warp threads; this is afforded through a twofold action that *kaîros* exerts on the *stēmōn* as a whole and on each warp thread:

to keep the warp threads *separated* from one other and in due order, so as to prevent them from entangling;

the way *kaîros* maintains and imposes order on the warp threads operates through a sort of binding together and interweaving: the action of *plekein* (itself a sub-category of weaving) and of crossing and distributing (conveyed by the adverbial *dia-*).

In the complex operation of setting up the warp-weighted loom for weaving, the ordered distribution of the warp threads – divided into even and odd – is guaranteed by two other devices in addition to *kaîros*: these are the starting border (from which the warp threads hang down and which can in some cases have the appearance of a cord) and the heddle-leashes (loops of thread attached to the *kanōn* and tied to every thread of the even or odd half of the warp), *diasma* and *mitos* respectively.[38]

Collected in the category c) are lexicographical glosses where *kaîros* is either identified with, or its function as overlapping with, that of the starting border and (more often) that of the heddle-leashes (*mitos*):

> *kaîros* as coextensive with, or a part of, *mitos*: 'some call *kaîros* the *mitos*';[39] 'others say that *kaîros* itself is *mitos*';[40] '*kaîros* is the binding/interweaving of the *mitos*';[41]
>
> *kaîros* as starting border: 'others (say that *kaîros* is) the borders of the garments';[42] 'the interweaving (*diaplokē*) in the *diasma* in which the warp threads are stretched down/descend'.[43]

The identification of καῖρος (*kaîros*) and μίτος (*mitos*) is especially revealing, as it is capable of accounting for the oscillation between the two in ancient lexicography while also lying at the root of one important modern reconstruction of the nature and function of *kaîros*.[44] A crucial implement for ordering the warp,[45] the *mitos* ('heddle-string', a collective singular indicating the set of individual heddles = heddle-leashes/loops, each tied to a warp thread) is attached to the *kanōn* and exerts its action on (one half of) the warp threads through leashes looped around individual warp threads, enabling the mechanical shed.[46] While the ability to pull the warp threads towards the weaver, creating a distinctive crossing of the two halves of the warp and generating the artificial shed, is what characterises the function and mechanics of *mitos*,[47] the heddle-leashes also serve the function of imposing order on the warp threads by keeping them in place. As ethnographic investigations on warp-weighted looms in traditional weaving communities in Northern Scandinavia have shown, a 'spacing cord' is chained across the warp, below the shed bar, to maintain an even space between warp threads: in a fashion partly similar to the operation of heddling, 'a small loop was crocheted around each double end [of the warp threads]', both those of the half lying in front of the shed rod and those of the other half lying behind the shed rod, with the ends of the two cords 'tied together around the uprights'.[48]

Admittedly, the technology and function of such spacing cords resonate with the descriptions of *kaîros* offered by lexicographers, and provide an elegant solution for tracing the inconsistencies of the ancient glosses to a device that, in its appearance of a cord/string tied to the warp threads via loops, shares characteristics of the *mitos* and, at least in the practice of traditional twentieth-century Scandinavian warp-weighted loom weavers, also of the 'heading cord' – a typology of starting border described by Hoffmann (1964: 41).[49] The existence of a chained spacing cord in the warp-weighted loom of ancient Greece is not confirmed by archaeological or iconographical sources – this being an element differentiating this case from that of heddles, whose currency in antiquity may be inferred by a few archaeological textile fragments.[50]

This being said, the spacing cord hypothesis, forcefully proposed by Blümner (1912: 145–6) and picked up by Gallet (1990: 22–29), seems to make good sense of the lexicographical evidence: however, projecting back into the technology of Classical antiquity, on the basis of technological functionality, a feature attested in modern practices of loom setup and warping (albeit clearly rooted in a very old tradition) may raise some questions. The integration of the spacing cord in the shed bar (the two together corresponding to *kaîros*), as possibly reflected in the Amasis painter's *lekythos* in the Metropolitan Museum, is proposed by Barber, who draws on Crowfoot's insights, as we have seen. This hypothesis is compelling, despite being grounded on a single lexicographical gloss identifying *kaîros* as a bar, and on a single piece of visual evidence (the Metropolitan *lekythos*) locating a string/cord leashed to the bar, itself problematic from the point of view of technological functionality.[51]

The orientation of this contribution is one that engages less with questions of reconstruction or correspondence of term and device than of exploration of the concept: in this perspective, what the *interpretamenta* of ancient and late antique lexica *also* seem to convey is the idea of *kaîros* as a configuration and site of order, a distinctive arrangement of warp threads in space and time that enables weaving. To make the latter point surface more clearly, a few further elements towards an 'archaeology of concepts of order' in ancient weaving have to be unfolded, and the abstract term *kairós* (καιρός) introduced into the enquiry.

EMBEDDED ORDER AT THE LOOM: *KAÎROS* AND THE SETUP OF THE WEAVE IN ANCIENT GREEK SOURCES

One point emerging from the synthetic overview of lexicographical sources on *kaîros* above is how, unclear as the exact nature of the device may be, its functions are graspable with a certain degree of clarity. They seem to be solidly anchored in the context of the operation of setting up the loom and, in particular, the distribution of the warp threads – which hang from the starting border and are kept in tension by being attached to loom weights – along the two horizontal rods via two systems of binding/tying (one being *mitos* and the other *kaîros*) that keep the warp threads in due order, enable the creation of the sheds and provide the basic patterning structure. Interestingly, the constellation of Greek terms for the setup of the loom happens to reproduce the pattern that we have observed for *kaîros*: lexicographical glosses and a few (again, mostly fragmentary) passages from Classical and Hellenistic poetry integrate each other and shape a picture where some of the terms that we have encountered so far (*diasma*, in particular) gain in consistency and may throw back some further light on *kaîros*.[52]

Barber's suggestion that *diasma* may refer to the starting border 'with the long strings of warp hanging from it' appears to make good sense from both the semantic and technological point of view, as does her explanation of the verb *diazesthai* as referring 'either to the manufacture of the band cum warp or to the long process of binding the band onto the upper beam while dividing ('shedding') the trailing warp threads' (Barber 1991: 271), a notion of distribution that the Greek prefix *dia-* (from the adverb and preposition διά 'through, in different directions, separately') appears to emphasise.[53] A closer look at the textual sources reveals that, just like in the case of *kaîros*, occurrences of the series *diasma*/*diazesthai* in the Greek literary corpus have reached us only as citations by lexicographers: in search of an anchoring context for making sense of a *terminus technicus*, compilers of lexica and scholia revert to excerpts from poetry containing the relevant term. In the case at stake here, namely that of the Greek terminology for the operation(s) associated with generating and setting up the warp, two verbs (*prophoreîstai* and *diazesthai*), each with its own specialisation of meaning, appear to cover much of the technology situated in preparing and setting up the warp.[54] Here are the facts:

> *prophoreîsthai* (προφορεῖσθαι): the verb, originally rooted in weaving technology, underwent a semantic generalisation/banalisation already in fifth century BCE where it came to mean something like 'to go back and forth';[55] a hint to the technical connotation of the term is provided by the scholia to

Aristophanes' *Birds* 4: 'prophoreîsthai is said to be the operation of carrying/bringing forth the warp to those (women) who set it up (on the loom) (*diazomenais*)';[56]

diazesthai (διάζεσθαι): a fragment by the fifth-century BCE comic poet Nicophon reads 'one weave/warp (*histos*) is finished, another is set up (*diazetai*)';[57] the *Suda* lexicon, describing the ritual weaving performed by priestesses of Athena together with the two Arrhephoroi (aristocratic young girls consecrated to the cult of Athena Polias) at the Athenian festival of the Chalkeia, mentions the practice of *diazesthai* the *peplon* for the goddess, which might refer to the weaving of the starting border of the *peplos*.[58] *Diazomenai* (διαζομέναι, 'women who are in charge of the setting up of the loom') are associated with the operation of preparing the warp, and thus also the starting border, also in Hesychius' gloss of the obscure term *arkanē*: 'the thread/band in which the *diazomenai* interweave the warp';[59]

diasma (δίασμα): as a noun derived from the verb *diazesthai*, *diasma* should denote the result of the operation of *diazesthai* and may refer to the warp threads once distributed through the bars; this would align well with a fragmentary line by Callimachus, collected in the *Etymologicum Magnum* as an explanation of *diasma*: 'if they ever bring forth (*propherointo*) the *diasmata*, beginning of the fabric'.[60]

A scholium to *Odyssey* 7.107, as we have seen, interestingly links *diasma* to *kaîros*: 'καῖρος is the interweaving (ἡ διαπλοκὴ) of/in the *diasma* in which the warp-threads (οἱ στήμονες) are inserted'; the best way to make sense of this difficult *interpretamentum* is, I suggest, to move from the frame of 'word excavation' (where terms denote objects) into an archaeology of concepts, open to the exploration of connotations and configurations of words. Both *kaîros* and *diasma* may be seen as displaying more than a set of features of physical objects: they share and convey a distinctive notion of order, rooted in weaving technology and embedded in a number of material instantiations (a bar, a cord, a band, a layer of threads) or functions (the binding and interweaving of threads, the distribution and division of the warp) – a notion that we may call 'order at the loom'.

FROM *KAÎROS* TO *KAIRÓS*: ARCHAEOLOGY OF A NOTION

Once it is suggested that the operation of setting up the warp, and the crucial role played in it by *kaîros* and *mitos*, define weaving at the warp-weighted loom as a distinctive site of order,[61] the obscure Homeric word *kairoseōn* at *Od*. 7.107 – glossed as 'well-*kaîros*-made, well-*mitos*-made, skilfully-woven,' (εὖ κεκαιρωμένων, μεμιτωμένων, εὐυφῶν) – becomes increasingly less opaque: καῖρος and μίτος guarantee the orderly disposition of the warp threads behind and in front of the bars and their orderly crossing when the sheds are 'open' for the insertion of the weft; it thus makes good sense that the synecdoche '*kaîros* = weaving' is employed, and especially so in poetic contexts.

In fact, however, the isolated and hard-to-grasp *kairoseōn* may not quite prove the only anchor to *kaîros* that Archaic Greek literature has to offer us. The perspective shifts quite dramatically if we are ready to postulate an etymological and semantic association – in fact even an original identity – between *kaîros* (καῖρος) and *kairós* (καιρός), with the latter a fundamental notion of aesthetic, ethic, and intellectual import in ancient Greek culture and thought.[62] Archaic and early Classical attestations of the term *kairós* (καιρός) conjure up a concept whose semantics may be, rather sketchily, traced back to the idea of 'appropriateness', with the spatial dimension ('due measure') predominant over the temporal ('due season, right time, opportunity'), as research has increasingly brought to light.[63]

The abstract sense of 'right measure, balance', attested as early as Hesiod and Archaic wisdom literature[64] – before emerging as the quintessential compositional principle of Pindar's epinician poetics[65] – does not do full justice to the richness of material imagery with which the notion of καιρός is imbued in Archaic Greek poetry. A significant sample of poetic images associates *kairós* with the mark or target of the archer;[66] seeing in this motif the remnants of the material matrix of *kairós* anterior to the development of the notion of 'due measure, opportunity', R. B. Onians reframes and refines the notion as less 'target, objective' than 'that at which archers aimed in practice' (1951: 344),[67] which he argues (drawing on the archery contest of *Odyssey* 19.573–76, 21.419–23) was for the Greeks 'a penetrable opening, an aperture, passage through the iron of an axe or rather twelve axes set at intervals in a straight line' (1951:

345).[68] Such a conceit of *kairós* ('what is right, the right aim, the right way')[69] is, according to Onians (1951: 345), capable of accounting for a good portion of the semantics of the term,[70] and likely to lie at the origin of the development of the abstract concepts of space ('due measure') and time ('opportunity' as 'opening in time').

The next stage in Onians' argument brings in *kaîros* and its lexicographical dossier into the picture: just as for *kairós*, what the technical term *kaîros* indicates is an *opening* – that provided by the counter-shed, which enables the insertion of the weft. Lexicographers, according to Onians, identify *kaîros* with 'the row of thrums which draw the odd warp-threads away from the even, making in the warp a triangular opening, a series of triangles, together forming a passage for the woof' (1951: 346);[71] the consequence, in terms of semantic interaction between *kaîros* and *kairós*, would then be that 'the use in weaving will better explain the sense 'critical time', 'opportunity' [...] for there the opening in the warp lasts only a limited time'.[72] While many of the logical (and philological) passages of Onians' hypothesis could be, and have been, questioned, the idea that an original notion of *kairos* (encompassing both καῖρος and καιρός) may have indicated a distinctive arrangement or configuration of time and space, itself an instantiation of the order of weaving, is worth further consideration and it may explain a number of occurrences of *kairós* where the spatial and the temporal aspects seem to coexist.[73]

Whatever the extent of the rooting of *kairós* in *kaîros*,[74] a defining aspect of the semantics of *kairós* which resonates with ancient lexicographical accounts of *kaîros* has been pointed out by Monique Trédé-Boulmer: the notion contains a polarity by integrating the two concepts of 'distinction/separation' (from the root **ker-*, Gr. κείρειν), which in turn produces '(right) part, limit, measure', and 'junction/intersection/combination' (from which the temporal-spatial sense of 'juncture').[75] In a similar fashion, the prominent separating function of the implement *kaîros* in the glosses of lexicographers – e.g., Eustathius' '*kaîros*: a cord (σειρά) in the loom through which the warp threads are kept separated' – is counterbalanced by Pollux's focus on the 'binding together-action' that *kaîros* exerts on the warp threads ('binding together [συνδῆσαι] the warp threads is to be called *kairōsai* [καιρῶσαι]');[76] it is probably worth noting that another weaving implement, the *kerkis* ('pin beater', 'shuttle', 'spool'), embodies these two concepts in its functions.[77]

Integrating and reinforcing a recognisable pattern of Archaic Greek terms associated with the notion of order, and especially resonating with the order of weaving (two remarkable instances are *poikilia* and *kosmos*),[78] *kairos* (as the notion keeping together καῖρος and καιρός) exhibits a capacious and fluid semantic spectrum in pre- and early-Classical Greek literature, one that provides rich material for exploring the mechanisms by which abstract concepts are created. For the present purpose, particularly rewarding is an effort at capturing aspects that the order of weaving – and especially those aspects triggered by the functions of *kaîros* – may have cast on particular usages of the term *kairós*. Especially intriguing, therefore, are Archaic occurrences of *kairós* in literary contexts that seem to engage with weaving – even more so when the notion of καιρός addresses modes of poetic composition, suggesting ways in which order and balance regulate practices of literary selection: the fragile equilibrium between abundance of topics and necessity of conciseness. Two gnomic passages in Pindar seem to do just that:

in the first (*Pythian* 1.81–2) the chorus caution themselves against excess in celebration: 'If you should speak according to *kairos*, stretching out (as to connect) the strands of many things in a short interval of time and space, less criticism follows from men';[79]

crucial to the interpretation of the passage is the correct understanding of the verb *syntanuein* ('stretch out as to join together'; the verb is a *hapax*) and of *peîrata* ('boundaries, cords, bands, bonds, strands'): it is tempting to relate the semantics of the verb to the function of *kaîros* as the string that keeps the warp threads separate and in tension (one could say also 'stretched out' along the width of the warp) through joining them together (see the series of terms transmitted by the lexica: *diaplokē*, *symplokē*, etc.); *peîrata* should thus refer to 'strands of warp threads', and the notation of brevity/shortness/conciseness (*en bracheî*) may point to the idea of width (many warp threads in a short width = a denser fabric) or to the brevity of the time slot within which, at the opening of the counter shed, *kaîros* exerts its action on the two layers of warp threads;

more explicitly rooted in weaving imagery is another *gnōmē* (*Pyth.* 9.76–79) exhibiting again the tension between abundance of material for song and necessity of a careful selection from myth: 'Great achievements are always worthy of many words; but to in-weave ancillary themes (βαιὰ) into the structure of the main themes (ἐν μακροῖσι) of the ode is appreciated by wise men (*sophoi*); *kairos* conveys the climax/essence of the whole just as well';[80] the occurrence of the verb *poikillein* (a denominative from the key term *poikilia*) reinforces the impression that Pindar is purposely suggesting a layer of reading that draws on weaving technology while at the same time expressing a paradigmatic statement of epinician poetics: to highlight moments of brilliance within an abundant repertoire of noble deeds is what a learned audience appreciate,[81] and *kairos* is the supreme notion of order that instantiates such a balance.

Further investigations into the ways in which the order of weaving may emerge in occurrences of *kairos* in Archaic Greek literature have the potential to enrich the semantic spectrum of the term with a layer of meaning that could bring together the spatial and the temporal dimensions of καιρός, and shed new light on the elusive term καῖρος and its technological implications; in fact, early Greek thought and Archaic Greek poetry represent a privileged vantage point for exploring a refreshing interaction of technology and concepts – and the text of Pindar an ideal terrain of observation.

CONCLUDING REMARKS: FOR AN ARCHAEOLOGY OF NOTIONS OF ORDER

Recent work by Leslie Kurke and Richard Neer reframes the concept of spatiality in Archaic and early Classical Greece as less a question of identifying *realia*, places, and objects than of exploring the preconditions for the ordering of 'larger relational fields, the gaps or spaces between things', which is how 'an insider's take', in the specific case Pindar's choral song, makes sense of space.[82] By refreshingly reconsidering art, architecture and song as 'crucial technologies in articulating Classical spatiality', Kurke and Neer resort to Foucault's considerations on the 'propinquity of things' and the 'common ground' of concepts as embedding order,[83] and reverse his spatial metaphors to claim that 'conceptual propinquity might cash out as, or even determine, spatial relations', as they explore 'the imbrication of concepts and technologies in the emergence of a notion of 'common ground' that subtended both Greek song in performance and the environment of Greek cities and sanctuaries'.[84]

Such imbrication of concepts and technologies is a distinctive trait of Archaic Greek thought, and the semantics of *kaîros/kairós* a case in point for addressing weaving as a technology that produces and projects concepts of order in a number of domains. Especially relevant for positioning weaving within the epistemic landscape of pre-Classical Greek thought is Kurke and Neer's characterisation of early technologies of space (for instance geographical maps) as pre-metrological, pre-standardised ways of conceiving of and manipulating measures and distances through drawings and algorithms;[85] in a comparable fashion, weaving technology generates order as a pre-scientific (but fully technical) mode of existence through the manipulation of threads as numbers, and by letting patterns emerge through algorithms. It is tempting, in situating such order, to resort once again to Michel Foucault's preface to *The Order of Things*, and project his 'middle region' – also described as 'the pure experience of order and its modes of being' – onto Archaic Greek thought, as in some sense 'the epistemological field [. . .] in which knowledge, envisaged apart from all criteria having reference to its rational value or to its objective forms, [. . .] manifests a history which is not that of its growing perfection, but rather that of its conditions of possibility'.[86]

ENDNOTES

1 Barber's adagio is quoted (also programmatically) at the opening of a reference volume on textile terminologies (Michel and Nosch 2010: ix), and her 'Word excavation' (1991: 260–82) has established itself as the most authoritative study of the Greek vocabulary of weaving for both textile scholars and classicists (see e.g. Nagy 2002: 76–82). Notwithstanding the importance of Barber's archaeo-linguistic investigation, grounded on the author's scholarly command of Linear B and other Indo-European languages, the contribution of lexicography, ancient and modern, is somewhat underestimated, and the interpretation of individual Greek literary passages at times questionable: see, recently, Neri (2016) on the case of ἠλακάτη ('spindle' and 'distaff'), with a well-grounded criticism of Barber's discussion of the term (1991: 264).

2 To be distinguished, for the moment, from the homograph *kairós* (καιρός) 'due measure, right time, opportunity', a defining concept of ancient Greek appropriateness (both ethical and aesthetic) and widely familiar also to non-classicists.

3 References to lexicographical sources throughout this contribution are of this kind: author, indication of the term or passage discussed (preceded by 's.v.' = *sub voce* in case of a term, or '*ad*' in case of scholia to a particular passage), alphabetic letter and numeration within the reference edition, followed by the abbreviated name of the editor(s); see for instance: Hesychius s.v. καιροσέων (κ269 L.-Cunn.); the editions are listed below, under 'Notes on abbreviations and conventions'. Typically, ancient lexicography (as a broader category encompassing lexica, *etymologica*, scholia, grammatical treatises, *commentaria* from Hellenistic to Byzantine times) resorts to literary quotations to provide a context for particular (often rare and obscure in meaning) terms (*lemmata*), and collects (rather than contributes) glosses, explanations and interpretations for these. Though often inconsistent and contradictory – and with varying degrees of technical and technological correctness – such collections of *interpretamenta*, which may go almost as far back in time as their original sources, remain a precious body of evidence for terms otherwise not attested in literary and epigraphical corpora. A valuable instrument to navigate ancient lexicography is Dickey 2007. For the importance, in approaching ancient lexicography, of distinguishing between different structural criteria (alphabetic order vs. grouping of terms within semantic fields) in the compilation of lexica see Tosi 1988 (on Pollux); see Restani 1995: 93–96.

4 For a reference diagram of the warp-weighted loom that largely matches the description and discussion below see Harlizius-Klück, this volume. On the setup of the loom and questions of mechanical shedding see Barber 1991:109–13 esp. fig. 3.27. See also Öhrman 2017: 280 on heddling as 'one of the most difficult elements of preparing a weave' and 'the element of preparing and setting up the warp that has the most influence on what type or pattern of weave will be created'.

5 The somewhat paradoxical consequence of this fact is that, while weaving technology escapes being crystallised in the written form of technical treatises (of which other *technai*, like medicine, agriculture, and architecture, benefited in antiquity), the *knowledge* of weaving as a mode of conceptualising and describing orderly structures is clearly traceable in Archaic Greek thought: see Fanfani and Harlizius-Klück 2016 and forthcoming.

6 This is how, from the methodological standpoint of scholarly work on corpora of technical terminologies in Greek and Latin languages, linguistics would tend to explain the absence of καῖρος from the extant body of Greek literature; important remarks on layers and degrees of technicality in specialised corpora are drawn by Stefanelli 1983: 406–8 (concerned more broadly with the Greek terminology of warping) and Gallet 1990: 45–47.

7 The semantic range (which takes on the temporal dimension of 'right time, opportunity, occasion') and domains of application (medicine and rhetoric, politics and military strategy, philosophy and religion) of the term καιρός in Classical, Hellenistic and Roman times largely exceed the scope of this discussion, which is concerned with the notion as it emerges in Archaic Greek thought.
8 A linguistic phenomenon not rare in ancient Greek: several examples are listed in Gallet 1990: 45.
9 Diversification/specialisation of meaning (the concrete *kaîros* and the abstract *kairós*) from a common term, etymologically rooted in the domain of 'separation' (from κείρειν 'to cut') but encompassing the idea of 'juncture': Tréde-Boulmer 2015, esp. 72–73. Common origin of the two homographs from the notion of 'passage, opening, aperture' (as 'that at which archers aimed in practice'): Onians 1951: 343–48. Functions of the weaving implement καῖρος as capable of explaining the whole semantic spectrum of the abstract καιρός: Gallet 1990: 9–176 (esp. 9–68). For detailed discussion see below.
10 A promising one is to group sets of recurring images; for instance, καιρός as the mark/target of the archer looms large in Archaic Greek poetry and tragedy: see Onians 1951: 343–45; Trédé-Boulmer 2015: 23–29, 37–39; see also Simpson 2015: 449–58 on the bow metaphor in Pindar, and its connection with the poetics of καιρός.
11 A few domains of early Greek thought where weaving *as* knowledge features prominently have been recently investigated: see Fanfani and Harlizius-Klück forthcoming (cosmology and number theory); Fanfani and Harlizius-Klück 2016 (Archaic Greek poetics); Fanfani 2018 (chorality). See also Harlizius-Klück, this volume.
12 Crowfoot 1936/1937. With a shift of focus, ethnographic comparison from Scandinavia is given prominence in the comprehensive study of the warp-weighted loom by Martha Hoffmann (1964) and made to bear on the interpretation of ancient depictions of the loom in vase paintings (pp. 297–321). For a rich and refreshing discussion on the topic see Edmunds 2012. Archaeological and literary sources ground the reference study of ancient technology by Forbes, who offers a selective overview of types of loom in antiquity (1964: 198–211) in the broader area of the Mediterranean and Ancient Near East, thus bringing into the discussion the significant exchange of textile terminology between Greek and Semitic languages. When it comes to the collection of Greek and Latin literary sources on ancient textile technology, Blümner's encyclopaedic study (1912; weaving: 135–70) is unsurpassed: his treatment of *kaîros* is exemplary in this respect, as we shall see.
13 On this specific point, and on the possibility (envisaged by Crowfoot 1936/1937: 43) of two shed rods without heddles being depicted on the Amasis painter lekythos, see the observation by Hoffmann (1964: 300): 'It is impossible to obtain two

mechanical sheds by means of rods without heddles. One shed may be kept with such a rod, but the other would have to be picked up by hand'. While Hoffmann is ready to concede that 'we have no decisive evidence, either philological, literary, or pictorial, of the use of a rod with heddles in ancient Greece' (p. 300), ancient lexicographical explanations of the terms *kanōn* and *mitos*, as Blümner (1912: 144–46) had already suggested, seem to point towards the existence of heddles; see, for instance Hesychius under the *lemma* κανών (κ681 L.-Cunn.): 'the stick/rod (ξύλον) around which [lies] the *mitos* ('heddle')' and below, xxx. See Barber 1991: 109–13.

14 The Metropolitan Museum of Art, Fletcher Fund, 1931; acc. no. 31.11.10.

15 Crowfoot 1936/1937: 43, also noting that the warp threads 'appear to be all on one side of the rod and the weights below hang all on the same level'; this trait seems to stand out against a recognisable pattern in ancient depictions of warp-weighted loom, namely the representation of the loom weights hanging 'at different levels in alternate rows', an indication 'that the crossing was kept between the rods, the weights being on bunches of odd and even threads alternately, as on the Northern looms'.

16 Crowfoot 1936/1937: 46 with n. 9: the references are to Pollux (*Onomasticon* 7.33 'binding together the warp threads should be called καιρῶσαι [a verb formed from καῖρος], and καίρωσις [substantive formed from καῖρος, possibly retaining the same meaning] the binding (σύνδεσις)') and Hesychius, for which Crowfoot's abbreviation, 'Hesych. 2', reads somewhat unclear. The explanations of καῖρος in Hesychius' lexicon, which collects a number of different and contradictory *interpretamenta*, none of which identifies *kaîros* with the shed bar, are to be found under the *lemmata* καιροσέων, καίρωσιν (κ269, κ272 L.-Cunn.) and the obscure ἀμφιβάλλος (which Musurus emended into ἀμφίμαλλος (α61 L.-Cunn.); see Blümner 1912: 145 n. 4. See below.

17 Barber 1991: 271 and 112 respectively; as we shall see further into the argument, such 'spacer cord' has been suggested as being the device that lexicographers label καῖρος.

18 φέρεται ἐν ῥητορικῷ λέξικῷ καὶ ὅτι μεσάκμων, τὸ τῷ κανόνι ὑποδεδεμένον ὃ καλεῖται καῖρος (1571.67–1572.1 Stallbaum). Curiously, the passage is not mentioned by either Crowfoot or Barber. Eustathius' commentary on *Odyssey* 7.107 (a passage containing καιροσέων, an obscure term derived from καῖρος) offers the richest collection of *interpretamenta* of the term *kaîros*. An excellent introduction to the intellectual significance of Eustathius and to his commentaries (*parekbolai*) on the *Odyssey* is the recent Cullhed 2016: 1*–33*.

19 The Phaeacian women share this combination of technical knowledge (*epistasthai*) and good mind (in both the moral and the intellectual sense: see Garvie 1994: 186) with Penelope, who earlier in the *Odyssey* (2.117) is described in the same (formulaic) terms – though she retains a quality of her own in being 'mindful in her heart' (φρονεύσ' ἀνὰ θυμόν, line 216).

20 For the specific operation implied here see Garvie (1994: 185): a glossy finish given to linen fabric with olive oil, or a means of softening it.

21 A first level is linguistic-philological: καιροσέων at *Odyssey* 7.107 is the manuscripts' reading and, as observed by Garvie (1994: 184–85), 'derives from an ancient orthography in which ου was written as ο, and double σ written only once'; Garvie, like many editors of the *Odyssey*, restores καιρουσσέων in the text, with a rare contraction from Ionic καιροεσσέων. For the purpose of the present argument the transmitted form καιροσέων, which may have been borne as a shortening of καιρουσσέων for metrical reasons (to obtain the required sequence - ⌣ ⌣), retains a particular interest, since it is the *lemma* discussed by the lexicographers; Eustathius (1571.65–66 Stallbaum), however, engages with a number of variations of the term, which he makes stem, correctly, from καιρόεις. On matters of semantics see Gallet (1990: 15) on the adjective καιρόεις, 'dont la formation laisse prévoir le sense de *pourvu de*, *riche en*'.

22 See e.g. Hesychius κ269 L.-Cunn.: καιροσέων· μεμιτωμένων· καῖρον δὲ τὸν μίτον φάσιν· οἱ δὲ εὖ κεκαιρωμένων, τουτέστιν εὖ ὑφασμένων ('*kairoseōn*: *mitos*-woven: some say that *kaîros* is (the same as) *mitos*: others (interpret *kairoseōn* as meaning) skilfully *kaîros*-woven, that is, skillfully woven'. Similarly, *Scholia* Hom. *Od.* η 107 e1 73–76 p. 34 Pontani (EG^{2}HM^{a}PVXY$_{y}$), *Souda* s.v. καιροσέων (κ1193 A.), Eustathius *ad Od.* 7.107, 1571.57 Stallbaum. Admittedly, the renderings '*kaîros*-woven' and '*mitos*-woven' do not make things clearer, as the meaning of each verb depends entirely on the sense given to the respective term (*kaîros* and *mitos*). Pollux, *Onomasticon* 7.33 explains the act of *kairōsai* (from *kairoō*) as 'the binding together (τὸ συνδῆσαι) of the warp threads'. The recent *Brill Dictionary of Ancient Greek* gives the following meaning for the verb *kairoō* (only attested in lexicography, as we have seen): 'to attach the fabric with the threads of the selvage', which is quite obscure; for *mitoomai*, which has two occurrences in Hellenistic epigrams, the rendering is 'to weave the web', which is exceedingly generic.

23 See Thomas (1983: 106–7), where the extent of Callimachus' engagement with the *Odyssey* passage is persuasively argued; Thomas renders the adjective καιρωτούς as 'well woven', drawing on the critical apparatus in Pfeiffer's edition (1949: 310, 'καιρωτούς igitur 'bene textos' significare videtur') where the hypothesis is entertained that Callimachus may have read καιρωτῶν δ' ὀθονέων instead of καιροσέων at *Odyssey* 7.107. Callimachus' intertextual engagement with Archaic instances of weaving imagery for poetics is a topic of itself, which I plan to treat in a future publication.

24 Eustathius (*ad Od.* 7.107, 1571.57 Stallbaum) reports that, derived from καῖρος, the term καιρωστρίδες in Callimachus refers to female weavers, 'instead of ὑφάντριαι'; see Hesychius (κ273 L.-Cunn.) where καιρωστρίδες is glossed as ἐργαστρίδες· ὑφαστρίδες ('worker; weaver'). The other Callimachean *kaîros*-related term is καίρωμα (found in fr. 547 Pf: 'transparent fabric [...] similar to membranes' ὑδαίτινον καίρωμα ⟨⌣

–⟩ ὑμένεσσιν ὁμόιον): possibly also a neoformation, the word is clearly a variant of καῖρος, as its significant currency in lexicographical accounts of the term confirms; in the case of Callimachus fr. 547 Pf., one of the sources transmitting the fragment reports that the object described by Callimachus was a garment/veil (*hyphasma*) to be offered to Hera in Delos (see Blümner 1912: 145 n. 3).

25 *Hyph-* is the main semantic root for 'weaving' in Greek (e.g. the verb ὑφαίνω 'to weave', ὑφή 'fabric').

26 A recent discussion of heddling is Öhrman (2017: 279–81 with fig. 1, 2, 3), in the broader context of an investigation of Latin term *licia* as indicating heddle-leashes.

27 See Gallet (1990: 17–18) on the nominal formations in -μα (like καίρωμα and μίτωμα) as usually indicating the result of verbal action (we shall soon discuss a limpid instance of this in the couplet διάζεσθαι – δίασμα).

28 Many of these terms are rooted in the verb *plekein* ('to plait, weave, braid'), often preceded by the 'distributional' preverb *dia-*, like διαπλοκή and διάπλεγμα. The notion of interweaving/crossing with which καῖρος is associated in the lexica qualifies and determines the nature of the bindings/ties through which the warp threads are kept in due order – while distributed on the rods. In conversation, Ellen Harlizius-Klück suggested to me the possibility that the semantic import of *plek-* in διαπλοκή and διάπλεγμα may in fact point to the crossing between odd and even warp threads that the heddle bar (*kanōn*) effects when pulled, but that takes place even at the shed bar; in this hypothesis, *dia-* may bring in the idea of the shed itself (as passage *through* the warp).

29 According to Stefanelli (1983: 407), καῖρος would be a case of a technical term changing its meaning in the course of time (a frequent pattern in technical terminology): its early literary attestations (καιροσέων of *Od.* 7.107), that is, do not match semantically with the glosses of *kaîros* offered by lexicographers, who in turn show just how difficult it was for them to restore the exact meaning of *kairoseōn* in the Homeric line. Stefanelli lists another factor determining the frequent mismatch between the literary use of a technical term and the explanations offered by ancient lexica: a *terminus technicus*, only circulating in the jargon of practitioners, can either be eschewed or appropriated by the vocabulary of popular language, in the latter case losing its technicality; I would be inclined to include καῖρος in this linguistic pattern, replacing 'popular' with 'literary'.

30 Photius κ60 Th.): καῖρος· σειρά τις ἐν ἱστῷ δι' ἧς οἱ στήμονες διείρονται. While the verb διείρειν has the value of 'to insert, introduce', which would make good sense in the Photius' gloss, a rendering of the passive διείρονται as 'are stringed/tied together' would be no less appropriate, as it draws on the semantics of the plain εἴρειν 'to string together'; the preverb δια- might be a reinforcement inserted to emphasise the idea of the crossing of the warp threads.

31 Eustathius in *Od.* 7.107, 1571.59 Stallbaum: καῖρος, σειρά δι᾽ ἧς οἱ στήμονες καθίενται.
32 *Schol. Gr. Hom. Od.* η 107 d 69–70 p. 34 Pontani (BEHM[a]P[1]TXY) καῖρος ἡ διαπλοκὴ τοῦ διάσματος ἐν ᾗ οἱ στήμονες καθίενται. For the term *diasma* (possibly indicating the starting border with the warp threads hanging from it and distributed across the two bars of the warp-weighted loom) see Barber 1990: 271.
33 Eustathius *Od.* 7.107, 1571.56 Stallbaum καῖρος δέ φασι καὶ καίρωμα τὸ διάπλεγμα ὃ οὐκ ἐᾷ τοὺς στήμονας συγχέεσθαι.
34 Pollux *Onom.* 7.33 τὸ δὲ συνδῆσαι τὸν στὴμονα καιρῶσαι λέγειν χρὴ καὶ καίρωσιν τὴν σύνδεσιν. Hesych. κ272 L.-Cunn.: καίρωσιν· τοῦ στήμονος τοὺς συνδέσμους. The source of both Pollux and Hesychius is the grammarian Diogenianus (2nd century AD), as indicated by Cunningham through the siglum D. I would like to thank Marco Ercoles for bringing this to my attention.
35 Hesych. κ269 L.-Cunn.: καιρώματα γὰρ τὰ διαχοριστικὰ τῶν στημόνων πλέγματα.
36 *Suda* κ1193 Adl.: καίρωμα δε ἐστι τὸ διαπλεκόμενον ἐν τῷ στήμονι παρὰ τὸν μίτον, ὑπὲρ τοῦ μὴ συγχεῖσθαι τοὺς στήμονας. Adler traces back this gloss to the tradition of Homeric scholia. See the almost identical gloss in *Etym. Magn.* 489.7.
37 Eustathius *Od.* 7.107, 1571.57 Stallbaum (see above n. 26).
38 A fairly precise description of *mitos* as heddle-leashes is offered by Eustathius (*Od.* 7.107, 1571.62 Stallbaum): '*mitos* is (the device) through which (weavers) crisscross/exchange the warp threads for the binding/interweaving with the weft' (μίτος δέ, δι᾽ οὗ τοὺς στήμονας ἐναλλάσσουσιν εἰς πλοκὴν τῆς κρόκης). For starting border as 'heading cord' see Hoffmann 1964: 40–41, in the context of an ethnographic investigation of the operations of warping and operating a traditional warp-weighted loom in a twentieth-century village in Norway; drawing on Hoffmann's description of the heading cord and suggesting, by analogy, a similar solution for the setup of the Greek warp-weighted loom, Gallet (1990: 26–28) goes as far as to hypothesise the existence of several instances of *kaîros* (as a cord regulating the space between warp threads) applied at different heights of the warp threads on the loom.
39 Hesych. κ269 L.-Cunn.: καῖρον δὲ τὸν μίτον φάσιν. See the almost identical gloss under the obscure but intriguing *lemma* ἀμφίμαλλος/ἀμφιβάλλος (α61 L.-Cunn.): 'some interpret it (i.e. the term ἀμφίμαλλος/ἀμφιβάλλος) as the *kaîros* in the looms; some others used to call *kaîros* the *mitos*'. A gloss of μίτος in Zonaras' lexicon, while quite precise in the description of the heddle, exhibits a lack of specificity that may help understand why often *mitos* and *kaîros* could be perceived as interchangeable: '*mitos*: the thread woven obliquely in the warp' (μίτος· τὸ ὑφαινόμενον ἐν τῷ στήμονι πλαγίως νῆμα).
40 Eustathius is here (*Od.* 7.107, 1571.63 Stallbaum) contrasting the view of the identity of *kaîros* and *mitos* with two glosses where the two are clearly kept distinct (see above nn. 42 and 44).

41 This gloss, as Blümner (1912: 145) explains, has been interpreted as establishing a distinction between *mitos* as the thread/string of which the heddles are made, and *kaîros* as the loops or leashes which are tied to each individual warp thread (of the even or odd half); Blümner refers to Hertzberg (1873: 8–10) for this view; see also Gallet (1990: 17–22).

42 Hesych. κ269 L.-Cunn. οἱ δὲ τὰς παρυφὰς τῶν ἀμπεχόνων.

43 *Scholia* Hom. Od. η 107 d 69–70 p. 34 Pontani (BEHM^{a}P^{1}TXY): see n. 40 above; interestingly, Öhrman's (2017: 279) description of the starting border comes very close to our scholiast's explanation: 'On the warp-weighted loom [...] warp-threads were affixed to the loom frame by means of being interwoven into a starting border (from which the warp-threads emerge)'. See also the definition by Chantraine in *DELG*: '«corde» qui fixe l'extrémité de la chaine au métier.'

44 As Forbes (1964: 201 n. 19) notes, heddle-loops seem to be associated with *kaîros* in a couple of passages in Torahic texts: 'We read about the loops of the heddle called *nîrîm* which can also be found at the *ḳêrôs* which keeps the warp threads apart'; although the term *ḳêrôs* looks like a loan word from Greek *kaîros*, one passage is particularly telling in that it mentions (*Shabbat* 105a9) 'one who makes two meshes, i.e., ties the threads of the warp, attaching them to either the *nirim* or the *keiros*'.

45 As Barber (1991: 267) notes in her excellent discussion of μίτος (which spans pp. 266–68), which indisputably situates the term within the group of three types of 'orderly threads' on the warp-weighted loom, namely warp, weft, and heddles; *mitos* appears to be the thread/string of the heddle-loops, made of linen and 'propagator for expressions of orderliness' (p. 267, with reference to κατὰ μίτον or κατάμιτον 'in due order': see e.g. Polybius 3.32.2 and Pherecrates 156.7 *PCG*; interestingly, the abstract term καιρός, homograph of καῖρος, is also generative of adverbial expressions, like κατὰ καιρόν 'in due measure, opportunely', pointing to a notion of order).

46 Hesychius *s. v.* κανών (κ681 L.-Cunn.): 'some say that *kanōn* is the rod around which the *mitos* (is wrapped)' *Scholia Hom. Il.* 23.762 Erbse: '*kanōn* is the rod around which the *mitos*, the weaving device, is wrapped (εἱλεῖται)'. The pulling of the *kanōn* towards to the breast of the weaver to create the mechanical shed, and the insertion of the spool with weft along the *mitos* are represented in a vivid Homeric simile (*Iliad* 23.758–63). A clear description of the mechanism of the artificial shed on the warp-weighted loom, in the basic setup of tabby, is offered by Öhrman (2017: 280): 'A detachable and higher-set heddle-rod is used to create one or more artificial sheds as loops or leashes are made to connect the warp-threads suspended behind the shed-rod, so that these can be pulled forward through the front-most part of the warp, thus creating a new opening between the two parts of the warp'.

47 Of a sort of crisscrossing or 'exchange' (the Greek verb is ἐναλλάσσειν) between the two (odd and even) halves of warp threads 'towards interlacing it with the weft' (εἰς πλοκὴν τῆς κρόκης, Eustath. *Od.* 7.107, 1571.62 Stallbaum).
48 Hoffmann 1964: 42, with pictures of the installation of the spacing cord (p. 44).
49 Blümner (1912: 146) mentions the practice among Scandinavian warp-weighted loom weavers of attaching a spacing cord to the upper part of the loom, where the fabric begins: this might well be a confusion caused by misunderstanding the technology of the starting border. Following Blümner on this point, see Gallet 1990: 26–28.
50 See the excellent discussion by Barber (1991: 110–13).
51 See below.
52 Though by any standard an excellent treatment of crucial terms like *mitos* and the series *diasma/diazesthai*, Barber 1991: 267–68 (μίτος as heddle string) and 271–72 (δίασμα as starting border with warp threads hanging, διάζεσθαι as referring to 'either the manufacture of the band' or the division and distribution of the warp threads) does not hint at the fact that, in lexicographical as in literary sources, these crucial notions are part of a constellation of terms in tight relation with one another.
53 The *Etymologicum Magnum* provides under the *lemma* δίασμα an interesting description of the term ('the first operation [of the production] of the garment'), and an attempt at deriving its etymology, which it connects to *daisis* (δαῖσις) 'apportioning' and, semantically, to *merismos* 'division': 'since they [the weavers] distribute the warp threads' (ἐπεὶ τοὺς στήμονας διαμερίζουσιν).
54 Less technical in the register, and more diffused in the literary record, is the expression στῆσαι τὸν στήμονα 'setting up the warp' (with the variant ἱστόν in place of στήμονα, a construct recurrent in Archaic epic: *Od.* 2.94, 24.129, Hes. *Erg.* 779); the equivalence with προφορείσθαι and διάζεσθαι is pointed out by Pollux *Onom.* 7.33 'setting up the warp (στῆσαι τὸν στήμονα)… is also called προφορεῖσθαι: for this way (i.e. προφορείσθαι) the inhabitants of Attica used to call what we now call διάζεσθαι'; see the detailed discussion in Stefanelli 1983: 413–15.
55 Compare with the image of 'running up and down the (same) street' (προφορεῖσθαι ὁδόν) in Aristophanes *The Birds* 4, glossed by the scholiast as 'moving in opposite direction here and there' (δεῦρο κἀκεῖσε πορευόμεναι εἰς τἀναντία), and that of dogs 'passing over the same footsteps over and over' in Xenophon *Cynegeticus*. 6.15.
56 *Schol.* Arist. *Av.* 4 (p. 10 Williams = *Suda s.v.* προφορουμένω π2925 Adl.): προφορεῖσθαι γὰρ λέγεται τὸ παραφέρειν τὸν στήμονα ταῖς διαζομέναις.
57 Nicophon fr. 13 *PCG* ὁ δ' ἐξυφαίνεθ' ἱστός, ὁ δὲ διάζεται. Here, as in several occurrences in Archaic Greek poetry, the term *histos* (in textile-related contexts generally meaning 'loom') doubles as a generic, less technical synonym of *stēmōn* 'warp' (see the formulaic phrase στησαμένη μέγαν ἱστόν 'having set up the warp' in Homer *Odyssey*. 2.94, 24.129; similarly, Hes. *Erga* 779). The verb ἐξυφαίνειν 'weave

out' occurs, with 'song' (μέλος) as its subject, in Pindar *Nem.* 4.44.

58 *Suda*, under the *lemma* Χαλκεῖα (χ35 A.): ἱέρειαι μετὰ τῶν ἀρρηφόρων τὸν πέπλον διάζονται 'the priestesses with the Arrhephoroi maidens make the setup [alternatively: 'weave the starting border'] for the *peplos*'; on the institution of the Arrhephoroi and its ritual connotations see the detailed study by Burkert (1966).

59 Hesych. *s.v.* ἀρκάνη (α73 L.-Cunn.): τὸ ῥάμμα ᾧ τὸν στήμονα ἐγκαταπλέκουσιν διαζόμεναι, an explanation that would make excellent sense if referred to the starting border.

60 The fragment (*Et. M.* p. 270.18 *s.v.* δίασμα = 520 Pf. εἰ δε ποτε προφέροιντο διάσματα, φάρεος ἀρχήν) is interesting as it once again showcases Callimachus' liberal usage of the technical terminology of weaving in poetic context; *diasmata* (plural of *diasma*) is here possibly denoting the starting border with the ordered warp threads attached and ready to be installed on the loom.

61 The etymological connection between English 'order' and Latin *ōrdior* 'to set up the warp', appealing as it sounds, must account for the fact that Latin *ōrdō* 'order' and *ōrdior* were not, according to Meillet, *DELL*, 467–68, perceived by the Romans as sharing a kinship.

62 Trédé–Boulmer (2015) offers a comprehensive investigation into the notion, from Homer to the end of the fourth century BC; Gallet (1990) presents an articulate discussion of the occurrences of the term in Pindar; see the survey on the studies on καιρός in Race 1981: 197 n. 1.

63 Bibliographical references are limited to scholarship on Archaic and early Classical occurrences of καιρός (roughly, from Hesiod to tragedy); especially relevant studies for the purpose of this contribution are Onians 1951: 343–48; Gallet 1990: 9–176; Tréde-Boulmer 2015; Wilson 1980; Race 1981, all with further bibliography.

64 The immediate context of Hesiod's *Works and Days* 694 (not overloading a wagon) suggests giving καιρός in the phrase 'keep the measure; *kairós* is best in all matters' (μέτρα φυλάσσεσθαι· καιρὸς δ' ἐπὶ πᾶσιν ἄριστος) the sense of '"the right degree" between too much and too little' (Wilson 1980: 179); more pronounced ethical connotations invest the usage of *kairós* in gnomic-sapiential literature: 'avoid excess; all fair things belong to *kairós*' (μηδὲν ἄγαν· καιρῷ πάντα πρόσεστι καλά) is a saying assigned to Chilon (one of the Seven Sages) in an epigram by Critias (7 West).

65 See Wilson 1980; the richest and most consistent repertoire of occurrences of Archaic καιρός is represented by Pindar's victory odes: see Gallet 1990.

66 The three passages listed by Onians as exemplifying the strand of imagery of καιρός as 'target, mark' are: Pind. *Nem.* 1.18 'hitting the *kairós* without any falsehood' (καιρὸν οὐ ψεύδει βαλών: an alternative interpretation is possible, though), Aesch. *Ag.* 365 (Zeus' arrow against Paris 'not falling short of the mark' μήτε πρὸ καιροῦ: an alternative interpretation is preferable), Eur. *Suppl.* 745 ('Oh you who strain your bow beyond the mark' καιροῦ πέρα). Interestingly, καιρός is not attested in Homer: potential traces of its circulation are four occurrences of the adjective καίριος in the *Iliad* (*Il.* 4.185, 8.84, 8.326, 9.439) where the term seems to indicate 'a place in the body where a weapon could easily penetrate to the life within' (Onians 1951: 344; see Trédé-Boulmer 2015: 23–29). Drawing on the archaeological remains of Mycenean bronze armour, Gallet (1990: 48–62) builds a case for the derivation of καίριος from *kaîros* (καῖρος), arguing that the fatal/lethal/decisive spot indicated by the adjective in the *Iliad* passages is not to be placed in the body but in the warrior's armour, where leather laces connect the metal plates at the borders.

67 Overall, the intuition that animates Onians' hypothesis about the common semantic ground of καῖρος and καιρός is remarkable, and it seems to grasp something fundamental about the notion; as has been noted, however, the details of the argument show some weakness – systematicity should be aimed at in semantic analysis, and Onians' choice and interpretation of the relevant literary passages containing the term καῖρος is highly selective at best.

68 Onians 1951: 345; though not decisive for the plausibility of Onians' argument, it is worth noting that there is no reference to καῖρος in the *Odyssey* passages (19.577–8 = 21.76–7; 21.419–23) describing the archery context, nor to a passage or penetrable opening, to be sure.

69 Onians 1951: 345.

70 Onians 1951: 345: 'it will explain καιρός and καίριος of parts of the body through which weapons could penetrate to the life within. It will explain καιρός apparently with a sense like 'parting, division'. It will also explain the use of καιρός to express 'opportunity', εἰς καιρόν, κατὰ καιρόν, etc.'.

71 Hesychius' *kairōmata* would indicate the individual heddle-loops, while the singular *kaîros* the row of loops; Hesychius' *interpretamentum*, as we have seen at section 2.3 above, reports that 'καιρώματα are the interweavings/bindings that keep the warp-threads separated'. Quite clearly, the passage that the artificial shed generates, with the series of triangular-shaped openings, is for Onians at the origin of the analogy that extends the use of καιρός to indicate the 'penetrable aperture' where archers aim.

72 Onians 1951: 346. The rest of Onians' discussion deals with a semantic and etymological analysis of the association between 'opening, passage through' and 'opportunity': Latin lets the connection emerge at its neatest (*opportunitas* from the root of *porta* 'entrance').

73 See e.g., Pind. *Pyth*. 4.286: 'since *kairós* in men's affairs has a brief span (*metron*)' (ὁ γὰρ και– / ρὸς πρὸς ἀνθρώπων βραχὺ μέτρον ἔχει); the sense of καιρός here seems to be 'the opportunity gained by not procrastinating', but also (especially in the immediate context of the ode) 'general flexibility' and 'right discrimination' (Wilson 1980: 185).

74 It is fair to admit that only a limited portion of the semantic range and usage of καιρός can be connected to the reconstructed meaning and notion of καῖρος: attempts at demonstrating a systematic derivation of occurrences of *kairós* from *kaîros* and its functions on the loom prove hardly compelling (this is a limit of Gallet 1990).

75 The complementarity of these two components is, Trédé-Boulmer argues (2015: 69), a matter of perception: 'selon le point de vue de l'observateur, le *kairos* peut être considéré comme point de séparation ou point de jonction de deux éléments d'un même object ou d'une même situation; la même réalité est conçue comme présentant deux aspects complémentaires: separation et jointure.' Interestingly, Trédé-Boulmer (p. 69) remarks that technical languages exhibit with particular clearness the fundamental association between separation/division and junction/connection. On *kairós* as *symmetria* see Trédé-Boulmer 2015: 66–69.

76 Photius 123.15; Pollux *Onomasticon* 7.33. Separating and combining are indeed the distinctive components of the craft of weaving, as a number of Platonic passages point out: *Crat.* 388b (on the act of κερκίζειν as separating [διακρίνειν] warp and weft), *Pol.* 281a (on the art of weaving as *symploké*), and most explicitly at 282b4–283b2, where the art of combining (ἡ συγκριτική) and the art of separating (ἡ διακριτική), which exemplify the very method of *diairesis*, are applied to the enquiry into the art of weaving.

77 See n. 78 above and the excellent discussion of *Cratylus* 388b in Ademollo, 107–10.

78 For *poikilia* see Harlizius-Klück and Grand-Clément, both in this volume; for *kosmos* see Fanfani and Harlizius-Klück (forthcoming).

79 καιρὸν εἰ φθέγξαιτο, πολλῶν πεῖρατα συντανύσαις / ἐν Βραχεῖ, μείων ἕπεται μῶμος ἀνθρώ– / πων· Detailed discussions of the passage in the broader contexts of the respective epinicians occur in Bergren (1975: 148–58) and Gallet (1990: 103–15).

80 ἀρεταὶ δ᾽αἰεὶ μεγάλαι πλύμυθοι· / βαιὰ δ᾽ ἐν μακροῖσι ποικίλλειν / ἀκοὰ σοφοῖς· ὁ δὲ καιρὸς ὁμοίως / παντὸς ἔχει κορυφάν. Gallet (1990: 83–103) offers a rich and stimulating discussion of the passage: by taking καιρός as an instance of syllepsis (literary ambiguity) on the part of Pindar, Gallet claims that the context invites a literal reading where καῖρος makes satisfying sense of the *gnōmē*, and he views καῖρος here as indicating the starting border which 'holds the summit of the whole fabric applying constant tension'; a detailed discussion of Gallet's argument would exceed the scope of this contribution: suffice to say that his reading appears to force the Greek of Pindar beyond the semantic range of some terms. See Fanfani 2018: 21.

81 The perception of brilliance and animation on a surface is a peculiar effect of ποικιλία: see Harlizius-Klück and Grand-Clément, both in this volume.

82 Kurke and Neer 2019: 1–5.

83 Foucault 1970: xv–xxiv.

84 Kurke and Neer 2019: 4.
85 The concept of epistemic landscape draws on Foucault (1970: xxiii–xxiv). Kurke and Neer, (2019: 25) aptly remark, after discussing the interaction (rather than contraposition) of material drawing and rational *logos* in the famous episode of Aristagoras of Miletus and King Cleomenes of Sparta in Herodotus 5.49–53, how 'so far from being immutable, rules of measurement and algorithms of conversion are precisely what ought to be up for historical analysis', and conclude that 'a nonreductive approach affords a richer and more capacious view of Greek technologies of space' (2019: 28).
86 Foucault 1970: xxiii–xxiv.

NOTE ON ABBREVIATIONS AND CONVENTIONS

The following abbreviations for reference editions and modern lexica are used:

PCG: *Poetae Comici Graeci*. 8 vols., R. Kassel and C. F. L. Austin, eds, (Berlin–New York: W. de Gruyter, 1983–1998).
DELG: Chantraine, Pierre. *Dictionnaire Étymologique de la Langue Grecque* (Paris: Klincksieck, 1968–1980).
DELL: Ernout, Alfred and Meillet, Alfred. *Dictionnaire Étymologique de la Langue Latine. Histoire de Mots* (Paris: Klincksieck, 2001 [first edition 1932]).

The texts of the lexicographers are cited according to the following editions:

Hesychius: *Hesychii Alexandrini Lexicon. Volumen IIa E–I*. Recensuit et emendavit Kurt Latte. Editionem alteram curavit Ian C. Cunningham. (Berlin: De Gruyter, 2020).
Suda: *Suidae Lexicon*. *Pars III K–O*. Edidit Ada Adler (Stuttgart: Teubner, 1967).
Eustathius: *Eustathii Commentarii ad Homeri Odysseam. Tomus I*. J.G. Stallbaum, ed. (Leipzig: J.A.G. Weigel, 1825).
Pollux: Pollucis Onomasticon. Fasciculum Posterior Libri VI–X Continens. E. Bethe, ed. (Leipzig: Teubner, 1931).
Etym. Magn.: *Etymologicon Magnum.* T. Gaisford, ed. (Oxford: Oxford University Press, 1848).
Schol. Hom. Od.: *Scholia Graeca in Homeri Odysseam. Tomus I*. Wilhelm Dindorf, ed. (Oxford: Oxford University Press, 1855).
Schol. Hom. Od.: *Scholia Graeca in Odysseam, IV, scholia ad libros η–θ*.
Filippomaria Pontani, ed. (Rome: Edizioni di Storia e Letteratura, 2020).
Schol. Arist. *Av.*: *The Scholia on the Aves of Aristophanes*. John Williams White, ed.

(Boston–London: Ginn and Company, 1914).

Passages from ancient works follow the abbreviations of *The Brill Dictionary of Ancient Greek*, Franco Montanari, ed. (Editors of the English Edition: M. Goh & C. Schroeder) (Leiden–Boston: Brill, 2015).

REFERENCES

Ademollo, F., *The* Cratylus *of Plato: A Commentary* (Cambridge: Cambridge University Press, 2011).

Barber, E. J. W., *Prehistoric Textiles: The Development of Cloth in the Neolithic and Bronze Ages* (Princeton: Princeton University Press, 1991).

Bergren, A. T., *The Etymology and Usage of Πεῖραρ in Early Greek Poetry* (Oxford: American Philological Association, 1975).

Blümner, H., *Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern* (Leipzig–Berlin: Teubner, 1912).

Burkert, W., 'Kekropidensage und Arrhephoria: vom Initiationsritus zum Panathenäenfest', *Hermes*, 94 (1966): 1–25.

Crowfoot, G., 'Of the Warp-Weighted Loom', *The Annual of the British Institute in Athens*, 37 (1936/1937): 36–47.

Cullhed, E., *Eustathios of Thessalonike: Commentary on Homer's Odyssey*. Volume 1. On Rhapsodies A–B (Uppsala: Acta Universitatis Upsaliensis, 2016).

Dickey, E., *Ancient Greek Scholarship* (Oxford: Oxford University Press, 2007).

Edmunds, S., 'Picturing Homeric Weaving', *Donum natalicum digitaliter confectum Gregorio Nagy sptuagenario a discipulis collegis familiaribus oblatum*. http://chs.harvard.edu/CHS/article/display/4365. (Center for Hellenic Studies, 2012).

Fanfani, G., 'Craftsmanship and Technology as Chorality: The Case of Weaving Imagery in Archaic and Classical Choral Lyric', *Dionysus ex Machina* 9 (2018): 9–40.

Fanfani, G., and E. Harlizius-Klück, '(B)orders in in Ancient Weaving and Archaic Greek Poetry', in G. Fanfani, M. Harlow, and M.-L. Nosch, eds, *Spinning Fates and the Song of the Loom: The Use of Textiles, Clothing and Cloth Production as Metaphor, Symbol and Narrative Device in Greek and Latin Literature* (Oxford: Oxbow Books, 2016), pp. 61–99.

Fanfani, G., and E. Harlizius-Klück, 'Pattern Weaving as Knowledge in Early Greek Thought', in R. Hahn and A. Herda, eds, *Knowledge in Archaic Greece* (Washington DC: Center for Hellenic Studies, forthcoming).

Forbes, R. J., *Studies in Ancient Technology*. Volume IV (Leiden: Brill, 1964).

Foucault, M., *The Order of Things: An Archaeology of the Human Sciences* (New York:

Tavistock Publications, 1970).

Gallet, B., *Recherches sur* kairos *et l'ambiguïté dans la poésie de Pindare* (Bordeaux: Presses Universitaires de Bordeaux, 1990).

Garvie, A. F., *Homer.* Odyssey. *Books VI–VIII* (Cambridge: Cambridge University Press, 1994).

Hertzberg, W., 'Bemerkungen zur Cultur den Griechen in Homerischer Zeit', *Philologus* 33 (1873): 1–12.

Hoffmann, M., *The Warp-Weighted Loom* (Oslo: Universitetsforslaget, 1964).

Kurke, L., and R. Neer, *Pindar, Song, and Space: Towards a Lyric Archaeology* (Baltimore: John Hopkins University Press, 2019).

Michel, C., and M.-L. Nosch, 'Textile Terminologies', in C. Michel and M.-L. Nosch, eds, *Textile Terminologies in the Ancient Near East and Mediterranean from the Third to the First Millennium BC* (Oxford: Oxbow Books, 2010), pp. i–xix.

Nagy, G., *Plato's Rhapsody and Homer's Music: The Poetics of the Panathenaic Festival in Athens* (Washington DC: Center for Hellenic Studies, 2002).

Neri, C., 'Telai, conocchie, fusi, e … lessicografe (per amor di ΗΛΑΚΑΤΗ)', in A. Casanova, G. Messeri, and R. Pintaudi, eds, *E sì d'amici pieno. Omaggio di studiosi italiani a Guido Bastianini per il suo settantesimo compleanno* (Firenze: Edizioni Gonnelli, 2016), pp. 555–63.

Onians, R. B. *The Origins of European Thought* (Cambridge: Cambridge University Press, 1951).

Öhrman, M., 'Listening for *licia*: a Reconsideration of Latin *licia* as Heddle-leashes', in S. Gaspa, C. Michel, and M.-L. Nosch, eds, *Textile Terminologies from the Orient to the Mediterranean and Europe, 1000 BC to 1000 AD* (Lincoln: University of Nebraska-Lincoln Libraries, 2017), pp. 278–87.

Pfeiffer, R., *Callimachus. Volumen I* (Oxford: Clarendon Press, 1949).

Race, W. H., 'The Word Καιρός in Greek Drama', *Transactions of the American Philological Association* 111 (1981): 197–213.

Restani, D., 'I suoni del telaio: Appunti sull'universo sonoro degli antichi Greci', in B. Gentili and F. Perusino, eds, *Mousike. Metrica, ritmica e musica greca in memoria di Giovanni Comotti* (Pisa–Roma: Istituti Editoriali e Poligrafici, 1995), pp. 93–109.

Simpson, M., 'The Chariot and the Bow as Metaphors for Poetry in Pindar's Odes', *Transactions and Proceedings of the American Philological Association* 100 (2015): 437–73.

Stefanelli, R., 'Per un tentativo di recupero dei lessici tecnici: La terminologia greca relativa all'orditura', *Annali della Scuola Normale Superiore di Pisa* 13.2 (1983): 403–19.

Thomas, R. F., 'Callimachus, the Victoria Berenices, and Roman Poetry', *The Classical*

Quarterly, 33 (1983): 92–113.
Tosi, R. *Studi sulla tradizione indiretta dei classici greci* (Bologna: CLUEB, 1988).
Trédé–Boulmer, M., *Kairos. L'à-propos et l'occasion* (Paris: Les Belles Lettres, 2015).
Wilson, J. R., 'Kairos as 'Due Measure'', *Glotta*, 58 (1980): 177–204.

5

WOVEN WITNESS: PHILOMELA, PROCNE AND VISUALISED NARRATIVES THROUGH TEXTILES

Anthony Tuck and Cole Reilly with Cinzia Presti and Joseph Capozzi

PROCNE, PHILOMELA AND THE PLAY OF *TEREUS*

THE NARRATIVE OF THE ATHENIAN PRINCESS PHILOMELA IS AMONG THE MORE troubling of the corpus of Greek myths.[1] Philomela's sister, Procne, is married to the Thracian king Tereus. After years of marriage, Tereus ventures to Athens, promising to bring Philomela back to visit with her sister. However, on their journey, Tereus betrays Procne and rapes Philomela. To obscure his violation of his wife's sister, Tereus cuts out Philomela's tongue. Now voiceless, Philomela weaves the account of her rape into a textile, a cloth that is presented to Procne. Upon receiving this textile and learning of her husband's actions, Procne kills their child, Itys, and feeds him to Tereus.

The grisly myth was the subject of a play by Sophocles (since lost), entitled *Tereus*.[2] The original performance of the play may have been memorialised by the commissioning of a statue depicting Procne moments before the murder of Itys, an image that was originally placed on the Akropolis of Athens (figure 5.1).[3] The play's limited surviving fragments provide few clues as to its original

FIG. 5.1 Procne & Itys, Athens Akropolis, late fifth century BCE (photo by Marios Philippides)

staging, but a curious reference to the play in Aristotle supplies a hint as to a prop likely used to facilitate Procne's recognition of Tereus' crime. Aristotle appears to suggest Philomela uses the 'voice of the shuttle' to communicate with her sister.[4] In the absence of the play's text, the precise meaning of this phrase remains obscure. Clearly, Philomela's glossectomy renders her mute, but her ability as a weaver permits her to communicate with her sister in unusual detail.

While the limitations of available evidence make certainty on many points impossible, we may still profitably speculate as to how Philomela's textile could communicate in this manner. One solution is simply to imagine that Procne receives Philomela's textile and moves offstage to examine it, returning to report what she has learned. However, recent work on props in Athenian drama argues that some objects 'attain the status of silent, nonhuman characters' (Mueller 2016: 7). Aristotle's characterisation of the 'voice of the shuttle' certainly appears to support this claim and suggests that Philomela's textile was an intended, visible feature of the performance. Other aspects of Sophoclean drama definitely employed props and it seems reasonable to assume that *Tereus* did in this case as well.[5] Therefore, it is likely that the play's original staging would have required the use of an actual textile of some form to facilitate the performance's *anagnorisis* scene.

Most attempts to reconstruct the play suggest Philomela weaves an actual text into her cloth (Dobrov 1993: 204; Fitzgerald 2001: 97–98). A minority of scholars have suggested the narrative is communicated through pictorial tapestry (Cahill 1995: 29–30). Either is possible, although both solutions create additional problems of prop design and staging. Indeed, it is difficult to imagine how Tereus would remain unaware of Philomela's strategy if he were present during the production or presentation of either form of cloth.[6] To these possibilities, we might add another. Sophocles' performance may have employed a textile depicting a geometric or non-figural pattern. However, as we will detail below, an Athenian audience may have potentially understood that non-figural patterns in textile could result from performed, mnemonic devices taking the form of metrically organised narratives encoding information related to those patterns. Conceivably, women from the same family who grew up producing textiles together would be able to recognise underlying narrative forms from whatever pattern resulted from the intertwined processes of recitation and weaving.

TEXTILE PRODUCTION AND SONG

The metaphorical notion of poetic performance as an act of weaving is widely observed across a range of linguistic and poetic traditions (West 2007: 36–38; Nagy 2008: 2§92; Fanfani 2017). However, observation of modern weaving in non-industrialised areas of central Asia shows that, within domestic spaces, there exist traditions of singing while weaving (Tuck 2006).

For example, the nineteenth-century rug merchant John Mumford records the following concerning the production of textiles in central Asia:

> But in the more remote sections, and among the nomads, women do all the weaving. They are the designers, too. They invent from year to year all the modifications of the old patterns. The head woman, the traveler Vámbéry relates, makes a tracing upon the earth, doles out the wool, and in some of the tribes chants in a weird sing-song the number of stitches and the color in which they are to be filled, as the work goes on (Mumford 1900: 25).

Recent ethnomusicological documentation captures a similar, surviving tradition in Iran (Aminian 2020; Aminian forthcoming; Seyf 1990: 210). Naqshe Khani – or Pattern Singing – possesses a number of regional variations. In southeast Iran, musical phrases are repeated with lyric variations signalling changes in the colour, count and position of knots in pile carpets. In this instance, the singing coordinates the knotting of multiple weavers, controlling the symmetricity of the woven design. Each repeating musical phrase communicates the number of knots of a given colour and their direction, and concludes in an audible shift in tone, signalling the end of that element of information.

The consistent characterisation, throughout Homeric poetry, of women singing while engaged in weaving (Tuck 2006) invites comparison with Mumford's description of central Asian women performing a 'weird sing-song' related to the numerical position of specific points of coloured thread within a large, knot-pile composition. While the text of the Odyssey does not record any detail concerning the songs of Calypso and Circe, the weaving of Circe is described as producing a 'great design,' suggesting some sort of patterning (*Od.* 10.220–28). Later texts such as that of Euripides' *Hecuba* record a similar tradition of singing in association with textile production, as does a fragment of Sophocles' *Epigonoi* (Euripides *Hecuba* 218–24; Sophocles *Epigonoi*, P Oxy 4807).

Furthermore, Euripides' *Ion* indicates that the environment of textile production sometimes involved the recitation of mythological narratives (Tuck 2009). In the passage below, the play's chorus observes the elements of the sculptural decoration of the Temple of Apollo at Delphi, recognising the images depicted because they hear the stories while weaving.

> Apollo's temple too has the twin pediments,
> Like brows on a smiling face
>
> Look at this! The Lernian snake
> Being killed by Heracles with his golden falchion
> Do look, dear!
>
> Yes, I see. But who is the other next to him
> Waving the flaming torch? Is it the man
> *Whose adventures we are told at weaving-time,*
> The brave fighter Iolaus
> Who went with Heracles to his labors
> And stayed until the bitter end?
>
> Oh! And look here
> At Bellerophon astride his winged horse
> Killing the monster with three bodies
> And fire belching from its nostrils!
> I am looking eagerly on every side.
> See, carved on the marble wall
> The Giants overcome by the Gods in battle!
>
> Yes, we can see it from over here.
> Ah! But behold her there, brandishing
> Her Gorgon shield over Enceladus –
>
> I see her, my own Pallas Athena!
>
> And the thunderbolt, smoldering and irresistible,
> Which Zeus holds ready to hurl form heaven!

> I see huge Mimas fiercely raging,
> Charred with the flame of the thunderbolt.
>
> Here's another earth-born giant
> Destroyed by Dionysus with no weapon
> But his thyrsus wreathed with ivy-shoots (Vellacott 1954: 40–41, emphasis added).

It is also encouraging to note that an Athenian audience witnessing a performance of the *Ion* would recognise that three of the mythological episodes described by the play's chorus are drawn from the Gigantomachy, a subject matter directly related to the production of the *peplos* of Athena, a garment that depicted the very same mythological narrative (Barber 1992). The correlation between stories heard while weaving and episodes from the Gigantomachy hints at a tradition – that would certainly be known to an Athenian audience – linking the performance or recitation of certain narrative forms to ritualised production of specific types of textiles.

Perhaps reflecting a similar phenomenon from an adjacent linguistic and cultural environment, a loom weight now housed in the Archaeological Museum of Este, Italy, preserves an inscription that has been translated as follows:

> Between the warps with speedy bobbins
> You weave and sing your songs of heroes[7]

Modern research concerning the sung performance of Homer and early musicality has illuminated many aspects of the auditory environment wherein such narrative would have been received (West 1981). However, and perhaps understandably, comparably little academic attention has sought to reconstruct the audial environment of textile production in Archaic manufacturing environments (Restani 1995). And yet, the few available points of evidence suggest that singing, perhaps related to numerical position on a loom, and potentially also at times in the form of mythological narratives, may have guided the production of pattern textiles in environments like that envisioned by a playwright such as Sophocles and in which he placed his character of Philomela.

This observation may help explain how Sophocles' audience would have understood the idea of the 'voice of the shuttle' and a textile that communicates a complex narrative. Within a family's tradition of weaving, we might imagine that specific patterns – abstract or otherwise – would have been immediately recognisable to siblings as representative of larger narrative forms.[8]

A PROOF OF CONCEPT

Reference to the Philomela myth in Homer and Hesiod suggests critical aspects of the legend were known to the Greek population at a point at least as early as the early Archaic period. Given the nature of the organic materials used in their production, examples of textiles dating to this period are

FIG. 5.2 Pedestal Krater, Athens, mid eighth century BCE (photo credit: Metropolitan Museum of Art Open Access Collection)

extraordinarily rare. However, numerous depictions of textiles are found on ceramic vessels associated with visible aspects of burial from this period. For example, numerous large ceramic amphorae and kraters used to mark places of burial employ scenes of *prosthesis* (Souza and Dias 2018). The body of the deceased is placed upon a bier as mourners stand to either side. Immediately beside the bier, mourners or attendants lift a funerary shroud, revealing the body of the deceased (figure 5.2). In virtually all such scenes, the image of the shroud is depicted with the same pattern of a repeating checkerboard-like design. Curiously, examples of lekythoi of later date – vessels frequently associated with funerary behaviours – are sometimes ornamented with a notably similar pattern. Several such lekythoi employ the pattern in a slightly diagonal form or with subtle variation in the geometry of the design, such as that visible in figure 5.3.

FIG. 5.3 Attic Lekythos with checkerboard pattern, mid fifth century BCE. Collection of Smith College (photo credit: Anthony Tuck with permission Prof. Scott Bradbury, Curator of the Smith College Cabinet of Antiquities)

As we will attempt to show below, the patterns represented on these types of ceramics display a curious similarity to graphic representation of certain metrical forms. To return to the myth of Procne and Philomela, an 'intact' version of the myth survives only in very late sources (Ovid *Metamorphosis* VI, 400–674). However, it is highly likely that if earlier versions of it were part of, and performed as part of, a rhapsode's repertoire, their performance would have followed the metrical structures seen in the rare examples of surviving texts of the early Archaic period – e.g., the *Iliad* and *Odyssey*.

The generational relationship of these two surviving Homeric texts to the forms that such narratives took during the Early Archaic period is challenging to reconstruct. However, if the performance of early versions of such poems was structured according to the metrical rules of dactylic hexameter (West 1982: 35–39), then it is possible to deduce at least a few features of the audial environment of their performance (West 1981: 114). The audience would hear variation in long and short vowels, with certain expressions of such variation occurring with predictable regularity. If we then imagine that such long and short vowels signalled to weavers some variation of dropping over or under the warp threads of a loom, those metrical forms would result in predictable patterns.

To test this concept, we imagined a scenario wherein the metrical patterns of the text of the *Iliad* communicated such information. Manually graphing variation of long versus short vowels is possible but was deemed prohibitively time consuming. In order to facilitate the quick production of multiple visualisations of patterns resulting from the visualisation of the *Iliad*'s meter, we constructed an algorithm, implemented in the Python programming language, that does the work of populating a weave pattern and saving it as an image.[9]

The scansion data for each book of the text was stored in its own CSV file, a filetype used commonly for simple spreadsheets. Each row of the file contains information including what line the sound is on, the number word the sound comes from, and whether the sound is a long or a short. An additional file was created conflating the metrical data for all 24 books stitched together into one continuous CSV.

In its simplest form the algorithm takes in the desired thread-count along with the specific book or books of the *Iliad*, and returns a 2D image where each pixel is coloured depending on whether the corresponding sound is long or short. The thread-count represents the number of threads that would have been in the loom, and as such is the number of pixels along the horizontal axis of the image. The algorithm constructs a table that has columns equal to the desired thread-count, and however many rows are needed to represent every sound in that book or books. The algorithm then looks at every sound in order and puts in colour data for that sound in the correct cell. The colour data is represented in an RGB value, and the cells were originally populated left to right, top to bottom. Later, in order to capture a more accurate form, the image was created by mirroring a boustrophedon-like style of the directional reversing of a shuttle passing through repeated sheds. For example, if the algorithm were fed the pattern short – short – long, the thread-count was set to 2, and short was black and long was white, the algorithm would construct a 2x2 matrix like this:

(255,255,255)	(255,255,255)
(0,255,0)	(0,0,0)

The top left cell is populated first, then the top right. From that point the algorithm moves down a row and populates the bottom right cell. When converted into an image each cell becomes a pixel with the colour of whatever is written in the cell. This would then become an image with a black line across the top, and below it a line that is half green and half white. Green serves as the default colour to make any errors in encoding obvious. The algorithm also has an enlargement process, where it takes a value 'k', and each cell is represented as a block of k by k pixels (if k=2 the cell is a group of 2x2 pixels, creating an image that would be 4 times larger). This process only increases the resolution of the final image and does not affect the placement or order of the cells in any way.

We call that algorithm 'singleweave', as it produces a single representation of a pattern at a specific thread-count. This creates single image visualisations of the poem's meter expressed at a specified horizontal count. While this method was initially useful, our team quickly realised that our inability to predict possible relationships of such patterns to a hypothetical loom's warp thread-count made the resulting, episodic representation less useful than we had hoped. As a result, we designed a slightly more advanced algorithm which we called call 'multiweave,' as it produces multiple weave representations at different horizontal count sequences. It does this by taking in a step count, calling the singleweave algorithm with a thread-count equal to the given step count, incrementing the step-count, and after the weave representation is saved as an image, repeating that process until the desired number of images is made. Multiweave always ends when the next thread-count is larger than the number of short and long sounds in that book or books, as this would create a weave representation that only has a single row. Both algorithms produced the described result trivially, and as such a formal mathematical proof of correctness will not be provided. The worst-case running time of an algorithm describes in terms of the provided input the maximum amount of time required to finish running the algorithm. The worst-case complexity of singleweave is O(n*(k^2)) where n is the number of sounds considered, and k is the magnification number. In order to create the image, each of the n sounds has to be looked at and placed into the grid, and each one of those spots on the grid has to be enlarged into a k by k square, where k is the desired enlargement value. The worst-case complexity of multiweave, then, is the time it takes to run singleweave s times, O(s*n*(k^2)). Each progressively greater number of the horizontal count is represented as an expanding grid, which allowed us to see certain repeating patterns as the horizontal count grew. However, while intriguing, none of the resulting patterns could be described as sufficiently coherent as to justify the belief that the poem's meter contained obvious, expressible patterns.

For example, figure 5.4 represents the metrical form of the *Iliad* in its entirety at a point count along the horizontal axis of 775 points when expressed through this process. To better mimic the weaving process, the metrical pattern is represented in a boustrophedon form – with its directionality alternating between left and right with each successive register.

Following this experiment, we were challenged to imagine an audial environment wherein some specific, repeating feature of the poem's meter signalled a shift or change in either the form or visibility of the associated visualised space.[10] We imagined that the audible form of the two short vowels of each dactyl might represent a point at which a weaver dropped beneath a warp thread. To explore

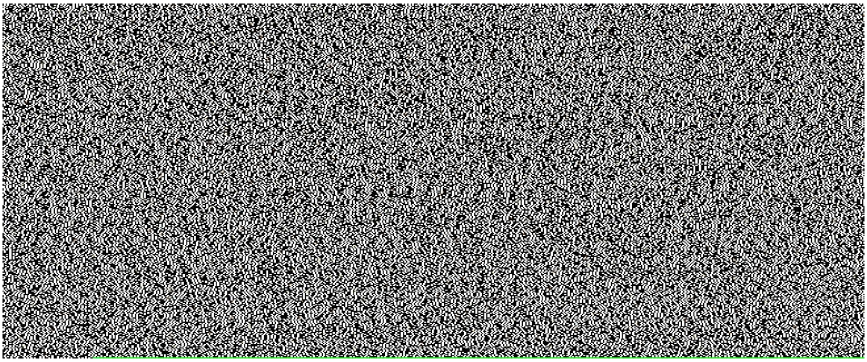


FIG. 5.4 Iliad graph at 775 point count

this possibility, the algorithm was modified slightly. Instead of having each syllable expressed with its own cell, pairs of short vowels were given a single cell on the table.

In order to accomplish this, the algorithm kept track of the last sound it found. When the next row of the CSV was looked at, the algorithm checked to see if the last sound it saw was short – if it was not, then the program continued as normal. If the last sound *was* short, the program skipped this current sound and moved directly onto the next. It did this knowing that the sound following a short sound will always be another short. This thus produced the desired effect: short pairs of vowels were represented as a single pixel instead of two, and nothing else concerning the representation was changed.

When the poem's metrical structure in expressed in this manner, a considerably greater degree of pattern coherence emerges. For example, figure 5.5

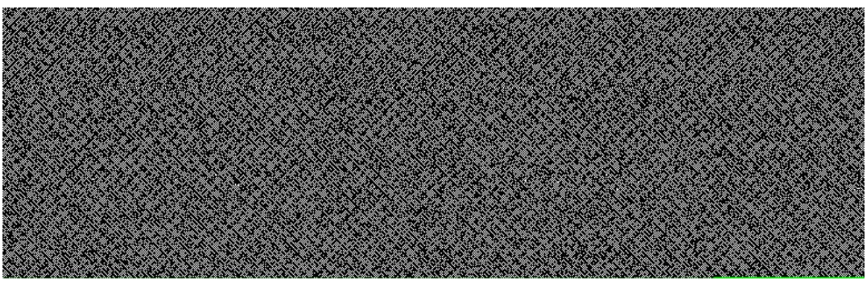


FIG. 5.5 Iliad graph at 775 point count and single short

represents the entire poem's meter visually expressed according to this variation along a horizontal axis of 775 points.

This point count results in a latent hatched pattern which is a result of the regular position of the spondees that conclude each line. Similar patterns with either hatched or diagonal emphasis tend to result from point counts of odd numbers. Conversely, point counts of even numbers tend to result in vertically oriented pattern forms.

Of course, this graph of the *Iliad* at a point count of 775 represents the approximate metrical structure at the terminus of the *Iliad's* textual tradition. Changes and alterations to the text over the course of time between its original conversion from an oral phenomenon into a text and the earliest surviving manuscript of the text surely occurred, and make impossible any attempt to reconstruct the 'original' form of the poem – if such a notion is even applicable to the living tradition of an oral poem. Moreover, the oral form of the poem would have been subject to a range of possible variations depending on any given rhapsodic performance. These changes to metrical patterns such as enjambment or substitution of concluding spondees for trochees would have made little difference in the performance of the poem. However, a weaver reproducing patterns in textiles would have had no such flexibility. Therefore, as an additional experiment, our team decided to graph the 'ideal' metrical pattern of traditional Homeric hexameter. This artificial form simply graphed at repeating intervals 17 units representing the following form:

DACTYL/ DACTYL/ DACTYL/ DACTYL/ DACTYL/SPONDEE

This sequence then consists of: Long/Short/Short: LSS:LSS:LSS:LSS:LL

When each double short is expressed as a single point, the linear counts are arranged in multiples of the 17 'syllables' of each line, and the directionality of each register is reversed in each successive row, a range of predictably geometric patterns form. By way of comparison, this 'pure' dactylic hexameter, represented in figure 5.6 at the same 775 point count as the image of the Iliad's meter shown above, looks like this:

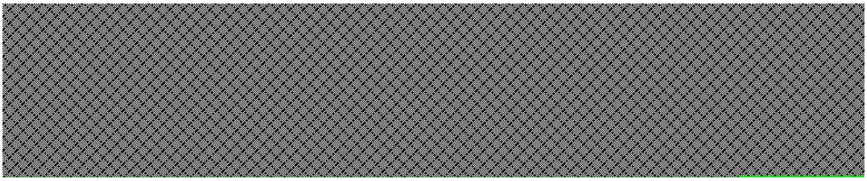


FIG. 5.6 Perfect dactylic hexameter at 775 and single short

The pattern shown above represents only the 'pure' form of hexameter – LSS/LSS/LSS/LSS/LSS/LL. A weaver interested in replicating this specific pattern would need to maintain this count sequence without variation throughout the entirety of a textile's production. However, work upon a warp- weighted loom does allow a weaver a considerable degree of flexibility in altering patterns throughout the process of production. If a weaver were translating a metrically structured narrative into a woven design, regular changes to that metrical pattern would therefore produce predictable, repeating variations to the resulting woven pattern.[11] As many scholars have noted, the registered arrangement of the ornamentation of geometric vase painting is notably similar to woven geometric designs produced in this manner (Barber 1991: 365–72). Moreover, this pattern is strikingly similar to the stylised representations of actual funerary shrouds found on eighth-century BCE vase painting shown above.

Forstall and Scheirer's observation that Long/Long combinations occur with unusual frequency in the first position of a line of the *Iliad* encouraged our team to graph another version where two lines of 17 syllables begin with such a double long. The third line in the sequence returns to the 'ideal' dactylic hexameter form with the first position occupied by a dactyl. At a count sequence of 788 shown in figure 5.7, the resulting graph creates strong zigzag lines and appears thus:

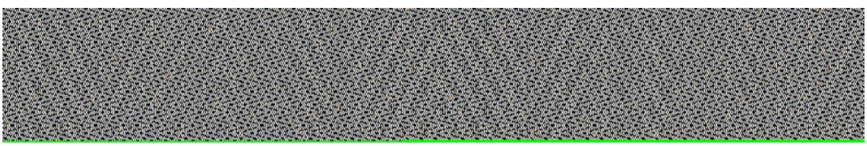


FIG. 5.7 Dactylic hexameter variation at 788 point count and single short

Another expression of the same metrical patterned rendered at a horizontal point count of 850 in figure 5.8 produces an elegantly complex checkerboard pattern:

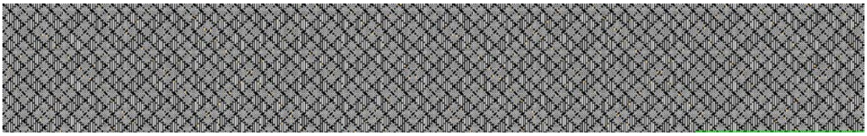


FIG. 5.8 Dactylic hexameter variation at 850 with single short

In total, this experiment generated thousands of different types of patterns, although the limitations of this published format only allow the presentation of a few representative samples. Moreover, those presented here only represent repeating patterns based on sequences of five or fewer 'ideal' or modified 'ideal' lines of hexameter. The repetition of these sequences when visualised in this manner inevitably creates these regular, geometric forms (Harlizius-Klück 2019). We are confident that with additional, detailed development, it would be possible to utilise such graphic representation of metrical variation to produce a wide range of geometric patterns. Moreover, we are especially encouraged to note that the geometric pattern employed on the depiction of a funerary shroud of a mid eighth-century grave marker shown in figure 5.2 represents a pattern easily produced by such a formula.

Of course, the metrical pattern of poems such as the *Iliad* is only one feature of how such poems would have sounded when performed – and it bears repeating that the *Iliad* in its surviving form is not an example of a metrically structured mnemonic device associated with textile production. Instead, we speculate that the poem's metrical form bears some ancestral relationship to such woven patterns, patterns that appear when graphed in the 'ideal' forms presented above. In the hypothetical space of a weaver, musicality such as that of the *Odyssey*'s Circe or Calypso and/or narrative forms such as those of *Ion*'s chorus girls embedded coded information used to signal changes to count or position on a loom, resulting in any number of imaginable variations to these basic patterns.

POTENTIAL APPLICATIONS AND CONCLUDING THOUGHTS

This test of concept shows that metrical patterns used to structure narratives could once have been associated with encoded information resulting in textile patterns. As a result, we might imagine how Sophocles' plot device of the 'voice of the shuttle' and the resulting textile was understood by an audience as communicating narrative information. If an ancient audience for Sophocles' play were aware of traditions of mnemonic devices, perhaps dismissed even then as 'weird sing-songs,' that conveyed narrative along with encoded information that could be rendered as a coherent pattern, perhaps this knowledge would be enough to signal to an audience how sisters might communicate in this manner.

In the same way that figures 5.4 and 5.5 represent the metrical pattern of the *Iliad*'s entirety when expressed at a specific point count, we might imagine how weavers, sufficiently attuned to the relationship between pattern and narrative, could recognise narrative and even communicate through similar abstract forms. The specific effect of designed variations in the code that both communicate narrative and result in distinct geometric patterns would thus serve as both text and textile. There is much we cannot know about the earlier versions of the Procne and Philomela myth. Early and vague reference to it in Homeric texts do not preserve reference to the idea of a textile used to communicate such detailed information about Tereus' crime. However, if this element of the story was present in versions of the myth contemporary with the formation of the Homeric and Hesiodic poems in which they are alluded to, we can be confident that the method of communication used by Philomela was not traditional literacy. The technology of literacy was simply not widely present in the Greek world at such an early date.[12]

There is another, related way in which we might imagine Philomela's textile communicating to her sister. Returning to the surviving text of the *Iliad*, the poem employs a prefatory statement well known to readers:

> Anger be now your song, immortal one,
> Akhilleus' anger, doomed and ruinous,
> That caused the Akhaian's loss on bitter loss
> And crowded brave souls into the undergloom,

Leaving so many dead men – carrion
For dogs and birds; and the will of Zeus was done.
Begin it when the two men first contending
Broke with one another – the Lord Marshal
Agamemnon, Atreus' son, and Prince Akhilleus.[13]

This introduction to the poem contains, in broad strokes, the poem's entire plot. It serves a function akin to a modern serialised television show's introduction – introducing characters and establishing tone. Given the modular structure of the poem and the nature of rhapsodic performance, we might imagine this passage serving in a similar manner, repeated at the beginning of any performed portion of the poem. Moreover, as a synopsis of the poem's plot, the metrical sequence of these seven lines, repeated sequentially, would form clear, coherent patterns as well.

That metrical sequence consists of:

– u u	– u u	– –	– u u	– u u	– –
– u u	– –	– u u	– –	– u u	– –
– –	– –	– –	– u u	– u u	– –
– –	– –	– u u	– u u	– u u	– –
– –	– u u	– u u	– u u	– u u	– –
– –	– –	– u u	– –	– u u	– –
– u u	– u u	– –	– –	– u u	– –

When expressed at a horizontal point count of 799 in figure 5.9, we see the following pattern:

FIG. 5.9 Iliad introduction at 799 with single short

At a horizontal point count of 806 in figure 5.10, the design reverts to vertical forms such as this:

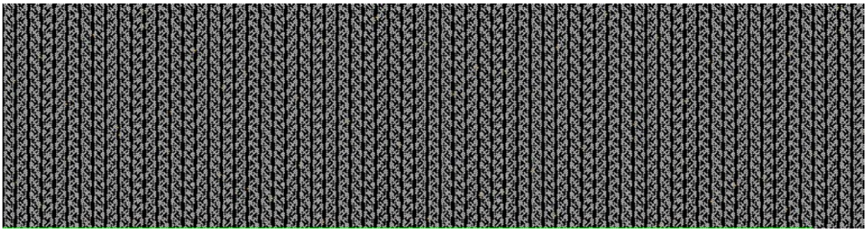


FIG. 5.10 Iliad introduction at 806 with single short

As seen with the graphs presented above, varying point counts result in widely varying versions of such repeating designs. And it bears repeating that to a weaver familiar with such patterns, they represent a synopsis of the *Iliad* as expressed in the poem's first seven lines. For textile producers intimately familiar with the interrelations between these patterns and the formulaic synopsis of the *Iliad's* introduction, they would serve as recognisable representations of that narrative, even if appearing to be mere geometric patterns to those unfamiliar with the encoded information.

If the Procne and Philomela myth originally contained some version of events wherein textiles communicated a form of narrative information, we might imagine that versions performed by rhapsodes imagined a textile produced by some version of the story itself. This use of textile to depict the events of the story wherein the textile is made is seen in Book III of the *Iliad* as well, wherein Helen herself is described in the act of weaving images of the events unfolding on the plain below her (*Il.* 3.126–30). Perhaps Philomela, in a similar manner, was imagined producing a representation of her own myth.

As the speculations presented here show, there is little about the early versions of the Philomela and Procne myth we can know with certainty. However, the glimpses of evidence that survive in the literary record, as well as the documentation of modern ethnomusicology and anthropology, clearly show that singing was a feature of textile production in the ancient experience and remains so in some regions of the world today. Expressions of the 'weird sing-song' of central Asia or the *Naqshe Khani* in present-day Iran show how repeating musical phrases serve as the conduit for information-sharing related to patterns in the production of knot pile carpets. However, this tradition may be but one regional variant of a much more widespread phenomenon, one that suggest far more complex types of narrative information encoded patterning in similar ways. If so, it is appealing to imagine that the silent textile, like the silenced Philomela, might still find ways to communicate a far larger universe of narrative.

ENDNOTES

1 Knowledge of some form of the myth is recorded in Homer *Od.* 19.518–23. The story is alluded to in other works, including Hesiod's *Works and Days* 568; Apollodoros 3.14.8; Pausanias 10.4.8; and Hyginus *Fabulae* 45. Ovid *Metamorphoses* 6.424–674, records a comprehensive, although very late iteration of the story.
2 Radt (1999), counts 17 surviving fragments of the play's text. The play's overall form is the subject of an attempted reconstruction, even though the surviving evidence is frustratingly insufficient to provide confidence on several points. See Fitzgerald 2001.
3 Stevens (1946), 10–11; Barringer (2005); Fitzgerald (2001): 90, n. 3 posits a terminus ante quem for the play at 414, casting a degree of doubt on the date of the play's original performance and its relationship to the possible commissioning of this image.
4 *Poetics* 1454b 36–37 = Soph. fr. 595 Radt (1999); Fitzgerald (2001): 97.
5 Mueller, M., *Objects as Actors: Props and the Poetics of Performance in Greek Tra*gedy (Chicago: University of Chicago Press, 2016).
6 Dobrov (1993: 205) imagines a staging of the scene wherein Tereus is on stage for the presentation of the textile. If so, it is possible that an actual text would have furthered the distinction between illiterate barbarian and elite, literate Athenian women.
7 Šavli, Bor and Tamažič 1996: 254–56. However, it must be noted that many translations presented in this volume have not met with wide acceptance. See Leeming 1998.
8 Öhrman (2018: 95–96) describes the industrial space of a Roman household wherein women of the same family would engage in this shared form of production.
9 The scansion of the *Iliad* employed in this project is available at Chamberlain 2020.
10 We owe this suggestion to Adriana Burton, a life-long weaver and essential contributor to this project.
11 Forstall and Scheirer 2012. This analytical study of the entirety of the *Iliad*'s text shows that variation to the formal meter tends to occur most frequently in specific metrical positions, perhaps providing a vestigial clue as to how weavers might have employed such variation.

12 The earliest extant expressions of written Greek are found in Italy and date to the later portions of the first half of the eighth century BCE. See Bietti Sestieri 1992: 184–85; Ridgeway 1996.
13 *Iliad* 1.1–7. Trans. Fitzgerald 1974.

REFERENCES

Aminian, M., '"The Woven Sounds": Demo documentary by Mehdi Aminian on pattern singing-Persian carpets', https://www.youtube.com/watch?v=vhgHJ6xiau8 [accessed 30 October 2023].

Aminian, M., 'Naqshe Khani: Weaving Sounds into Carpets', in preparation.

Barber, E. J. W., *Prehistoric Textiles: The Development of Cloth in the Neolithic and Bronze Ages with Special Reference to the Aegean* (Princeton: Princeton University Press, 1991).

Barber, E. J. W., 'The Peplos of Athena', in J. Neils, ed., *Goddess and Polis: The Panathenaic Festival in Ancient Athens* (Princeton: Princeton University Press, 1992), pp. 103–17.

Barringer, J., 'Alkamenes' Prokne and Itys in Context', in J. M. Barringer and J. M. Hurwit, eds, *Periklean Athens and its Legacy: Problems and Perspectives* (Austin: University of Texas Press, 2005), pp. 163–76.

Bietti Sestieri, A. M., *The Iron Age Community of Osteria dell'Osa* (Cambridge: Cambridge University Press, 1992).

Cahill, J., *Her Kind: Stories of Women from Greek Mythology* (Ontario: Broadview Press, 1995).

Chamberlain, D. https://hypotactic.com/use-the-source/ [accessed 13 January 2020].

de Souza, C. D., and C. K. B. Dias, 'The Iconography of Death: Continuity and Change in Prothesis Ritual through Iconographical Techniques, Motifs, and Gestures Depicted in Greek Pottery', *Classica-Revista Brasileira de Estudos Clássicos*, 31.1 (2018): 61–87.

Dobrov, G., 'The Tragic and the Comic Tereus', *The American Journal of Philology*, 114 (1993): 189–234.

Edmunds, S. T., 'Picturing Homeric Weaving', *Donum Natalicium Digitaliter Confectum Gregorio Nagy* (Center for Hellenic Studies 2012), https://chs.harvard.edu/CHS/article/display/4365 [accessed 20 January 2020].

Fanfani, G., 'Weaving a Song: Convergences in Greek Poetic Imagery between Textile and Musical Terminology. An Overview on Archaic and Classical Literature', in S. Gaspa, C. Michel, and M.-L. Nosch, eds, *Textile Terminologies from the Orient to the Mediterranean and Europe, 1000 BC to 1000 AD* (Lincoln, Nebraska: Zea Books, 2017), pp. 421–36.

Forstall, C. W., and W. J. Scheirer, 'Revealing Hidden Patterns in the Meter of Homer's Iliad', *Proceedings of the Chicago Colloquium on Digital Humanities and Computer Science* 2012, https://tesserae.caset.buffalo.edu/blog/wp-content/uploads/2012/10/forstall-scheirer.dhcs2012.pdf [accessed 30 October 2023].

Fitzgerald, D., 'Tereus', *The Classical Quarterly*, 51(2001): 90–101.

Harlizius-Klück, E., 'Das Pepita-Virus – Herstellung und Verbreitung eines Stoffmusters', 2012, http://www.saumweberei.de/http:/www.saumweberei.de/das-pepita-virus-herstellung-und-verbreitung-eines-stoffmusters/ [accessed 2 December 2020].

Harlizius-Klück, E., 'Digital Sieves', in B. Baert, *About Sieves and Sieving: Motif, Symbol, Technique, Paradigm* (Berlin and Boston: De Gruyter, 2019), pp. 95–104.

Leeming, H., 'Review of Šavli, Bor, and Tamažič, *Veneti: First Builders of European Community', The Slavonic and East European Review*, 76.2 (1998): 342–43.

Mumford, J. K, *Oriental Rugs* (New York: Scribner 1900).

Nagy, G., *Homer the Classic, Hellenic Studies Series* 36 (Washington, DC: Center for Hellenic Studies, 2008), http://nrs.harvard.edu/urn-3:hul.ebook:CHS_Nagy.Homer_the_Classic.2008 [accessed 30 October 2023].

Öhrman, M., 'Textile Work in Shared Domestic Spaces in the Roman House: The Evidence from Latin Poetry', *Fasciculi Archaeologiae Historicae*, 31 (2018): 93–101.

Radt, S. L., *Tragicorum Graecorum Fragmenta IV: Sophokles* (Göttingen: Vandenhoeck & Ruprecht, 1999).

Restani, D., 'I suoni del telaio: Appunti sull'universo sonoro degli antichi Greci', in B. Gentili and F. Perusino, eds, *Mousike: Metrica ritmica e muscia greca in memoria di Giovanni Comotti* (Pisa and Rome: Istituti editoriali e poligrafici internazionali, 1995), pp. 93–109.

Ridgway, D., 'Greek letters at Osteria dell'Osa', *Opuscula Romana*, 20 (1996): 87–97.

Šavli, J., M. Bor, and I. Tamažič, *Veneti: First Builders of European Community* (Vienna: Editiones Veneti, 1996).

Seyf, A., 'Carpet Manufactures of Iran in the Nineteenth Century', *Middle Eastern Studies*, 26.2 (1990): 204–13.

Stevens, G., 'The Northeast Corner of the Parthenon', *Hesperia*, 15 (1946): 1–26.

Tuck, A., 'Singing the Rug: Patterned Textiles and the Origins of Indo-European Metrical Poetry', *American Journal of Archaeology*, 110 (2006): 539–50.

Tuck, A., 'Stories at the Loom: Patterned Textiles and the Recitation of Myth in Euripides', *Arethusa*, 42.2 (2009): 151–60.

Vellacott, P., *Euripides: The Bacchae and Other Plays* (London: Penguin, 1954).

West, M. L., 'The Singing of Homer and the Modes of Early Greek Music', *The Journal of Hellenic Studies*, 101(1981): 113–129.
West, M. L., *Greek Metre* (Oxford: Clarendon Press, 1982).
West, M. L., *Indo-European Poetry and Myth* (Oxford: Oxford University Press, 2007).

6

THE TEXTILE EXPRESSION GAP

Lars Hallnäs

THERE IS ALWAYS A CERTAIN GAP BETWEEN FORM AS DEFINITION, THE WAY in which material builds a thing, and expression as that which displays a thing *in concreto*. In textile design this gap is rather specific and to some extent paradoxical in nature.

We define (design) a 'traditional' house, car, chair, table and then we build it. There is a gap between the abstract form, as a definition, and the concrete gestalt of the house, the car, the chair, the table. Being able to define doesn't necessarily mean you can build it, it doesn't necessarily mean you understand and can master possible relevant means of expression.

It is not only that there is a gap between the abstract (form) and the concrete (expression), but there is also a gap between different sets of skills and practices. It is a challenge to bridge these gaps, yet nevertheless, in many cases, something you need to be able to do. The painter, the composer, must take on such a challenge in different ways, and the same goes for the craftsperson who designs and builds the chair. To build a house or a car is a different story and there the gap is certainly very present.

In all these cases it is rather clear what we mean when we say that the actual house, the actual car and so on, express (display) a form (a definition), the gestalt of the house, the car. It is also rather clear what we mean when we talk about the expressiveness of the materials that build the house, the car and so on. The difference between form, the way in which material builds the house, the car, and expression, that which displays the house, the car, is quite clear. There is a gap that is clear by nature in some non-trivial sense. We are dealing here with solid things.

A textile is typically something we form, shape, as a garment we wear, as a textile thing we use. These are textiles as flexible, adaptable and responsive things.

But what is the form, the expression of a towel, of a jacket? It is not only that there is something ambiguous, evasive about the notion of form in these cases that makes the question difficult to grasp, but there is also the expressional gap between the textile thing and the textile itself. The textile formula defines the way in which the yarn builds the textile and the yarn is at the same time that which displays the formula. Although this does not directly explain the expressions of a towel, it is still both a formal and material foundation.

. . .

What happens if we use this elementary foundation in a systematic way to form a textile design aesthetics? Form being the textile formula – the way in which the yarn builds the textile thing, and the yarn the expression – that which displays the textile thing. To bring the things back home to this elementary foundation is in some non-trivial sense what characterises textile thinking (ArcInTex 2019).

Now we are dealing with textiles as flexible, adaptable and responsive things.

There is a surface, texture, but no shape (gestalt); a textiles has no form, it is not a thing, it is material.

Textiles have no shape (form), but a definition and that is somehow the form. It is not a thing, it is just form.

Form and material collapse into a definition (the textiles design formula). This is a form-material paradox (Hallnäs 2018).

This collapsing of form and material into a definition is one way to express the core of textile thinking.

Forget form, forget material, see the definition and its logic – the process of formalising.

See the surface, feel the texture – the process of materialising.

In a near field reading of a textile it dissolves into a definition, a textile formula. In that sense a definition is what builds a textile; the yarn is the all-important link with which it is written.

But as we use a textile thing, the textile itself becomes a material, i.e., it builds the textile thing.

To make sense of this 'paradox' is somehow a basic problem in textile design aesthetics. It is a 'paradox' that builds the textile expression gap, i.e., the gap between the textile design formula that defines the textile as material and the expression of the textile things it builds in use.

Take the example of a plaid. The wind forms the plaid as you pick it up, and wrapping it around yourself forms it again, as you sit there in the cold wind feeling a bit warmer. The textile formula is there somewhere in the background setting the boundaries, the yarn more in the foreground expressing the given plaid in some sense; it is after all the yarn that displays the plaid as a thing.

So, we might think of the formula, the weaving pattern, the knitting pattern and so on as the form of the plaid, and the yarn as its expression. What would that mean?

Why is this discussion about form and expression important, interesting? We could say it is the use of the plaid that is important, and that it is the use of the plaid that defines what it is. That does not help very much in the process of designing and making. We design and make *something,* and *then* we may use it.

It is clear that use defines and redefines what that something is. But we still initially define and make something, and it is through form and expression that we express that something. These notions are central in the foundation of designing and making, as they help us to grasp what it means to design and make things, and thus provide a conceptual foundation for the development of methodological and technical tools.

This is a theoretical discussion where we look for interpretations and explanations useful in the design and making processes, not a philosophical discussion concerning the true meaning of 'form' and 'expression', what the 'form' of a textile *really* is.

The textile formula defines the way in which the material builds the textile, 'material' then refers to the yarn we use. This is 'form' in its most elementary sense, and does not directly refer to the shape, the gestalt of a three-dimensional thing.

We could say that this also applies to a correspondent definition of the form of a house. But there is a fundamental difference here: we can derive the three-dimensional gestalt of the house from its elementary form, whereas that does not make sense for the textile. This makes it in some sense natural to relate the textile formula more to matters of expression.

But what would form then be? Given the textile paradox, it is well motivated to use the textile formula as the basic notion of form of textiles since it provides for a simple and clear interpretation and explanation of them as flexible things.

It is, in some sense, a bit strange to say that a given textile is a 'carpet' in answer to the question 'what is this?' Yes, that is the intended use of the thing. But a more precise initial answer would be to present its definition, the form that defines what it is as an elementary textile thing.

Expression is a notoriously difficult notion to grasp with precision. Intuitively we know what we are talking about. But how could we introduce this concept in a more precise and suggestive manner, as a foundational notion of aesthetic design? Not what it 'really' is, but as a notion theoretically useful.

Saying that the expression of a thing is *that* which displays the thing is to say that it is a presentation, that which turns an idea into a thing. Means of expression are the tools and things we use to actually make the thing, the materials, the techniques.

What is it that actually displays a textile thing? For just any thing we could say that use is what displays the thing, moving in to a newly built house, working once again with the well-used old camera, climbing up the mountain in your new jacket, making the table using that special tablecloth, etc.

This is certainly true in some sense, but there is something invariant across different contexts and different forms of use that so to speak display the thing as such. It is a trivial fact that there always is a context, but it is equally true that we can see the specific identity of things in any given context. In the process of designing and making, it is the form and expression of these *elementary* things that are in focus, even if our work is guided by intended use for things in certain given contexts. What these things display is not use, but properties that are more elementary, that build the thing as such as something invariant across use and contexts.

Take the computer keyboard in front of me. What is it that displays this thing as such? I see the plastic keys, the printed symbols on the keys, the aluminum frame, its angle in relation to the table, the colours of the frame and the keys, the size of the frame and so on. One way to answer the question, which I feel is very natural, is to say that the expression of the keyboard are these things in *their places*.

What is it that puts all these different things in their places? Making of course. But "their places" that is what the form of the keyboard defines. This is the meaning of the idea that form defines expression.

So given a, woven or knitted, textile we can say that the expression of the textile is the *yarn in its places*. The places of the yarn then being defined by the textile formula.

Compare this with Hanslick's characterisation of music as 'tönend bewegte(n) Formen' (Hanslick 1854).

The textile expression gap is this divide between textiles as these elementary things and textiles as they are defined in use, the everyday flexible thing we use to wear, to furnish our living spaces, things that surround us everywhere in one way or another. What the elementary thing does is to open up a space for definition by use in a very specific manner.

For the textile as an elementary thing, 'its place' is defined by the textile formula, whereas for the textile thing in use it is me that defines 'its place' within the boundaries given by the form of the elementary thing.

I put the textile thing on the floor and it becomes a carpet, but a carpet is also something I can fold and put away, 'its place' now becomes points in space. This transformation is quite different in nature from what happens when I put away the computer keyboard where the internal relation between different keys does not change.

For the elementary textile, 'its place' in more abstract terms refers to a pattern that of course does not change during the transformation of folding a carpet and putting it away, or the transformation that takes place as I put on my favorite jacket. The pattern is invariant under transformations of use, the gestalt, the shape of the everyday textile things is on the other hand not invariant under transformations of use (see Landahl 2015).

We have a thing A where it is rather clear what form and expression is all about. Through intentions and adaptations, we turn A into a thing B defined by use. In B, we can always, by focusing and bracketing, see A, but we cannot see B in A. The central issue here is what B is as a thing.

What would it mean to say that the expression of B is A in 'its places' and consequently that the form of B is what defines these places? What we do is that we in use put A in certain places, places that A makes possible. Not points in a three-dimensional space, but ways of use, the ways we dress, the ways we furnish.

What is specific to the textile expression gap is that the distinction form-material somehow seems to disappear. It is not centered around the idea of materialising form, it is the gap between A and B, where A basically is the central invariant of B.

There is really no need for a notion of material in textile design aesthetics. This might seem a bit strange, but it is no more strange than the textile design paradox itself.

Textiles are flexible and responsive things. What does that mean? We could say that here we have material we form in the use of textile things, it is material we can bend and twist – the rubber band geometry. But we could also say that there is no material here.

The yarn, in its places, expresses the 'building'. But the 'building' itself is abstract, it is just form. The basic invariant. Yarn is not material then, but means of expression. We do not use the yarn to build something, it is already built. We use it to display what we already built.

The elementary textile is in that way abstract as a thing. Or the boundaries of a thing in use.

What is useful with such a theoretical framework is, among other things, that we can handle the idea of textile precision in a reasonable simple manner. The idea of precision becomes a very complex issue if we think of the elementary textile in mechanical or topological terms.

In relation to the elementary textile, we can view textile precision as a quality of the way in which the yarn 'in its places' displays the textile formula, i.e. the abstract textile thing. Precision, the quality of being exact. Here the exactness of expression, an aesthetical notion.

REFERENCES

ArcInTexETN Research Program (August 2019), http://www.arcintexetn.eu/research/research-program/ [accessed 27 October 2023].

Hallnäs, L., 'The Textile Thinking Paradox', in E. Kurbak, ed., *Stitching Worlds* (Berlin: Revolver Publishing, 2018), pp. 18–25.

Hanslick, E., Vom Musikalisch-Schönen: Ein Beitrag zur Revision der Ästhetik der Tonkunst (Leipzig: Rudolph Weigel, 1854).

Landahl, K., 'The Myth of the Silhouette – on Form Thinking in Knitwear Design', *University of Borås Studies in Artistic Research* 16 (2015).

PART II

EXPLORATIONS OF PATTERNS AS KNOWLEDGE OF ORDER

7

MODULAR PATTERNS: A SURVEY OF THE TEXTILE ORIGIN OF NEOLITHIC DESIGN AND ITS CALCULATIONAL IMPLICATIONS

Kalliope Sarri

ANCIENT TEXTILE PRODUCTION APPEARS TO BE CLOSELY LINKED TO THE human intellect and wisdom. Through the archaeological evidence and literary sources, we recognise that weaving, even in early antiquity, relates to notions of order and that it might have been one of the primary forces that motived humans to create sophisticated technologies and eventually to embark on scientific thought. The sophisticated textile industries of the Greco-Roman world (Harlow and Nosch 2014; Mee 2015; Spantidaki 2016) interacted with other high technologies not merely to fulfil basic everyday needs but to reveal a systematic engagement with the concept of nature (Harlizius-Klück 2014: 49). Moreover, fine arts, poetry and philosophy were occasionally associated – conceptually and metaphorically – with the manufacture of cloth, showing that weaving was an essential driving force to the understanding of structural space (Harlizius-Klück and Fanfani 2016).

But how far back in the past does this relation go? How could the invention and the early practising of weaving have influenced the human mind to such an extent that it could better understand natural laws and move to more advanced technological stages? Such questions can be approached through the study of prehistory, by observing weaving, if not from the earliest stages of textile technology, at least from the Neolithic period, for which we have adequate evidence (Barber 1991: 133–44; Siennicka, Rahmstorf, and Ulanowska 2018: 3–5). In this paper, I address the question of conceptual weaving by focusing on the cognitive environment where we can first discern the relation between weaving and empirical mathematics and their visual expressions on forms of material culture and art. Our guide to this survey will be the decorative patterns of the Neolithic era, with particular reference to the Aegean.

TEXTILE-EVIDENCE IN THE NEOLITHIC

We know that people began to weave nets, textiles and baskets during the Upper Palaeolithic period, but there is no adequate information about the weaving activities of the mostly nomadic populations of this long era (Soffer, Adovasio and Hyland 2000). Some scarce and indirect evidence shows us, however, that Palaeolithic artefacts were decorated with typical, sometimes even intricate 'textile' patterns known to us from later times.[1] The vague picture of the earliest textile crafts alters with the permanent settlements of the Neolithic period when people had more time to accomplish laborious household tasks and to proceed to create sophisticated artefacts. By exploring permanent or temporary Neolithic settlements, archaeologists were able to collect plentiful data and better examine the prime technologies of the era. Tools for hunting, fishing, agricultural work and house construction, as well as remarkable pieces of figurative art, were found at many sites of the known world. Tools connected to textile craft were discovered in all Neolithic cultures of Mesopotamia, the Aegean, the Balkans and in Central and Western Europe.[2] Certain kinds of these tools, such as bone sewing needles and weaving beaters do not look much different from those used until recently or still in use in some areas.[3] The evidence, however, that first and foremost confirms the existence of Neolithic textile production is the rich assemblage of spindle whorls for making thread, sets of bone tools for connecting pieces of textiles or as auxiliary weaving implements, and later, when the warp-weighted loom was invented, the loom weights.[4]

TEXTILE PATTERNS IN NEOLITHIC ICONOGRAPHY

The elements that best reflect the aesthetic and decorative technologies of Neolithic textile art are the so-called 'textile patterns' – that is, patterns imitating woven structures, which are commonly seen on Neolithic pottery. We will focus on this evidence to explore whether, how early and for how long pottery decoration was linked to textile craft and how valuable is the information it offers, not only from a technological perspective but also within the field of the cognitive environment of the Neolithic weavers.[5]

While naturalistic figurative art has existed since the Palaeolithic era, straight-linear geometric shapes and compositions do not exist in the natural environment: thus Neolithic people must have copied them from another man-made craft that required working on pre-set axes, a process which would later give rise to the primary geometric shapes and compositions. Knowing the basic technologies of the Neolithic (stone knapping and polishing, bone curving, stone building, and so on) it is hard to imagine any other craft acting in a more structural framework than the textile craft, where the loom, of any kind, offers a three-dimensional canvas structure, the stretched threads play the role of guide lines and grids, and the patterns produced represent the basic two-dimensional geometrical shapes or even complex geometrical compositions. The same structural possibilities are offered by the craft of basketry which, without the aid of a loom, uses only the twisting, coiling, crossing and manipulating of threads made of the same or similar natural fibres to create woven artefacts.

EARLY RENDERING OF WEAVING PATTERNS

The earliest evidence of pattern weaving goes far back into the past, but we have been tracking it since the Early Neolithic (6500–6000 BCE) in the Aegean (Björk 1995: 128; Winn 1989: 96–100, 137, fig. 5.70; Pyke and Yiouni 1996: 86–88; Vitelli 1948: 190–92). During this period, simple symmetrical patterns, mainly arranged in zones, are commonly observed. They include solid motifs, based on triangles, bands and simple linear patterns such as zigzag lines, parallel chevrons and rows of triangles (figure 7.1). They are drawn with earthen colours on the surface of the pot, usually placed on the vase's belly or on the shoulder zone.[6] Around the end of the period, more complex patterns, such as checkerboard motifs and frames of small triangles are added, and at the same time black paint and slipped ground were introduced. (Phelps 2004: 39) There are certain variations of this style in the different geographical areas, but all the areas were moving along certain major axes of the decorative programme, in terms of painting techniques, syntax and hues. The ornaments of this period, at least of its earliest phase, do not yet reveal a clear connection to textile craft; they inform us, however, about the first conscious rendering of geometric shapes, which were repeated all over the vase's perimeter and rendered with high precision, showing understanding and conscious use of symmetries perhaps derived from weaving.[7]

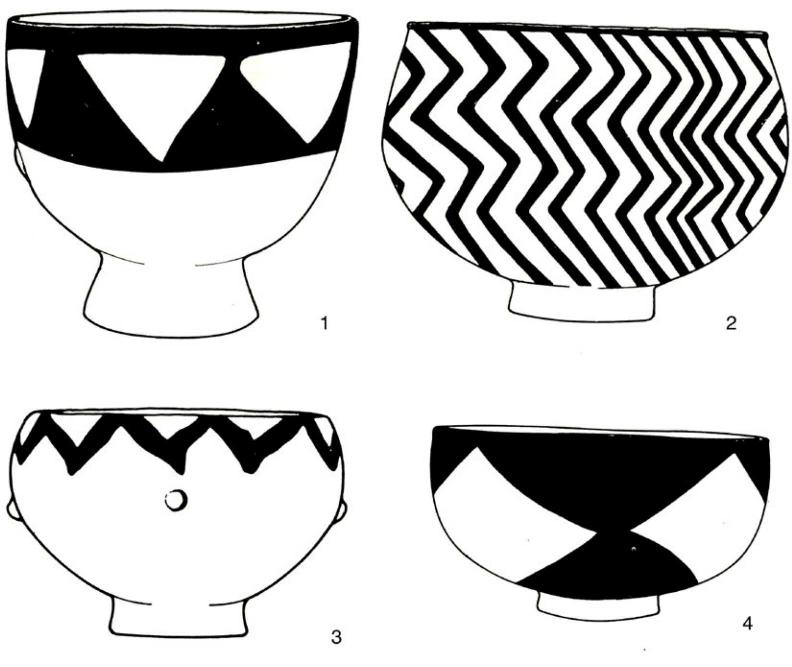


FIG. 7.1 Early Neolithic vases with simple geometric decoration (after Theocharis 1993, Plate IV)

TEXTILE DECORATION AS CRAFT TRANSFER

This simple geometric style of the Early Neolithic period showed a rapid development in the Middle Neolithic (6000–5500 BCE), when pottery decoration became complex, now showing more evident affinities with patterned textiles.[8] At the same time, a greater variety in the use of colours can be discerned: large black, red and brown patterns are shaped on the plain surface of the vases but sometimes also on a thick creamy slip.[9] We can observe entire ranges of connected or interlocking patterns such as networks, triangles, rhombuses, various kinds of grids, checkerboards and systems of zigzag lines (figure 7.2).

FIG. 7.2 Middle Neolithic vases with textile patterns (after Theocharis 1993, Plates IV and V)

Most of these geometric motifs are familiar to us from fabrics, kilims and carpets of all periods and regions. A very common pattern of the so-called Urfirnis Middle Neolithic pottery[10] is that composed of groups of crossed lines arranged in zones (figure 7.2, 2). Another very popular pattern of the same style features rhombuses framed by denticulated outlines commonly described as flame patterns (figure 7.2, 5–6). This particular motif is one of the most common textile patterns, occurring almost identically in the textile art of quite different areas and periods, presumably because of its highly decorative and easy to weave shape. During this period, rectilinear patterns are preferred, but simple curvilinear shapes, such as concentric circles and arc segments, are also occasionally included in the motif repertoire. Frequently, the decoration consists of stepped, diagonally arranged, square modules, bringing to mind the technical challenge of weaving curvilinear patterns or long vertical shapes without slits, a fact that provides an additional reason to see these decorations as representations of patterned textiles. The whole arrangement of the basic decorative elements is characterised by modularity (Jablan 2002 and 2020), strongly reminiscent of the syntax of traditional oriental kilims woven using the tapestry technique.[11] The same decorative trends can also be seen in the contemporary Neolithic pottery styles of the Balkans. In the pottery styles of the Karanovo culture in Bulgaria and the Cucuteni culture in Romania such simple modular patterns, along with some other more complicated syntheses, also signify textile prototypes.[12] Striking analogies can also be found in the Neolithic pottery of Anatolia. In the Hacilar culture, for example, the decorative mode shows the same choice of motifs and a clear similarity between its decorative syntax and the Aegean textile patterns (Mellaart 1970: 119, Figs. 309–27).

A particular category of the Aegean Middle Neolithic decoration is the canvas style, where the motifs have been placed as groups of stepped digitlike units upon a painted canvas.[13] Through the filling of empty squares, the units shape large intricate patterns covering large parts, or the entire surface, of the vase (figure 7.3). Here we can discern not only a distant inspiration from woven products but also how the textile patterns were precisely executed based on a pre-planned graphic template. This almost naturalistic iconographic expression is so evident that it raises another question about how the original decoration was technically achieved on the textiles, in particular about whether the embellishment was woven, embroidered or even stamped.[14] It is not, however, easy to settle on a particular textile technique, since both main options, weaving and embroidery, could have been used as inspiration by the potters. Besides, there are some composite techniques, such as in-woven embroidery, which is accomplished on the loom by adding colourful weft threads to create motifs. Nevertheless, both these textile techniques are ideally applied on a canvas structure and give a similar visual result. On the other hand, it is also possible that the grid-based designs do not represent a woven fabric but an ideal weaving or embroidery guide, or perhaps a net lace with empty and filled spaces. Several examples of this distinctive decoration come from the Sporades islands in the central-northern Aegean and have some distant similarities with particular styles of Thessaly and central Greece[15] so that we can refer to it as a typical local production from the central Aegean.

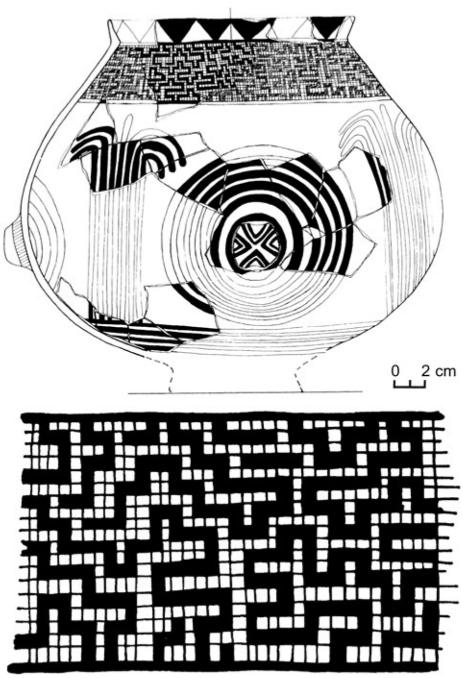


FIG. 7.3 Middle Neolithic jar with canvas decoration from the cave of the Cyclops (after Sampson 2008, Plate 3.4)

FROM GEOMETRIC TO PICTORIAL DESIGN

The woven styles, which seem to copy elaborate textile designs, flourish remarkably in the Late Neolithic (5500–4500 BCE), when composite curvilinear shapes, such as spirals and wavy patterns, are added to the linear motifs, often shaping very complex compositions (figure 7.4, 1; 3; 5–7). During this period, pottery decoration seems not only to have been inspired by colourful fabrics, but it sometimes appears to have been purely figurative, depicting real textile objects such as fringed carpets or colourful woven bands. (Sarri 2018: 166) These new figurative elements supply an additional hint to the textile origin of the pottery decoration.

The intricate Late Neolithic interlocking decoration that covers the entire body of the vase is reminiscent of the seamless patterns of stamped fabrics which are reproduced through square modules covering the whole surface of large pieces of cloth (figure 7.4, 3). This kind of tiled pattern can be used as an additional key for the recognition of textile prototypes.[16] Sometimes the design

FIG. 7.4 Late Neolithic vases of the Dimini culture (after Theocharis 1993, Plate VIII)

consists of large panels that do not follow the usual horizontal arrangement, but they look like connected pieces of differently decorated fabrics (figure 7.4, 1). This style is very common on the large open bowls of the Dimini style, where panels with checkerboard patterns or spiral designs are combined, each covering almost a half of the pot.

TRACING FURTHER TEXTILE TECHNOLOGIES

We are not able to accurately reconstruct either the textile technologies or the precise tool kit of the Early and Middle Neolithic, but we can assume that simple early loom types, such as the backstrap loom, the two-beam loom, small weaving frames, or the horizontal ground loom, might have been used but not yet the warp-weighted loom that seems to appear towards the later Neolithic. It does so, at least, in Southern Greece, while it might appear earlier in the Middle Neolithic in Northern Greece, perhaps following Balkan traditions.[17] Moreover, certain decorative elements indicate that sophisticated techniques were used, such as band weaving, joining different fabrics with a patchwork technique or decorative joining stitches. (Sarri 2018: 165–67)

BASKET WEAVES

Towards the end of the Late Neolithic period, during the Aegean Late Neolithic II or the Final Neolithic (4500–3200 BCE), painted decorations largely decline in central and southern Greece, and the patterns of vases now often resemble the products of basketry. They consist of incised, impressed or relief stripes that appear interwoven in horizontal, vertical or lateral arrangements and completely cover the surface of the vessels. The plastic rendering of the decoration reveals the original inspiration which seems to be the relief surface of baskets. A similar aesthetic effect is often achieved by so-called pattern-burnishing, in which the decoration is created by the contrast of polished and non-polished areas of the vase surface. However, it is not only monochrome and relief-decorated ceramics that show relationships with basketry: as many traditional and contemporary examples demonstrate, the alternation of colours on basketry could be achieved not only through the use of materials of different origins but also through painting. Thus, ceramics decorated in two or more colours can also represent basket weaves.

It is not always possible to distinguish which ceramic decoration is inspired by textile weaving and which by basketry. Some examples, however, are obviously influenced by basketry techniques, especially those that feature spiral or very open weaves, since they resemble similar traditional and contemporary basketry work. (Sentence 2007: 56–118) In particular, the rendering of such open weaves in basket style is sometimes combined with analogous shapes showing basket prototypes. A very characteristic example of this case is seen on a ceramic-handled lid from the Neolithic site of Sitagroi, phase III, which bears graphite-painted decoration with diagonally crossing bands, leaving ample space between them (figure 7.5). Here both the decoration and the shape of the pot seem to imitate an open basket lid.[18] The materials used in basketry could have been straw lengths, various reeds, rushes, grasses, roots, leaves or pieces of bark.[19] The fibres could be interwoven with each other but also with diverse other materials such as hair, bands of skin and hide. The basketry techniques could have included plaiting, twining, coiling, bundle coiling or twilling.[20] This phenomenon of craft transfer seems logical and to be expected within the general concept of Neolithic pottery, since the ceramic repertoire often appears as an expression of skeuomorphism, including imitations of plant shapes such as pumpkins and leather objects such as flasks.[21] It is quite plausible that basketry was invented earlier than weaving, since the material used was easy to find and did not required elaborate preparatory processes such as cleaning, retting, combing and spinning. This possibility leads us to believe that the whole invention of ceramic creation could have come from basketry, especially since we know that some of the first woven products were baskets covered with clay, lime, tar or resin to make them waterproof.

REPRESENTATIONS OF ROPES

During the Late and especially during the Final Neolithic, the first 'rope decoration' appears; this is a style where one or more plastic strips are decorated with

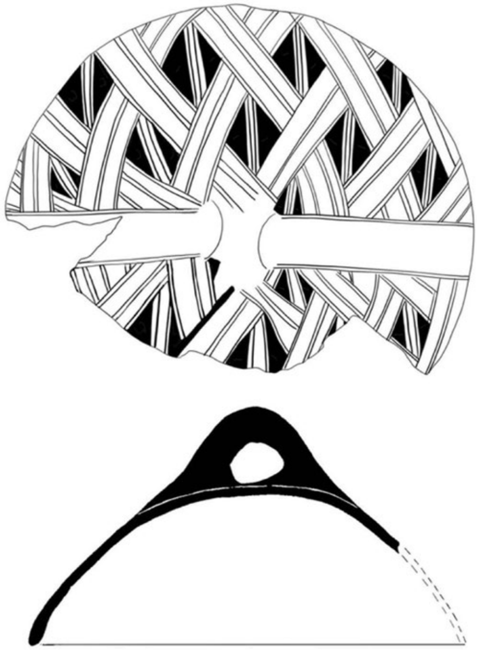


FIG. 7.5 Vase lid decorated with a basket-weave pattern from Sitagroi, phase III (after Bonga Fig. 63.1)

indents or incisions so as to resemble thick ropes tied onto the vase's body (figure 7.6). This style, beside its decorative value, also had a utility function, since plastic strips helped to provide a solid grip when moving large vessels. Moreover, it might reflect a contemporary custom of tying large vases and pithoi with ropes during their transport, as many ethnological sources demonstrate. This kind of decoration later became a common trend and is often seen in the coarse household pottery of various Bronze Age sites of Central Greece, as well as in the pottery of Minoan Crete.[22] Except for a sometimes clearly visible twist with an S or Z direction, the rope-imitating bands are rendered too abstractly to define the exact rope-making techniques; the presence of this pattern on the vases, however, provides evidence that potters were eager to transfer the idea of fibre artefacts to pottery. Sometimes, though, decoration details are more obvious: a distinctive group of Early Bronze Age pithoi from the site of Lerna

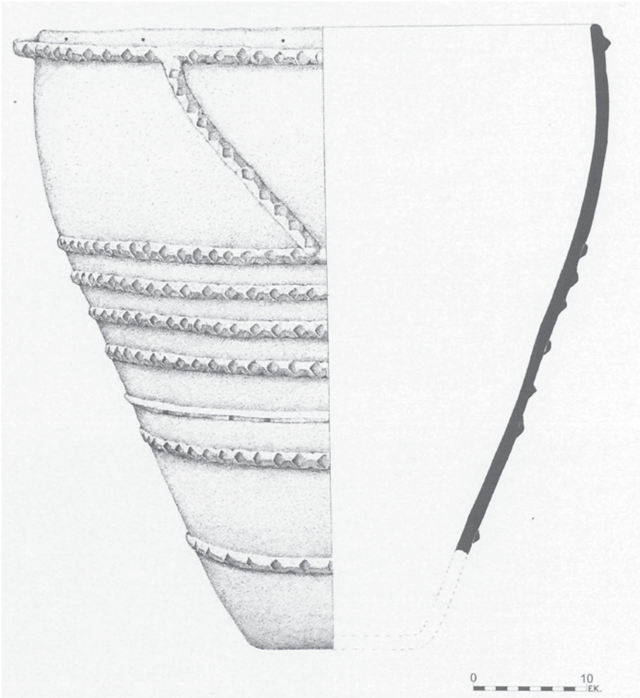


FIG. 7.6 Final Neolithic storage jar with rope decoration from the Alepotrypa Cave (after Papathanssopoulos and others 2011, Fig. 163)

displays braiding and net making techniques on its broad plastic bands. (Wiencke 1970: pl. 29, 102 and 116)

PATTERNS AND SYMMETRIES

All painted decorative features show that textile patterns were highly standardised and that weavers were able to repeat them accurately, which in terms of the weaving procedure means precision in counting. Even if some simple free patterns could have been randomly created, the more complex ones, and certainly the tiled patterns, could not have been woven and certainly not repeated if the weavers had not been able to count the warp and weft threads. That is to say, we encounter the perception and manipulation of two and three-dimensional structural space as an early expression of visual mathematics.[23] Crystallised concepts of shapes are shown by the deliberate rendering of abstract two-dimensional shapes in the three-dimensional textile structure and then in their return as two-dimensional linear shapes on the surface of the pottery.

Looking at early technologies, none of the other Neolithic crafts we know of could have reached this cognitive, artistic and technological level. The manufacture of pottery, stone, or bone artefacts, for example, requires strength, skills and kinetic precision but not counting and measuring.[24] Neither does it require abstract thinking and accurate visual skills such as are needed to copy and transfer from a two-dimensional shape to a three-dimensional medium. Moreover, calculations would have been necessary at other stages of textile production. Estimation of raw materials and precise planning of the work would have been required, since fibres were not able to be purchased in finished form through trade but were collected from nature at certain times of the year. In all succeeding stages of the *chaîne opératoire*, estimation of quantities, weights, and values was needed in order to process certain quantities of fibres, to produce particular dyes, to divide warp threads and set series of loom weights, and to estimate the value of the textile products for offering or exchanging with other goods.[25]

WEAVING AND COUNTING

The hypothesis that metrology, in the sense of a common understanding of units, originated in the textile arts is of great importance for understanding the knowledge background of the Neolithic people since, in the absence of known measurement systems from this era, it gives us an idea of how people may have started to develop complex manipulation and planning skills to improve their standard of living.[26] The multiple possibilities that yarn offers for three-dimensional representations of objects and symbols, as well as counting and measuring concepts, is shown by a series of ancient applications, the most typical being the *khipu* devices of the Incas.[27] These were threads which used combinations of loops and knots to encode words and numbers so precisely that they were used as administrative documents in official state archives.[28] In other parts of the world, we can see a similar counting concept in the prayer beads of various religions, such as the various types of woven rosaries of the

Catholic and Greek Orthodox Churches, and a similarly functioning device, the Buddhist 'mala'. It is worth noting that these simple threaded measuring tools, in addition to being used in calculating, were also used for measuring time.

The arrangement of the decoration on axes and the counting of the warp threads to create colour changes and shapes brings to mind the concept of the abacus, which is also a three-dimensional binary system with a horizontal and a vertical axis.[29] Moving back to the past, we can imagine that Neolithic weavers, by observing the textile structure they created, understood the loom's principle and perhaps realised its value as a computational system. By lifting a certain number of warp threads as they wove to pass the wefts through them, a process similar to that used on an abacus, they were able to create the symmetrical coloured forms seen on pottery, and, through this creative experience they may have perceived the principal geometric shapes.

ARCHAEOLOGICAL IMPLICATIONS

The ornamentation of Aegean Neolithic pottery with textile patterns is not a unique phenomenon, but it epitomises a case where craft transfer, particularly skeuomorphism, can be clearly seen.[30] In the contemporary cultures of the Balkans, Anatolia and the Near East,[31] we can see a parallel development, and since it is widely believed that the Neolithic lifestyle came to the Aegean from the east in the first half of the seventh millennium BCE,[32] the pottery inspiration may have been part of this cultural movement. One of the classic examples of the connection of Neolithic ceramic ornamentation with Anatolian textile craft has been recognised by the interpretation of Neolithic ornaments as a rendering of coloured kilims by the British pioneer archaeologist James Mellaart.[33] Similar decorative patterns observed in contemporary Stone Age cultures lead us to the tracing of population movements. Moreover, the possibility of a common origin of Neolithic motifs from the textile crafts also gives us an alternative explanation for why geometric ornaments are so similar in very remote areas.

If we aim to explore why these technical cross crafts and interrelations exist, we realise that when acts of imitation and mingling of techniques were carried out, art proceeded to new paths of creation, and remarkable innovations were observed; thus one can assume that the desire of the craftspeople and the textile consumers for new artistic expression brought to the foreground the styles and techniques of other crafts.

Beyond the artistic creation of new styles, it is suggested that the decoration of Neolithic pottery, especially symmetrical modular patterns, opens a way for us to realise that prehistoric people conceived the mathematical notions of arithmetic and geometry through textile crafts and long experimentation on woven symmetries. The practice of weaving helped artisans to create precise shapes and symbols, and to use their knowledge of calculation in metric and weight systems, achievements that were implemented in a series of later technological applications developed in the ancient world.

ENDNOTES

1 On the Palaeolithic modular patterns from Mezin, see Jablan 2002: 284–85.

2 For the archaeological textile artefacts of the Cucuteni Culture, see Marian 2009: 112–17.

3 On Neolithic weaving bone tools, see Sarri 2020: 100.

4 Barber 1991: 91–113; Carington Smith 1975: 122–26; Perlès 1992: 246–54. On weaving tools made of bone, see, de Diego and others, 2018: 73–76; Sarri 2020: 95–102.

5 Textile decoration can also be seen on Neolithic seals, figurines and architectural features. Perlès 1992: 252–54; Türkcan 2006: 180; figurines: Sarri 2018: 168–69.

6 For a classification and analysis of the Early Neolithic patterns, see Washburn 1983.

7 On a definition of symmetry and different kinds of symmetry transformation, see Darvas 2007: 4–11.

8 Theocharis has noted the affinities with weaving and argued that the nature of the weaving material leads to geometric patterns. Theocharis 1993: 67. On the decoration of Neolithic pottery, see also Otto 1976 and 1985.

9 See the development of the decoration motifs from the Early to Middle Neolithic in the Achilleion site in Gimbutas, Winn and Shimabuku 1989, Fig. 5.31.

10 For the style and distribution of Urfirnis pottery, see French 1972: 8–11; Holmberg 1964: 35, and Phelps 2004: 44–47.

11 Mellaart has indicated the relation of Neolithic design to textile art: Mellaart 1989; 1970: 38–39.

12 See some examples of the decorative pottery of Karanovo in Hiller and Nikolov 1997: Fig. 66–67, 104; of Cucuteni A–B period in Lazarovici 2010: 144; of Donja

Branjevina in Budja 2009: 128, fig. 3 right.

13 This type of decoration was interpreted as copied from the weaving craft by Katsarou-Tzeveleki (2008: 100–2). See some characteristic examples in Theocharis 1973: fig. 258; and Papathanasopoulos 1996: fig. 4 and 212, fig. 5.

14 For challenges of defining decorative textile techniques in antiquity, with a special emphasis on traditional tapestry, see Wace 1948: 53.

15 See the distribution of the fabric in Katsarou-Tzeveleki 2008: 101. The closest style in Thessaly is seen on the Tzani Magoula: Papathanasopoulos 1996: 255, fig. 101. In Central Greece, the red-on-white Chaeroneia style better represents this kind of weaving imagery, sometimes seen on figurine clothing (Papathanasopoulos 1996: 236, 315). On Chaeronea ware, see French 1972: 6–7.

16 On the syntax and variations of tiled modular patterns, see Jablan 2020 (no pages).

17 The earliest loom weights in Europe have been located in the Balkans; see Barber 1991: 93–98 and Mazăre 2014: 14–19. On warp-weighted loom, see Sarri in press ('Horizontal Loom'). On spinning tools, see Vakirtzi 2018: 188–89.

18 Compare Fig.7.5 with Bonga 2013: 63.1 and Papathanasopoulos 1996: 250, fig. 87 with a basket made with coconut leaves in Sentance 2007: II, above right.

19 For possible fibres and other materials used in basketry, see Sentance 2007: 16–51.

20 On prehistoric basketry, see Belogianni 2004.

21 On skeuomorphic relations in prehistoric art, see Nakou 2000: 49. Diverse aspects of craft transfer are discussed in Rebay-Salisbury, Brysbaert, and Foxhall 2014. For skeuomorphism in the Neolithic of the Near East, see Wengrow 2001: 178.

22 For the early development of the Greek pithos, see Cullen and Keller 1990. On Early Helladic III pithoi with relief rope decoration, see Wiencke 1970: plate 19, L 752. On Minoan storage vessels with relief rope decoration, see Christakis 2005: 23–36. On Bronze Age to Iron Age pithoi, see Lis and Rückl 2011.

23 On visual mathematics, see Darvas 2007: 28–33; Jablan 2002.

24 On Neolithic artefact production, see Perlès 1992: 130–41.

25 On the stages of textile production, see Andersson Strand 2012.

26 We can define metrology in this early period as a common understanding of units and determining of measured values. The early measuring systems in Europe are discussed in Budja 1998 and 2003; possible interpretations of Neolithic artefacts as counting objects are suggested by Marangou 2001: 18–22. For the invention and development of counting, see Schmandt-Besserat 1992 and Malafouris 2010.

27 For information on *khipu*, see Ascher 1986 and 1991: 16–26; Conklin 2002; *The Harvard Khipu Database Project*; Day 1967; On a methodology of ethnomathematical research concerning basketry, see Adam 2010: 701–2. For mathematical concepts in early prehistoric societies, see Merzbach and Boyer 2010: 6–7.

28 For more on *khipu* principles, see Chapter 10 (pp. 183–85) of this volume.

29 For the relation of Neolithic textiles tools and counting, see Sarri 2020: 20–21.

30 For cases of skeuomorphism, see Brysbaert 2007: 336.

31 Breniquet and others 2017.

32 On the discussion of the Neolithicisation of the Aegean, see Perlès 2001: 58–63.

33 Mellaart 1989.

REFERENCES

Adam, N. A., 'Mutual Interrogation: A Methodological Process in the Ethnomathematical Research', *International Conference in Ethnomathematical Research. Procedia. Social and Behavioral Sciences,* 8 (2010): 700–7.

Andersson Strand, E., 'The Textile *chaîne opératoire*: Using a Multidisciplinary Approach to Textile Archaeology with a Focus on the Ancient Near East', *Paléorient,* 38.1–2, (2012): 21–40.

Ascher, M., *Ethnomathematics: A Multicultural View of Mathematical Ideas* (Belmont, California: Wadsworth, 1991).

Ascher, M., 'Mathematical Ideas of the Incas', in M. P. Closs, ed., *Native American Mathematics* (Texas: University of Texas Press, 1986), pp. 261–89.

Barber, E. J. W., *Prehistoric Textiles: The Development of Cloth in the Neolithic and Bronze Ages, with Special Reference to the Aegean* (Princeton: Princeton University Press, 1991).

Belogianni, M., 'Η καλαθοπλεκτική και τα προϊόντα της στην προϊστορική Ελλάδα', in A. Kyriatsoulis, ed., *Althellenische Technologie und Technik von der prähistorischen zur hellenistischen Zeit mit Schwerpunkt auf der prähistorischen Epoche,* (Ohlstadt, Weilheim: Verein zur Förderung der Aufarbeitung der Hellenischen Geschichte, 2004), pp. 429–54.

Björk, C., *Early Pottery in Greece: A Technological and Functional Analysis of the Evidence from Neolithic Achilleion, Thessaly,* Studies in Mediterranean Archaeology 115 (Göteborg: P. Åström, 1995).

Bonga, L., 'Late Neolithic Pottery from Mainland Greece, ca. 5300–4300 BC', PhD diss., Temple University, 2013.

Breniquet, C., 'Weaving and Potting during the Late Neolithic Period: Are There Textile Patterns in the Early Painted Pottery of Mesopotamia?', in W. Cruells, I. Mateiciucová, and O. Nieuwenhuyse, eds, *Painting Pots Painting People: Neolithic Ceramics in Ancient Mesopotamia* (Oxford and Philadelphia: Oxbow Books, 2017), pp. 213–24.

Brysbaert, A., 'Cross-Craft and Cross-Cultural Interactions During the Aegean and the Near Eastern Mediterranean Late Bronze Age', In S. Antoniadou and A.

Pace, eds, *Mediterranean Crossroads* (Athens: Pieridis Foundation, 2007), pp. 325–19.

Budja, M., 'Clay Tokens: Accounting before Writing in Eurasia', *Documenta Praehistorica*, 25 (1998): 219–35.

Budja, M., 'Early Neolithic Pottery Dispersals and Demic Diffusion in Southeastern Europe', *Documenta Praehistorica*, XXXVI (2009): 117–37.

Budja, M., 'Seals, Contracts and Tokens in the Balkans in the Early Neolithic: Where in the Puzzle?', *Documenta Praehistorica*, 30 (2003): 115–30.

Carington Smith, J., 'Spinning, Weaving and Textile Manufacture in Prehistoric Greece', PhD Thesis. University of Tasmania, 1975.

Christakis, K. S., *Cretan Bronze Age Pithoi: Traditions and Trends in the Production and Consumption of Storage Containers in Bronze Age Crete* (Prehistoric Monographs 18) (Philadelphia: INSTAP Academic Press, 2005).

Conklin, W. J., 'A Khipu Information String Theory', in J. Quilter and G. Urton, eds, *Narrative Threads: Accounting and Recounting in Andean khipu*, (Austin, Texas: University of Texas Press, 2002), pp. 53–86.

Cullen, T., and D. R. Keller, 'The Greek Pithos Through Time: Multiple Functions and Diverse Imagery', in W. D. Kingery, ed., *The Changing Roles of Ceramics in the Society: 26,000 BP to the Present,* Ceramics and Civilisation V (Westerville OH: The American Ceramic Society Inc, 1990), pp. 183–209.

Darvas, G., *Symmetry: Cultural-Historical and Ontological Aspects of Science-Arts Relations. The Natural and Man-made World in an Interdisciplinary Approach*. Trans. by D. R. Evans (Basel: Birkhäuser, 2007).

Day, C. L., *Quipus and Witches' Knots: The Role of the Knot in Primitive and Ancient Cultures* (Kansas: University of Kansas Press, 1967).

de Diego, M., R. Piqué, A. Palomo, X. Terradas, M. Saña, I. Clemente-Conte, and M. Mozota, 'Evidence of Textile Technology in the Early Neolithic Site of La Draga (Banyoles, Spain): Some Hypotheses', in M. Siennicka, L. Rahmstorf, and A. Ulanowska, eds, *First Textiles: The Beginnings of Textile Manufacture in Europe and the Mediterranean* (Ancient Textiles Series 32) (Oxford: Oxbow, 2018), pp. 69–80

French, D. H., *Notes on Prehistoric Pottery Groups from Central Greece* (Athens: privately circulated, 1972).

Gimbutas, M., S. Winn, and D. M. Shimabuku, eds, *Achilleion: A Neolithic Settlement in Thessaly, Greece, 6400–5600 BC* (Monumenta Archaologica 14) (Los Angeles: Cotsen Institute of Archaeology, 1989).

Harlizius-Klück, E., 'The Importance of Beginnings: Gender and Reproduction in Mathematics and Weaving', in M. Harlow and M.-L. Nosch, eds, *Greek and Roman Textiles and Dress: An Interdisciplinary Anthology*, Ancient Textile Series

19 (Oxford: Oxbow Books, 2014), pp. 46–59.

Harlizius-Klück, E., and G. Fanfani, '(B)orders in Ancient Weaving and Archaic Greek Poetry', in G. Fanfani, M. Harlow, and M.-L. Nosch, eds, *Spinning Fates and the Song of the Loom: The Use of Textiles, Clothing and Cloth Production as Metaphor, Symbol and Narrative Device in Greek and Latin Literature,* Ancient Textiles Series 24 (Oxford and Philadelphia: Oxbow Books, 2016), pp. 61–99.

Harlow, M., and M.-L. Nosch, eds, *Greek and Roman Textiles and Dress: An Interdisciplinary Anthology* (Oxford and Philadelphia: Oxbow Books, 2014).

'*The Harvard Khipu Database Project',* Harvard: Gary Urton, https://khipukamayuq.fas.harvard.edu/Home.html [accessed 20 July 2020].

Hiller, S., and V. Nikolov, eds, *Karanovo: Die Ausgrabungen im Südsektor 1984–1992,* I.2 (Salzburg–Sofia: Archäologisches Institut der Universität Salzburg and Archäologisches Institut mit Museum der Bulgarischen Akademie der Wissenschaften, 1997).

Holmberg, E. J., *The Neolithic Pottery of Mainland Greece* (Göteborg: Wettergren & Kerber, 1964).

Jablan, S. V., *Modularity in Art* (Belgrade: Mathematical Institute of the Serbian Academy of Sciences and Arts) http://www.mi.sanu.ac.rs/~jablans/d3.htm [accessed 20 July 2020].

Jablan, S. V., *Symmetry, Ornament and Modularity: Series on Knots and Everything,* Vol. 30 (London: World Scientific Publishing, 2002).

Katsarou-Tzeveleki, S., 'Early Neolithic Weavers Paint: Youra Red Painted Patterns as Markers of the Local Group's Identity', in A. Sampson, ed., *The Cave of the Cyclops: Mesolithic and Neolithic Networks in the Northern Aegean, Greece. Vol. 1, Intra-Site Analysis, Local Industries, and Regional Site Distribution,* (Prehistory Monographs 21) (Philadelphia: INSTAP Academic Press, 2008), pp. 69–110.

Lazarovici, C.-M., 'Cucuteni Ceramics: Technology, Typology, Evolution and Aesthetics', in D. W. Anthony and J. Y. Chi, eds., *The Lost World of Old Europe. The Danube Valley 5000–3500 BC* (Princeton and Oxford: The Institute for the Study of the Ancient World & Princeton University Press 2010), pp. 128–61.

Lis, B., and Š. Rückl, 'Our Storerooms Are Full: Impressed Pithoi from Late Bronze/Early Iron Age East Lokris and Phokis and their Socio-Economic Significance', in W. Gauß, M. Lindblom, R. A. K. Smith, and J. C. Wright, eds, *Our Cups Are Full: Pottery and Society in the Aegean Bronze Age. Papers presented to Jeremy B. Rutter on the occasion of his 65th birthday* (Oxford: Archaeopress, 2011): 154–68.

Malafouris, L., 'Grasping the Concept of Number: How did the Sapient Mind Move Beyond Approximation?', in I. Morley and C. Renfrew, eds, *The Archaeology* *of Measurement: Comprehending Heaven, Earth and Time in Ancient Societies* (Cambridge: Cambridge University Press, 2010), pp. 27–34.

Marangou, C., 'Evidence for Counting and Recording in the Neolithic? Artefacts as Signs and Signs on Artefacts', in A. Michailidou, ed., *Manufacture and Measurement: Counting, Measuring and Recording Craft Items in Early Aegean Societies*, Μελετήματα 33 (Athens: Research Centre for Greek and Roman Antiquity, National Hellenic Research Foundation, 2001), pp. 9–43.

Marian, C., *Meşteşuguri Textile în Cultura Cucuteni* (Iaşi: Trinitas, 2009).

Mazăre, P., 'Investigating Neolithic and Copper Age Textile Production in Transylvania (Romania): Applied Methods and Results', in M. Harlow, C. Michel, and M.-L. Nosch, eds, *Prehistoric, Ancient Near Eastern and Aegean Textiles and Dress: An Interdisciplinary Anthology*, ed. by, (Oxford: Oxbow Books, 2014), pp. 1–42.

Mee, M. M., *Body, Dress and Identity in Ancient Greece* (Cambridge: University Press, 2015).

Mellaart, J., *Çatalhöyük and Anatolian Kilims: The Goddess from Anatolia*, Volume 2., ed. by J. Mellaart, U. Hirsch, and B. Balpınar (Milan: Eskenazi, 1989).

Mellaart, J., *Excavations at Hacilar: Occasional Publications of the British Institute of Archaeology at Ankara* (Edinburgh: British Institute of Archaeology at Ankara, 1970).

Merzbach, U. C. and C. B. Boyer, *A History of Mathematics*, 3rd ed. (New York: Wiley, 2010).

Morley, I., and C. Renfrew, eds, *The Archaeology of Measurement: Comprehending Heaven, Earth and Time in Ancient Societies* (Cambridge: Cambridge University Press, 2010).

Nakou, G., 'Metalwork, Basketry and Pottery in the Aegean Early Bronze Age: A Meaningful Relationship', in A. Serghidou, ed., *Dorima: A Tribute to the A. G. Leventis Foundation on the Occasion of its 20th Anniversary* (Nicosia: The A. G. Leventis Foundation, 2000), pp. 27–57.

Otto, B., *Die verzierte Keramik der Sesklo- und Diminikultur Thessaliens*, Keramikforschungen 6 (Mainz: Philipp von Zabern, 1985).

Otto, B., *Geometrische Ornamente auf anatolischer Keramik: Symmetrien frühester Schmuckformen im Nahen Osten und in der Ägäis* (Mainz: Philipp von Zabern, 1976).

Papathanasopoulos, Y., ed., *Neolithic Culture in Greece* (Athens: Nicholas P. Goulandris Foundation, Museum of Cycladic Art, 1996).

Papathanasopoulos, Y., V. Katsipanou-Margeli, and G. Philippaki, *To Neolithiko Diro: Spilaio Alepotrypa* (Athens: Melissa, 2011).

Perlès, C., *The Early Neolithic in Greece: The First Farming Communities in Europe* (Cambridge: Cambridge University Press, 2001).

Perlès, C., 'Systems of Exchange and Organization of Production in Neolithic Greece', *Journal of Mediterranean Archaeology*, 5.2. (1992): 115–64.

Phelps, W. W., *The Neolithic Pottery Sequence in Southern Greece*. BAR 1259. (Oxford: Archaeopress, 2004).

Pyke, G., and P. Yiouni, 'The Early Neolithic Pottery: Technology Analysis and Comparison with other Neolithic Ceramic Materials', in K. A. Wardle, ed., *Nea Nikomedeia I: The Excavation of an Early Neolithic Village in Northern Greece 1961–1964, directed by R.J. Rodden.* The Excavation and the Ceramic Assemblage, (British School at Athens, Supplementary Vol. 25) (London: British School at Athens, 1996), pp. 55–193.

Rebay-Salisbury, K., A. Brysbaert, and L. Foxhall, 'Material Crossovers: Introduction', in K. Rebay-Salisbury, A. Brysbaert, and L. Foxhall, eds, *Knowledge Networks and Craft Traditions in Ancient Mediterranean* (Routledge Studies in Archaeology) (New York and London: Routledge, 2014), pp. 1–6.

Sampson, A., and T. Skoteini, *The Cave, the Settlement and the Cemetery* (Athens, 1993).

Sarri, K., 'Aesthetics and Apparel in the Neolithic Period', in M. Lagogianni-Georgakarakos, ed., *The Countless Aspects of Beauty in Ancient Art* (Athens: National Archaeological Museum and Archaeological Receipts Fund, 2018), pp. 163–74.

Sarri, K., 'In the Minds of Early Weavers: Perceptions of Geometry, Metrology and Value in the Neolithic Aegean', in L. Quillien and K. Sarri, eds, *Textile Workers: Skills, Labour and Status of Textile Craftspeople between the Prehistoric Aegean and the Ancient Near East. Proceedings of the Workshop Held at 10th ICAANE in Vienna, April 2016* (Oriental and European Archaeology 13) (Vienna: Austrian Academy of Sciences Press, 2020): 17–25.

Sarri, K., 'Taming the Fibres: Traditions and Innovations in the Textile Cultures of Neolithic Greece', in W. Schier and S. Pollock, eds., *The Competition of Fibres: Early Textile Production in Western Asia, South-East and Central Europe (10,000–500 BCE)* (Oxford: Oxbow, 2020), pp. 95–110. https://doi.org/10.2307/j.ctv13pk7d6

Sarri, K., 'Weaving on the Ground: Positive and Negative Evidence for a Reconstruction of the Prehistoric Horizontal Loom', in *VII Purpureae Vestes* International Symposium, Granada, 2–4 October 2019 (Granada: University of Granada, in press).

Schmandt-Besserat, D., *Before Writing: From Counting to Cuneiform* (Texas: University of Texas Press, 1992).

Sentance, B., *Basketry: A World Guide to Traditional Techniques* (London: Thames and Hudson, 2007).

Siennicka, M., L. Rahmstorf, and A. Ulanowska, eds, *First Textiles: The Beginning of Textile Manufacture in Europe and Mediterranean* (Ancient Textiles Series 32)

(Oxford: Oxbow, 2018): 1–16.

Soffer, O., J. M. Adovasio and D. C. Hyland, 'The "Venus" Figurines: Textiles, Basketry, Gender, and Status in the Upper Paleolithic', *Current Anthropology*, 41.4 (August–October 2000): 511–37.

Spantidaki, S., *Textile Production in Classical Athens* (Ancient Textiles Series 27) (Oxford: Oxbow, 2016).

Theocharis, D., 'Development and Diversification: The Middle Neolithic of Thessaly and the Southern Regions', in D. Theocharis, ed., *Neolithic Greece* (Athens: National Bank of Greece, 1973), pp. 59–88.

Theocharis, D., *Νεολιθικός πολιτισμός. Σύντομη επισκόπηση της Νεολιθικής στον ελλαδικό χώρο,* 3rd ed. (Athens: National Bank of Greece Cultural Foundation, 1993).

Türkcan, A. U., 'Some Remarks on Çatalhöyük Stamp Seals', in I. Hodder, ed., *Changing Materialities at Çatalhöyük: Reports from the 1995–99 Seasons* (British Institute at Ankara, McDonald Institute for Archaeological Research, 2006), pp. 175–85.

Vakirzi, S., 'Fibre Crafts and Social Complexity: Yarn Production in the Aegean Islands in the Early Bronze Age', in M. Siennicka, L. Rahmstorf, and A. Ulanowska, ed., *First Textiles. The Beginning of Textile Manufacture in Europe and Mediterranean* (Ancient Textiles Series 32) (Oxford: Oxbow, 2018), pp. 187–200.

Vitelli, K. D., *Franchthi Neolithic Pottery: Classification and Ceramic Phases 1 and 2. Excavations at Franchthi Cave, Greece,* Vol. 8. (Bloomington: Indiana University Press, 1993).

Wace, A. J. B., 'Weaving or Embroidery?', *American Journal of Archaeology,* 52.1 (1948): 51–55.

Washburn, D. K., 'Symmetry Analysis of Ceramic Design: Two Tests of the Method on Neolithic Material from Greece and the Aegean', in D. K. Washburn, ed., *Structure and Cognition of Art* (Cambridge: Cambridge University Press, 1983), pp. 138–64

Wengrow, D., 'The Evolution of Simplicity: Aesthetic Labour and Social Change in the Neolithic Near East', *World Archaeology,* 33. 2, Archaeology and Aesthetics (Oct. 2001): 168–88.

Wiencke, M. H., 'Banded Pithoi from Lerna III', *Hesperia,* 39 (1970): 94–110.

Winn, S., 'Pottery', in M. Gimbutas, S. Winn, and D. M. Shimabuku, eds, *Achilleion: A Neolithic Settlement in Thessaly, Greece, 6400–5600 BC* (Monumenta Archaologica 14) (Los Angeles: Cotsen Institute of Archaeology, 1989), pp. 75–164.

8

POIKILIA, GEOMETRY AND LIVING PATTERNS IN THE GREEK ARCHAIC AND CLASSICAL MIND

Adeline Grand-Clément[1]

INTRODUCTION: FROM *KOLAM* TO *POIKILIA*

IN HIS *ART AND AGENCY* (1998), WHICH DEALS WITH VARIOUS KINDS OF artefacts from a range of cultures around the world, the anthropologist Alfred Gell argued that the nonfigurative decorations of some crafted objects (usually labelled as 'works of art') possess an active power.[2] This effect, he claimed, provides the key to understanding the social meaning and function of the objects. Indeed, Gell explains that the very nature of what we call 'art objects' does not stem from their beautiful appearance but rather from the agency and intentionality they possess: they deeply affect the viewer by rousing in them a kind of shock ('captivation'). These objects draw their power from the intricacy of an ornamentation that plays with repetition, symmetry, translation and inversion, and it is for this reason that Gell pays special attention in his studies to designs, patterns and the structures that underlie them. He shows that certain visual tricks developed by the craftsmen who produced these works aim to give the observer an impression of animation and movement. The inability of the viewer to distinguish figure from ground, together with the complexity of relations at play in the patterns, means that the captive gaze is unable to unravel the geometrical rules according to which the design is constructed.

These patterns thus 'slow perception down, or even halt it, so that the decorated object is never fully possessed at all, but is always in the process of becoming possessed' (Gell 1998: 81). Gell gives as an example the Indian *kolam* designs, which are drawn on the doorsteps of houses using colourful powders. These designs are hard to 'read', in that the viewer is unable to apprehend the general principle that guides the pattern of the *kolam*. In a way, *kolam* designs work like the Cretan labyrinth, made up of twists and turns on a path that leads from the starting point to the centre; in making the *kolam*, Indian women aim to mislead the demons who must be repelled or trapped by the colourful designs (Gell 1998: 107).

Textiles did not fall within the scope of Gell's analysis of non-figurative decorations,[3] but I suggest that the same kind of process is at play in the art of weaving. The notions of 'agency' and 'captivation' are, I think, useful if we want to gain a better understanding of the value attached to decorated textiles in ancient Greece. The process of weaving, i.e., of intertwining different threads, shares some common features with the designing of *kolam*: both belong to what Gell calls the 'technology of enchantment' (1994). The main argument I deploy in support of this hypothesis relies on the meaning of a key notion intimately associated with the technology of weaving in the Greek mind: *poikilia*, usually translated as 'variegation', although the word is applied to such a variety of things in the written sources that it is very difficult to render it accurately. The Greeks used the adjective *poikilos* to describe all kinds of artefacts characterised by the juxtaposition of varied colours and materials, and with an elaborate arrangement of patterns on their surface. Its usage thus overlaps in large part with the range of artefacts considered by Gell. However, the application of this language to the products of weaving *as well* helps us to see how the domain of Gell's analysis can usefully be extended. Indeed, interlacing threads for the crafting of colourful textiles was one of the main means by which a craftsman could achieve such a visual arrangement. What all these variegated artefacts had in common was a visual appearance that was intended to exert a seductive effect on the viewer, in the same manner as did the various decorated objects or surfaces studied by

Gell. But there is more: as I have demonstrated elsewhere,[4] the mode of action of *poikilia* does not result only from the visual, for other sensory perceptions (like sound, for instance) are also stimulated and interfere with each other, generating a broader cross-sensory effect (LeVen 2013).

In this paper, I will not present and analyse the different ways in which the term *poikilos* is used to characterise artefacts, especially textiles, in Archaic and Classical Greek texts, since this lexical work has already been carried out (Rinaudo 2009). Rather, I will endeavour to tackle the key notion of *poikilia* in a fresh way: I will look closely at some of the few cases in which we find *poikilos* attributed not to decorated and colourful textiles but, rather, to living beings whose appearance and behaviour appear in some 'unnatural' way and thus somehow blur the divide between the natural world and the realm of craftsmanship.[5] In this paper, I will focus in particular on two animals that were closely connected to the notion of *poikilia* in Archaic and Classical Greek texts. First, I will consider an intriguing bird, the wryneck (*iunx* in ancient Greek), whose feathers display complex and intricate patterns, and which, as we will see, moves quite 'unnaturally'. Secondly, I will explore the imagery of snakes, whose scales display a certain kind of geometric arrangement and whose behaviour was often perceived as being unpredictable. My aim will be to identify which features of these animals the Greek mind associated with woven textiles, and to understand the reasons underlying this perceived affinity. In doing so I will address a number of related questions. To what extent does geometry play an important role in these associations? Does the visual appearance of *poikiloi* textiles and animals provoke the same kind of effect in the viewer? And are there other, non-visual, sensory features which also need to be taken into account if we are to understand the connection between living beings and woven artefacts?

FROM THE WRYNECK TO THE 'MAGIC' GIRDLE OF APHRODITE

The wryneck (*Iunx torquilla*)[6] is a Eurasian bird which possesses a distinctive, extraordinarily complex plumage (figures 8.1, 8.2, 8.3). With its fine lines, stripes and spots mixing subtle shades of grey, brown and black, the feathery body of the wryneck has the outstanding appearance of tree bark or the scaly skin of a snake. The first ancient writer to provide a somewhat detailed description of the bird, including remarks on its physical appearance, is Aristotle in his *History of Animals* (written sometime around the end of the fourth century BCE). The philosopher stresses several features that mark the wryneck out as different from the vast majority of birds.

> [...] ὀλίγοι δέ τινες δύο [δακτύλους] μὲν ἔμπροσθεν δύο δ᾽ ὄπισθεν, οἷον ἡ καλουμένη ἴυγξ. Αὕτη δ᾽ ἐστὶ μικρῷ μὲν μείζων σπίζης, τὸ δ᾽ εἶδος ποικίλον, ἴδια δ᾽ ἔχει τά τε περὶ τοὺς δακτύλους καὶ τὴν γλῶτταν ὁμοίαν τοῖς ὄφεσιν· ἔχει γὰρ ἐπὶ μῆκος ἔκτασιν καὶ ἐπὶ τέτταρας δακτύλους, καὶ πάλιν συστέλλεται εἰς ἑαυτήν. Ἔτι δὲ περιστρέφει τὸν τράχηλον εἰς τοὐπίσω τοῦ λοιποῦ σώματος ἠρεμοῦντος, καθάπερ οἱ ὄφεις. Ὄνυχας δ᾽ ἔχει μεγάλους μὲν ὁμοίως μέντοι πεφυκότας τοῖς τῶν κολοιῶν· τῇ δὲ φωνῇ τρίζει.
>
> A few [birds] have two [toes] in front and two behind, such as the bird called the wryneck. This bird is slightly larger than the chaffinch, and *mottled in appearance*. The arrangement of its toes is peculiar, and its tongue is like the serpents': it can extend its tongue for a distance of four fingerbreadths and then draw it again. Further, it can turn its neck round right back while keeping the rest of its body unmoved, like the serpent. It has large claws, though in nature they are similar to those of the green woodpecker. Its note is a shrill cry.[7]

Aristotle uses *poikilos* in his description of the bird but does not provide any accurate details regarding the nature of the patterns that generate the impression of *poikilia*. We may initially feel a little bit disappointed that Aristotle remains so allusive. But a closer look at the wryneck (figure 9.1) helps us to see how difficult it might be to describe through words the intricate colouring and patterns on its body. Perhaps only specialists in textiles and weaving, well-trained in identifying shapes and motifs, would be able to do so? In any case, looking at this fascinating plumage brings to mind Gell's allusion to the tricky composition of ornamentation on some of the artefacts he had studied. As he writes, 'the motifs in decorative art often do seem to be engaged in a mazy dance in which

FIG. 8.1 Eurasian wryneck (*Jynx torquilla*) (photo by Pepe Reigada in May 2015; https://commons.wikimedia.org/wiki/File:Wryneck_by_Pepe_Reigada.jpg

FIG. 8.2 A wryneck expanding its tongue. Image from *The natural history of British birds, or, A selection of the most rare, beautiful and interesting birds which inhabit this country: the descriptions from the Systema naturae of Linnaeus*, London, 1794, 63; https://archive.org/stream/naturalhistoryof41797dono/naturalhistoryof41797dono#page/n63/mode/1up

FIG. 8.3 The snaky bird: a wryneck turning his head (photo by Solymári in August 2017, https://commons.wikimedia.org/wiki/File:Jynx_torquilla_%C3%93csa_1.jpg

our eyes become readily lost' (1998: 76). The wryneck's *poikilia* acts on the viewer in a similar way, despite not being the product of a skilled craftsman. At first sight, the *poikilia* of the wryneck displays no regularity at all: the blurring of patterns is impressive, making it impossible for a viewer to distinguish figure from background.

It might be said that such complexity is not unique to the wryneck. And this is indeed correct: many other birds do have variegated feathers. Still, there is a significant difference that distinguishes this particular species from the wider crowd: the *poikilia* of the wryneck does not stem only from its plumage. If we turn back to the description provided by Aristotle we can note that the philosopher stresses two other distinctive features of the bird: first, the length of its tongue, and second, the unusual mobility of its neck. It is these features that account for the comparison Aristotle draws between wrynecks and snakes – a comparison that modern ornithologists would not gainsay. First, the impressive tongue of the wryneck is retractile and is equipped with a viscous fluid that enables the bird to catch its prey (figure 8.2). Second, the wryneck can move its head in all directions while keeping its body still. The bird uses this capacity – now thought to be the mimicking of the behaviour of a snake – to ward off potential threats (figure 8.3).[8] Aristotle is certainly right to note these unusual characteristics: the reptilian features of the wryneck are uncommon for a bird. They create a sight which is both fascinating and troubling, generating the impression of a supernatural potency. The snake-like characteristics of the bird do not stop at the visual level: when the wryneck is attacked, in order to discourage the potential predator, it emits a whistling that is quite similar to the hissing of a snake. It is possible that Aristotle refers to this particular noise when he uses the verb *trizô*, which refers to a shrill, high-pitched sound.[9] Moreover, this sonic specificity is in tune with the possible etymology of the noun, for *iunx* might be cognate with the verb *iuzô*, 'shout, cry out', 'emitting a sound similar to the snake hissing'.[10] Moreover, according to myth, Iunx was the name of the daughter of Pan and the sonorous nymph Echo. She was turned into a bird by Hera either because she seduced Zeus or because she helped him to have his love affair with Io.[11]

The visual *poikilia* displayed by the bird thus goes hand in hand with its undulating and snake-like mobility. These features make the wryneck look like a hybrid being, blurring the frontiers between the avian and the reptilian animal classes. Moreover, the *iunx*-bird is truly *poikilos* in the sense that the 'variegation' is not restricted to the visual appearance of the wryneck but is also related to its deceptive behaviour. Indeed, we know that the notion of *poikilia* is intimately related to the field of *mètis*, a crafty and cunning kind of intelligence that plays a crucial role in the Greek imaginary.[12] *Mètis* refers to a non-dialectical kind of thought which proceeds by circumvention and follows indirect and somewhat maze-like routes. *Polumèkhanos* and *poikilometès* Odysseus is probably the best example of a man full of *mètis*, which helps him greatly during his long trip back to his home.[13] Of course, this form of intelligence is not restricted to humans:

it helps Zeus – who swallowed the goddess Mètis, his spouse – to maintain his power as king and to govern the cosmos wisely. Other deities are also associated with *mètis*: Athena, Hermes, Prometheus, and, as we shall see below, Aphrodite and Eros. We may add that the *iunx*-bird is not the only animal that behaves in a *poikilon* way: the Greeks associated a series of animals with this concept, including the octopus, the fox, and the snake. What these species all have in common is behaviour that is connected to notions of shiftiness, instability, undulation, twistiness, and enticement.[14]

The intriguing abilities of the snake-like bird might account for the fact that, according to Pindar, it was used for the fashioning of a magical device, a kind of wheel that was also called *iunx.*[15] Indeed, in a poem composed in 462 BCE for Arkesilas of Cyrene, who won the chariot race at Delphi, Pindar narrates the story of the invention of the object by Aphrodite herself, the goddess of erotic desire:

πότνια δ᾽ ὀξυτάτων βελέων
ποικίλαν ἴϋγγα τετράκναμον Οὐλυμπόθεν
ἐν ἀλύτῳ ζεύξαισα κύκλῳ
μαινάδ᾽ ὄρνιν Κυπρογένεια φέρεν
πρῶτον ἀνθρώποισι, λιτάς τ᾽ ἐπαοιδὰς ἐκδιδάσκησεν σοφὸν Αἰσονίδαν·
ὄφρα Μηδείας τοκέων ἀφέλοιτ᾽ αἰδῶ, ποθεινὰ δ᾽ Ἑλλὰς αὐτάν
ἐν φρασὶ καιομέναν δονέοι μάστιγι Πειθοῦς.

> And the queen of sharpest arrows brought the dappled iunx from Olympus, bound to the four spokes of the indissoluble wheel: Kyprogeneia brought the driven-mad bird to mortals for the first time, and she taught the wise son of Aeson prayers and incantations, so that he could rob Medea of reverence for her parents, and a longing for Greece would lash her, her mind on fire, with the whip of Persuasion.[16]

In this poem, Pindar explains how Jason succeeded in his quest thanks to the help of Medea, who fell in love with him. It was the mighty goddess Aphrodite who taught the hero certain magic spells and gave him a powerful tool – a magic wheel – to seduce Medea. This device was created by taking advantage of the extraordinary faculty of the *poikilon* bird. Pindar indicates that the goddess chained the wryneck on a four-spoked wheel in order to control its movement: we can infer – although it is not clearly stated here – that when the wheel was activated[17] the wryneck would swirl and produce its shrill whistling, which carried a persuasive and bewitching power. The *iunx*-wheel created by Aphrodite was useful for the erotic purpose of arousing lust. The seductive power of the instrument probably lies both in its physical motions (the spinning of the wheel) and in the sound it produced.[18] The importance of sound comes out clearly in a passage of the poem *Pharmakeutriai* by Theocritus (beginning of the third century BCE), in which the author depicts the auditory aspect of the iunx (which is closely linked to its visual aspect). Indeed, the *iunx* is 'invoked' like a refrain that gives incantatory rhythm to poetry and contributes to the efficacy of the love charm (*Idylls*, 2.17–63). This refrain, meant to be sung, evokes a circular movement, close to the whirling of a spinning wheel. Again, we deal here with the multisensory dimension of *poikilia*.

We do not know whether Pindar was the first to imagine a connection between the origin of the *iunx*-wheel and the *iunx*-bird. As a matter of fact, none of the fourth-century BCE vase-paintings that might depict the *iunx*-wheel[19] features a bird yoked on it. In these images, the presumed *iunx*-wheel looks like a kind of small jewel-like or plaything-like spoked wheel, with a cord or a string passed through two holes in the middle of it (figure 8.4). Drawing on the visual testimony provided by these vase-paintings, Gow (1934: 7) attempted a reconstruction of the iunx-wheel to show how it worked. The ends of the string were tied together so that the cord formed a loop; by alternately pulling and releasing the loop from either end, the metallic wheel could be made to spin rapidly. Most of the vase-paintings show the wheel held by Aphrodite herself, or by Eros, suggesting that it was used during weddings or for love magic[20] – which would account for the fact that, in some Greek texts, the term iunx happened to mean 'love, attraction, love charm'.[21]

Unfortunately, very few archaeological finds have been identified as possible votive *iunx*-wheels and in the case of those that have, the identification remains highly unconvincing. For example, one item from the fourth century BCE that has been so identified consists of round metallic objects formed of two shallow bowls of bronze joined together, pierced through the centre and mounted on a forked rod. However, since the device differs from the wheel activated by a string depicted in our images, it cannot reasonably be considered to be a *iunx*-wheel.[22] Another type of artefact that has been compared to a *iunx*-wheel is a series of terracotta wheels or disks decorated with birds that date from the Geometric period, but these are far bigger that the jewel-like objects displayed on vases and their function remains completely unknown.[23]

Nonetheless, I think that one of these finds – a four-spoked wheel now in Boston and dating from the late eighth century BCE – might deserve our attention.[24] Indeed, the artefact carries an impressive decoration with elaborate geometric designs. On the upper side of the wheel, eleven birds with folded wings are seated on the rim, their bodies displaying a mix of various motifs such as dots, lines, zigzag patterns and diamonds. The four spokes are decorated with a checkerboard pattern.[25] On the underside of the wheel, the painted decoration consists of alternating eye-shaped or leaf-shaped designs, checkerboard patterns, cross-hatching and cross-hatched triangles. The overall effect conveys 'a weird impression of occult power', pointing to a sort of magical instrument, according to the archaeologist Grace W. Nelson.[26] The various perforations for suspension found on the item indicate that the whirling device was activated in a manner that differed from the *iunx*-wheel: it was probably intended to be hung from a roof. What is more interesting for us is that the Boston wheel should probably be considered as the most ancient (and the most successful?) attempt at depicting wrynecks in Greek visual art, for the black lines and designs covering the body of the birds convey a deep sense of variegation – *poikilia* – even though only two colours are used. On vase-paintings of the Classical period, by contrast, the birds identified by modern scholars as *iunx*[27] display no distinctive features and are not variegated at all.[28] Actually, we cannot even be sure that we are dealing here with wrynecks, since the identification is inferred only from the erotic context and, sometimes, from the presence of the *iunx*-wheel on the same image – see, for instance, the scene on the fourth-century BCE Apulian amphora from Ruvo held in London (British Museum, F331) (figure 8.4).[29]

As far as texts are concerned, we have to read through the *Greek Anthology*, a collection of poems composed during the Hellenistic (through the Imperial)

FIG. 8.4 A iunx-wheel and a iunx-bird? Drawing from Daremberg et Saglio, *Dictionnaire des Antiquités grecques et romaines*, Paris, 1817, 864, showing a detail of a fourth century BCE Apulian amphora from Ruvo held in London (British Museum, F331)

period, to find a short (anonymous) Alexandrian poem that may evoke the appearance of an *iunx*-wheel dedicated as a gift to Aphrodite:

> ἴυγξ ἡ Νικοῦς, ἡ καὶ διαπόντιον ἕλκειν
> ἄνδρα καὶ ἐκ θαλάμων παῖδας ἐπισταμένη,
> χρυσῷ *ποικιλθεῖσα*, διαυγέος ἐξ ἀμεθύστου
> γλυπτή, σοὶ κεῖται, Κύπρι, φίλον κτέανον,
> πορφυρέης ἀμνοῦ μαλακῇ τριχὶ μέσσα δεθεῖσα,
> τῆς Λαρισσαίης ξείνια φαρμακίδος.

> Nikô's *iunx*, which can draw a man from across the sea and children out of their rooms, carved from translucent amethyst, *inlaid* with gold, and hung upon a soft thread of purple wool, is dedicated to you, Kypris, by the Larissan enchantress, as your own possession.[30] [my emphasis]

It is very difficult to reconstruct the actual appearance of the *iunx*-object dedicated by Nikô[31] and to determine whether it was genuinely a magic wheel (as the English translator suggests) or rather a kind of amulet. No bird decoration is mentioned. Nonetheless, what is clear from the poem is that the *iunx* is linked to magic (*pharmakis*, translated here by 'enchantress', meaning 'expert in *pharmaka*, i.e., all kinds of drugs and charms') and to Thessaly, a place that was famous in Antiquity for being full of sorceresses. The *iunx* that is carefully described in the epigram is truly *poikilos*: the object is made of different colours and materials, purple wool, precious stone and glimmering gold – a mix of brilliant colours and animated surfaces that were chosen because they perfectly suited Aphrodite and her divine erotic power and were credited with a special efficacy in the field of love magic. As mentioned above, the goddess herself is cunning and resourceful: she shows *mētis*.[32] With the help of both her son Eros and *poikiloi* devices, she knows how to turn human and divine hearts upside down, to change minds by generating passion and overwhelming desire.

What has emerged from our analysis so far is that the *poikilia* of both the *iunx*-bird and the *iunx*-wheel stems from a multisensory combination of colours and textures, a swirling movement and a sonorous whistling. Both characteristics were regarded by the Greeks as potential 'weapons' that might be used by Aphrodite to attract and seduce humans. Are we far from the realm of woven textiles here? I do not think so, since Aphrodite is also 'the one who braids wiles' (*doloploke*), as Sappho puts it at the beginning of a prayer invoking the help of the mighty goddess.[33] Indeed, among the *poikiloi* devices that generate erotic attraction we find woven textiles. The variegated girdle that Aphrodite gives to Hera in the *Iliad*, in order to seduce Zeus, is a powerful 'weapon' that may parallel the *iunx*-wheel:[34]

> Ἦ, καὶ ἀπὸ στήθεσφιν ἐλύσατο κεστὸν ἱμάντα
> *ποικίλον*, ἔνθα δέ οἱ θελκτήρια πάντα τέτυκτο·
> ἔνθ᾽ ἔνι μὲν φιλότης, ἐν δ᾽ ἵμερος, ἐν δ᾽ ὀαριστὺς
> πάρφασις, ἥ τ᾽ ἔκλεψε νόον πύκα περ φρονεόντων.
> τόν ῥά οἱ ἔμβαλε χερσὶν ἔπος τ᾽ ἔφατ᾽ ἔκ τ᾽ ὀνόμαζε·
> τῆ νῦν τοῦτον ἱμάντα τεῷ ἐγκάτθεο κόλπῳ

ποικίλον, ᾧ ἔνι πάντα τετεύχαται· οὐδέ σέ φημι
ἄπρηκτόν γε νέεσθαι, ὅ τι φρεσὶ σῇσι μενοινᾷς.

> She [Aphrodite] spoke, and loosed from her bosom the embroidered girdle, *variegated*, in which are fashioned all the charms; in it is love, in it desire, in it dalliance – seduction that steals the wits even of the wise. This she placed in her hands, and spoke and addressed her: 'Take now and place in your bosom this *variegated* girdle, in which all things are fashioned; I say you will not return without having whatever you desire in your heart be accomplished.'[35] [my emphasis]

It is difficult to deceive Zeus, since he is the supreme god who owns *mētis*. Hera thus needs the help of Aphrodite if she wants to convince her husband to turn away from the battlefield and make love to her. The transfer of power from one goddess to the other is achieved through the giving of a piece of cloth called *himas*, which has been variously interpreted by modern scholars.[36] Be it a waistband or a bra, a strap or a girdle, it is certainly not a casual *accessoire*: its strong power of enchantment, which Gell would have called its 'agency', lies in its rich ornamentation, probably playing with different colours, patterns, and, likely, shapes and materials (various fabrics, beads and metallic applications). Unfortunately, we have no visual representation of this mythical waistband on any vase-painting. But the verb *teukhô*, translated here by 'fashioned', refers less to weaving than to the making of metallic artefacts, notably the weapons and armour of warriors, which are composite and variegated, inlaid with bronze, gold, silver, tin, lapis-lazuli and so on. The word *thelkterion* indicates that the motifs of the garments are magical: they are charms that can affect the viewer and assert a strong hold over him.[37]

However, we know nothing about the shape of the patterns woven onto the fabric. Gabriella Pironti has persuasively suggested a link with the strong effect produced by Athena's aegis.[38] We may think indeed of the description provided in the *Iliad* when the goddess joins the Achaeans on the battlefield: 'bearing the precious aegis – ageless, immortal, from which a hundred solid gold tassels are hung, all of them cunningly woven, each worth a hundred oxen.'[39] Of course, this 'dazzling' and 'awful' talisman,[40] a protective and aggressive weapon at the same time, is not expected to produce the same result as the beautiful waistband. Nevertheless, in both cases the agency of the divine attribute seems to be activated by motion: the girdle has to be tied and untied to produce its alluring effect (perhaps enhanced by the rattling of metallic ornaments); the aegis has to be shaken to repel enemies.[41]

In summary, we have seen that the connection between the bewitching wryneck, the magic *iunx*-wheel and the beautiful girdle of Aphrodite arises from an array of common features: complexity of pattern, combination of textures and hues, mobility and even sonic effect (whistling, hissing, rattling). It is possible that a conjunction with perfume might also be at play,[42] which would further emphasise the multi-sensory dimension of the seductive power of this class of things. The bird, the wheel and the textile are therefore all intimately connected to the notion of *poikilia*, which goes beyond the visual and tends to blur the frontiers between living beings and (woven) artefacts.[43]

FROM UNPREDICTABLE SNAKES TO PERSIAN TROUSERS

We saw that Aristotle compared the wryneck to a snake. As we will now see, exploring the Greek imagery related to snakes will help in taking us a step further and expanding our enquiry to the role played by geometry in the association between decorated textiles and animals. Even more than wrynecks, snakes were considered by the Greeks as living beings characterised by *poikilia*. We find a large number of occurrences in Archaic and Classical texts where snakes are said to be *poikiloi*. The written evidence strongly suggests that the *poikilia* of the snake was not solely a matter of visual appearance: snakes were also thought to have a *poikilon* behaviour. Indeed, ancient writers underlined the hybrid nature of the snake: an elusive and deceptive animal whose twisting movements conveyed a sense of unpredictability. Serpents were conceived of as connecting the subterranean with the earthly parts of the world. They were also ambivalent in the Greek mind – depending of course on the species, whether grass snakes or vipers: some of them were benevolent guardians whereas others were dangerous enemies.[44] This is the reason why the poet Theognis (sixth century BCE) warned his nephew Kyrnos to beware of the man concealing the *poikilon* snake he was carrying with him:

> Cursed be you, hated by the gods and distrusted by men,
> who kept a cold and variegated (*poikilon*) snake in your bosom[45]

Here, the *poikilon* snake seems to be a dangerous weapon, used by traitors. It might be, thus, as powerful as the *iunx*-wheel and the Aphroditean waistband are, although it is used for a different purpose. It especially reminds one of the fearsome aegis worn by Athena on the battlefield.

There are many architectural sculptures and images on vases that offer insights into the ways in which the Greeks conceived of the *poikilia* of reptiles, and the potential relations these conceptions established with woven textiles. Fortunately, these images are both much more detailed and far more numerous than those we have of the wryneck. It is therefore possible to analyse the various graphic and chromatic strategies used by craftsmen. On most of the vase-paintings, the backs of the snakes are mottled with dots and circles, or decorated with scaly patterns, zigzag lines or stripes. The use of the dot pattern was not specific to snakes: the same graphic device also featured on other animals, such as birds, panthers and fawns. A similar pattern appears on certain garments as well, which establishes a link between the *poikilia* of snakes and the *poikilia* of fabrics.[46]

There is nonetheless a slight difference between the dotted costumes and the dotted wild animals: in the first case, the decorative pattern tends to be more regularly distributed, whereas in the second case the dots sometimes cluster more densely and are, generally, distributed in a random fashion, probably to convey the idea of the untamed. There are, however, exceptions: two peculiar kinds of dress were depicted in a way that bore significant similarities to the depictions of the bodies of snakes: first, the garments worn by the Persians and the Amazons, to which we will shortly return; second, the aegis worn by Athena – which should not be too surprising, since it bore the Gorgon head, with its serpentine hair.[47] Indeed, we can easily recognise the goddess' aegis on images thanks to the presence of snake's heads all around its borders. Indeed, in some notable cases, the painter accentuates the serpentine aspect by rendering the *whole* surface of the aegis as covered in scales, which seems quite odd when we recall that the aegis was made of a goat's skin.[48] For an example of this type, see, for instance a red-figured Athenian cup painted by Douris around 480–470 BCE, on which we see Jason being regurgitated by the snake who guards the Golden Fleece. Athena stands to the right, with her helmet, holding a spear in her right hand and a bird in her left hand. The goddess' aegis perfectly echoes the skin of the great serpent.[49]

The connection between snakes and textiles turns out to be much more consistent on sculptures, whose forms invariably provided canvases for applied polychromy in Antiquity.[50] Indeed, the craftsmen tended to use geometrical patterns to suggest the *poikilia* of the snakes. A good example can be seen on the fragment of a *poros* limestone sculpture that decorated the pediment of a sixth-century BCE temple on the Akropolis of Athens (figure 8.5). The body of the reptile is covered by a regular pattern made of diamonds, bands and egg friezes. The decoration is incised on the stone and the remaining traces of red, blue (or green?), and yellow pigments testify that the original was vividly colourful. The main goal of the painter was not to *imitate* the appearance of an actual snake: the alternation of patches of contrasted colours, following a geometric and regular pattern, aim rather at generating a sort of hypnotic effect. Additionally, the coiling movement of the snake's body contributed to the *animation* of the sculpture, providing a sense of elasticity and motion to the viewer. This device, in both its plastic and graphic dimensions, was intended to display the rich *poikilia* of snakes: the scaly – almost metallic – and heterogeneous texture of their skin, very different from that of humans, and their undulating motion.

As on vase paintings, but in an even more obvious way, on sculptures the geometric patterns that decorated the bodies of snakes were also used for the distinctive garments worn by Asian people (such as Persians, Scythians or Medes), whose *poikilia* is frequently emphasised by written sources (see, for example, the description of the Persian army by Herodotus).[51] For instance, the statue of a horseman known as the 'Persian rider', dating from approximately the same period and also coming from the Athenian Akropolis, strongly reminds us of the snake of the pediment. The sculptor aimed to show the specificity of

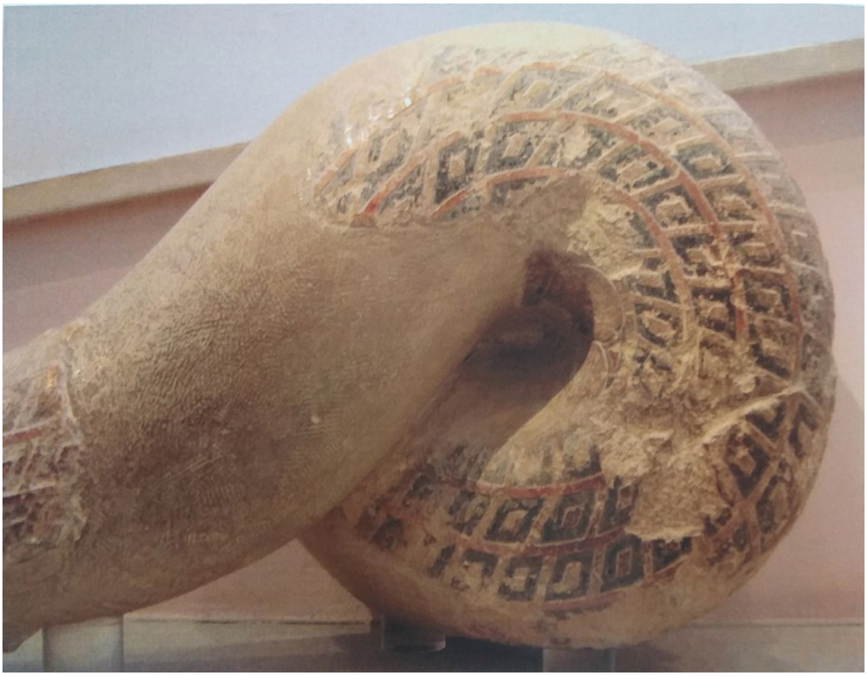


FIG. 8.5 Detail of the coiled body of one snake, at the corner of the East pediment of an Archaic temple on the Athenian Akropolis, around 570 BCE. The pôros sculpture, which was originally brightly painted, retains some traces of pigments (Athens, Akropolis Museum, inv. 37)

the costume: trousers (*anaxyrides*) and a long-sleeved jacket (*kandys*), which differed markedly from the loose and draped garments worn by the Greeks. The horseman is therefore dressed as a Barbarian warrior: probably a Persian rider – hence the name given to the sculpture by modern archaeologists. A reconstruction of the original polychromy has been proposed by Vinzenz Brinkmann and Ulrike Koch-Brinkmann, thanks to the analysis of the remaining pigments to be found on the surface of the marble (figure 8.6).[52]

The legs of the warrior here clearly resemble the colourful body of the snake. Another significant example is the statue of a Trojan archer (Paris, perhaps) found at the corner of the West pediment of the temple of Aphaia on Aegina (built at the beginning of the fifth century BCE). When the sculpture was unearthed in the spring of 1811, it retained traces of pigments, primarily blue and red. Unfortunately, the remains of the original polychromy are now lost and

FIG. 8.6 Colour reconstruction by Vinzenz Brinkmann and Ulrike Koch-Brinkmann of the so-called 'Persian horseman' found on the Athenian Akropolis. The original marble sculpture, from the late sixth century or early fifth century BCE, is held in the Akropolis Museum (inv. 606) and retains remains of pigments (photo by Ana Belén Cantero Paz in 2010) https://commons.wikimedia.org/wiki/File:Jinete_persa.jpg

technical analysis undertaken in the 1990s was unable to provide any conclusive evidence regarding the colour scheme. Nevertheless, an investigation of the surface under ultraviolet light showed that the marble had been unevenly preserved and revealed a complex diamond pattern on the archer's leg and undergarment. Drawing a comparison with contemporaneous sculptures like the Akropolis horseman enabled Vinzenz Brinkmann and Ulrike Koch-Brinkmann to propose a polychrome reconstruction in 2003, based on a five-colour scheme (red, blue, yellow, green, brown).[53] Although their experimental reconstruction remains highly hypothetical as regards the colour-scheme,[54] the geometry of the pattern seems to be quite secure. Here again we find a diamond network, although this example is even more elaborate than that on the leg of the Persian rider, since the craftsman has differentiated between the sleeved top, with its zigzag pattern, and the trousers, which were decorated with a *double* zigzag pattern. Was such an elaborate pattern a work of pure creativity on the craftsman's behalf? The answer is no. Thanks to experiments led by the textile conservator of the Bavarian National Museum, Dagmar Drinkler, we now know that all these motifs could also be achieved on real fabrics using the sprang technique (Drinkler 2009). According to Drinkler, this technique is the only way to obtain the elasticity required to make this kind of tight-fitting outfit. A two-colour reconstruction of the hose and shirt has been made, and the comparison with the painted sculpture is highly convincing ((figure 8.7).

Now, the question is: did the sculptor aim to reproduce the visual appearance of an actual Asian outfit? To this we may answer 'Not necessarily'. As in the depictions of snakes, I suggest that the main goal of the sculptor was to trigger the imagination of the viewer and to make him realise that the vivid garments were non-Greek; from the Greco-Persian wars onwards, Trojans, like

FIG. 8.7 Plaster reconstructions of the Trojan archer from the pediment of the temple of Athena Aphaia in Aegina (one painted reconstruction, by Vinzenz Brinkmann and Ulrike Koch-Brinkmann, and one plaster cast covered with a garment woven by the textile conservator of the Bavarian National Museum, Dagmar Drinkler). The original marble sculpture, from the beginning of the fifth century BCE, is held in the Glyptothek in Munich (photo by A. Grand-Clément during the HOMO TEXTOR conference, in September 2019 in Munich)

Amazons, were mythical equivalents for Scythians and Persians. In fact, when we look at Achaemenid images, it does not seem that the Persians depicted themselves with diamond-patterned and tight clothing at all, to which we may add that the archaeological findings suggest that they probably wore loose garments.[55] Nevertheless, a glaze brick from the walls of the palace of Darius I at Susa shows part of the leg and foot of a Median servant wearing trousers decorated with a zigzag pattern with three different alternating colours:[56] this image gives us some reason to think that diamond patterns were linked with the Median people rather than with the Persians. Additionally, the scarce archaeological evidence we have for Scythian textiles of the fifth century BCE indicates that rhombic patterns appear among other geometrical patterns on their carpets, headdress, and saddlecloths. However, we do not know to what extent this pattern was used on other pieces of clothing, especially trousers.[57]

While we are thus unable to draw strong conclusions about the actual historical clothing styles of Asian peoples, we can safely conclude that diamond patterns and tight-fitting trousers became part of the Greek imagery that was used to depict them. The Greeks knew that Barbarian outfits were made of fabric that might differ from wool or linen (felt or leather, for instance), and were cut in a different shape, clinging more closely to the body. It was therefore a challenge for the Greek craftsmen to convey a sense of otherness in their works. In crafting their depictions, they probably had in mind the elaborate pieces[58] of clothing made with sprang technique, but also, as I will argue below, the scaly and elastic skin of *poikiloi* snakes.

In the remaining part of this paper, I would like to expand on the reasons for the Greek use of a diamond pattern in characterising the Eastern Barbarians. My hypothesis is that the network of diamond shapes, which was closely connected to snakes, was regarded as visually encoding the notions of otherness and hybridity. To support this idea, it will be necessary to explore further a number of issues relating to geometry and graphics. Michel Pastoureau's typology for medieval images, although very schematic, may be useful in this regard for reading and understanding Greek iconography. In his book *L'étoffe du diable*,[59] the historian draws a distinction between three main ways of depicting garments on images: first, there are plain, monochrome, undecorated textiles ('l'uni'); second, spangled textiles ('le semé') with the motifs regularly and sparingly distributed; third, spotted, striped, hatched, chequered or variegated textiles ('le bigarré') which include a large range of patterns that are denser in their distribution. The last two kinds of decorated textiles do not convey the same values; 'le semé' is a mark of belonging to a high-status class, whereas 'le bigarré' is depreciated and points towards transgression or deviance: Pastoureau (2008: 47) shows that striped clothes are used to stigmatise ridiculous people, fools, prostitutes and even evil figures. The character of Harlequin is one of the most familiar figures of the 'dark side' of variegation. Pastoureau also argues that striped or diamond-patterned garments were associated with dissident characters because of the deceitful appearance of the decoration. He explains that, in the case of an alternation of stripes or diamonds, it proves impossible to distinguish the background from the motif; the eye of the viewer is lost and trapped – as it is with the *kolam* designs with which we began.

My hypothesis is that the Greek choice of a diamond pattern for depicting Barbarian garb may well have its origins in similar thought processes. Indeed, the concentration of motifs and the saturation of colours would have been regarded by the Greeks as a mark of disorder and threat. Since the sight of such a decorated pattern could rouse fascination and allure, it might at the same time constitute a threat, a danger. In this light, it is worth noting that, according to Euripides, the Trojan war broke out because of the fancy trousers worn by Paris: Helen was driven mad when she saw his beautiful *poikiloi* trousers, which made her immediately fall in love with him.[60] The effect of the trousers here is similar to what we might expect if Paris had used an *iunx*-wheel or displayed Aphrodite's band.

Pastoureau focuses mainly on stripes in his book. We have already seen that the Greek sculptors tended to use lozenges, rather than stripes or chequerboard patterns, to decorate the body of snakes as well as the surfaces of Persian clothing. The term used in Euclidean geometry to designate a lozenge is *rhombos*, which Aristotle defines as 'a four-sided figure with all the sides, but only the opposite angles, equal'[61], which means an equilateral parallelogram with oblique angles. However, the use of the term *rhombos* was not restricted to the field of geometry and mathematics. Indeed, it has in ancient Greek the basic meaning of 'anything that may be whirled'.[62] In Pindar, it refers to the trajectory of a javelin and to the swoop of an eagle, which seems to point towards a vibrating, rotating movement.[63] But it was above all the name given to certain devices used by the Greeks for the purpose of specific rituals or as toys for children, the efficacy of which stemmed from the swiftness of the whirling and from the whistling sound thus produced. Indeed, among the basic definitions of rhombus to be read in dictionaries, we have 'bullroarer', that is, an oblong block of wood or metal attached to a cord and whirled around the head to produce a 'roaring' sound – a kind of instrument well known to anthropologists.[64] Another meaning is 'spinning top' or 'magic wheel, spun alternately in each direction by the tension of two cords passed through two holes in it, used as a love charm'.[65] The *rhombos* so defined certainly reminds us strongly of the *iunx*. In fact, modern scholars still debate whether both terms might in fact denote the same kind of object[66] (*rhombos* being a more generic category, under which the *iunx*-wheels fall) or if the words refer to two very distinct wheel-like/spinning devices used for magic and rituals. I find the second option more convincing, for it does indeed seem that the *rhombos* rotated in the same direction, while the *iunx*-wheel went around first in one direction and then turned backward, thanks to the twisting of the wire.[67] In any case, the *rhombos* undoubtedly pertained to the field of *poikilia* and cunning intelligence (*mètis*), as did the *iunx*-wheel.

Why was the word *rhombos* also used to designate the lozenge? The connection between the two meanings remains unclear. In etymological dictionaries, *rhombos* is connected with the verb *rhembomai*, meaning 'to turn round and round', 'to go about, to wander, to roam around, to act at random'.[68] This etymology accounts for the 'spinning instrument' meaning, but there is nothing here that helps to provide a convincing explanation of the way *rhombos* came to mean 'diamond-shaped'. Chantraine suggests that it was probably the shape of the spinning devices that led the Greeks to designate lozenges as *rhomboi*,[69] but I would like to consider another hypothesis, according to which the processes of translation and distortion might have played a role. Indeed, a diamond can be understood as a square that has been twisted and whose angles have consequently been distorted. It is even possible that the sprang technique, involving the twisting of threads in order to achieve elastic textiles, was associated with *rhomboi*, whereas the traditional weaving technique on the warp-weighted loom was used to produce rather squared patterns.

In any case, what kind of link can be established with Asian dress? It has been shown that, in the Greek mind, Scythian, Thracian and Persian warriors were perceived as being unfair, cowardly, and deceitful fighters, in contrast to the courageous hoplites struggling along with their fellow citizens in the rectangular-shaped phalanx while firmly grasping their round shields.[70] Asian riders, like Amazons, were credited with a potentially deceptive, 'twisting' behaviour, the action of the mounted archer who sets his horse to run from the enemy but then twists round to fire off his arrows. The rhombus could thus have been taken as an appropriate graphic device for conveying otherness. Such a hypothesis would also account for the numerous images in which we find rhombuses or scaly patterns on Athena's aegis – as is the case, for instance, on the pediment of the temple of Aphaia, where the colourful aegis worn by the goddess[71] echoes the Asian garb of the archer: 'the multi-coloured scaly aegis then points to its nature as an artful, complex, magical and potentially dangerous monster's skin'.[72] The Asian archer of the Aegina pediment was certainly depicted as being on the wild side, positioned in the Greek mind next to the coiling, unpredictable and deceitful snake, and the powerful and fearsome divine aegis.

CONCLUDING REMARKS

In this paper, I have tried to determine what was at play in the connection that the Greeks established between certain peculiar animals and decorated textiles. I took the examples of wrynecks and snakes, exploring both texts and images to analyse how these animals were depicted and why they were considered to be living examples of *poikilia*. In both cases, the connection between *poikilia* and *mètis* came to the fore, as did the importance of the sensory (often multi- and cross-sensory) perception that constitutes such a fundamental part of the notion of *poikilia* in Archaic and Classical Greece. Both animals display multiple or changing colours, intricacy of patterns, unpredictable motion and a whistling sound. Although in a different manner – the wryneck, because of its plumage and snaky features, the snake, because the regular geometry of its scales changes as it moves in its distinctive way – both embody the idea of optical illusion, trickery, something that cannot be trusted by the eye, like Gell's technology of enchantment, and which may thus arouse mixed feelings compounded of both repulsion and attraction. Hence, there is no barrier between nature and craftsmanship. The bird has the magic *iunx*-wheel as a counterpart, but also the Aphroditean ribbon; the snake is on the side of the sonorous rhombus, as well as Athena's aegis and Asian trousers.

The fact that many sensory features – especially movements, colours, textures and sounds – are at play in the imagery we have studied might be interesting in the context of the broader scope of the technology of weaving taken as a 'mode of existence'. In their seminal study, Giovanni Fanfani and Ellen Harlizius-Klück rightly point out 'that weaving in antiquity is not a clear gesture nor a simple unification of opposites but a complex composition of woven and plaited parts integrated into a finished product by repeated gestures of turning the piece around or upside down'.[73] We might add that weaving also implies a peculiar sensorium: we may think of the role played by sounds, music and songs during the weaving process, or of the choreography of hands and threads induced by sprang technique or tablet-weaving. One might, for instance, suggest that the use of erotic *iunx*-wheels had something to do with weaving techniques, since the use of the string and the twisting motion of the alternating forward and backward movement recalls the process of tablet-weaving, while the diamond pattern may be associated with the result achieved with sprang technique. Perhaps weaving and magic have much more in common than we usually think.

ENDNOTES

1 I would like to warmly thank Giovanni Fanfani, Ellen Harlizius-Klück, Annapurna Mamidipudi, David Konstan, Jan S. Østergaard and Thomas Galoppin for their pertinent comments and valuable advice on this paper. Paul Scade was also of great help in revising the English but also in clarifying some ideas. All remaining mistakes are, of course, mine.

2 Gell 1998. Gell's theory relies on ideas already advanced by Gombrich (1979: 66), according to whom the artist's virtuosity may still consist in working the materials so well that 'miraculous transformations' seem to take place: wood looks like lace, needlework becomes similar to a painting. For a critical view of Gell's work, see

Derlon and Jeudy-Ballini 2010. The authors emphasise that the power of fascination is not unique to art and invite the reader to reassess the importance of the notion of beauty, which they believe was neglected by Gell. They rightly argue that beauty and efficiency go hand in hand and are not mutually exclusive.

3 He does, however, take tattoos into account in one of his chapters. I find it rather surprising that Gell did not pay due attention to the realm of textiles, since we know that in many societies certain items of clothing were endowed with the same kind of agency as other valuable artefacts: they were also 'works of art'.

4 Grand-Clément 2015, esp. 412–16.

5 Of course, we should bear in mind that the divide between what we might call 'nature' and 'culture' is a modern Western cultural construct, beyond which scholars must move if they are to understand properly many past and present societies: see Descola 2015. Indeed, Ellen Harlizius-Klück and Giovanni Fanfani (2016: 62–64), drawing on the works of H. Blumenberg, rightly stress that, for the ancient Greeks, *physis* (nature) and *technè* (technology) were closely interconnected.

6 On the *Iunx torquilla*, a bird that is widespread throughout Europe, see Thompson 1936: 124–28; Arnott 2007: 118–119.

7 Aristotle, *Historia Animalium*, 2.12 504a (transl. A. L. Peck, modified).

8 See, for instance, two videos showing the snaky movement of the head: https://commons.wikimedia.org/wiki/File:Wryneck.ogv and https://www.youtube.com/watch?v=0reJ84wB5yg. I thank Jan S. Østergaard for sending me the link. Dionysius (*On Birds* 1.23) writes that the bird moves its neck incessantly, like celebrants worshipping the goddess Rhea.

9 The basic meaning is 'utter a shrill cry', according to Liddell, Scott, and Jones (1996); the verb is mainly used to denote sounds emitted by animals, especially birds. Aelian describes the wryneck cry as sounding like the *aulos* (*De Natura Animalium*, 6.20). For an insightful inquiry on the imagery of the snake hissing and its potential relation to music in Greek sources, see Perrot 2012 (although without reference to the wryneck).

10 Another possible etymology considers *iunx* as an expressive word (as is the case for a number of names of birds and musical instruments). Consequently, the connection between *iunx* and *iuzô* would be a folk etymology. Chantraine (2009: 455) does not choose between the two possibilities, while Beekes (2010: 605) argues in favour of the second and suggests that *iunx* is a loan word.

11 See, for instance, Callimachus fr. 685 Pfeiffer. On the different versions of the myth, see Detienne 1972: 163; Pirenne-Delforge 1993: 285–6; and Johnston 1995: 182.

12 See Detienne and Vernant 1974. On the close connection that originally existed between *poikilia* and *mètis*, see 25–31.

13 *Polumèkhanos*: *Il.* 2.173; 4.358; 8.93; *Od.* 1.205; 5.203; 10.40; *poikilometès*: *Il.* 11.482; *Od.* 3.163; 7.168; 13.293; 22.115, 202, 281.

14 Detienne and Vernant 1974: 32–57.
15 On the *iunx*-wheel, which is mentioned in a number of written sources, see for instance Gow 1934; Pirenne-Delforge 1993: 283–84. A full bibliography is given in Johnston 1995.
16 Pindar, *Pythian* 4.213–19 (transl. D. Arnson Svarlien, modified).
17 *Contra* Faraone (1993:11–16), who thinks that the device was not intended to be moved. Faraone also believes that the bird was tortured (driven mad) and that the effect produced on it was intended to be transferred to the victim.
18 Sarah Iles Johnston (1995: 178) convincingly argues that the sonic effect has predominance over the visual agency: according to her, 'the *iynx* was understood to work by emitting a sound that was seductive and persuasive but that also – like so many seductive and persuasive sounds – was possibly deceptive, spelling ruin for its listener'.
19 We should be cautious with the interpretation of the toy-like objects as *iunx*-wheels, as Faraone argues (1993: 2 n. 3).
20 Reproductions of some of these vase paintings are discussed in Gow (1934: 4–5). Greek jewellery of the Classical and Hellenistic periods also shows figures of *erotes* manipulating such wheels: see Williams and Ogden 1994: 9.
21 See, for instance, Pindar, *Nemean* 4.35; Aeschylus, *Persians* 989 (the Persian king evokes the grief precipitated by the loss of his beloved companions); Aristophanes, *Lysistrata* 1110.
22 Gow 1934: 11.
23 Therefore, the identification with the *iunx*-wheel is problematic: see Génière 1958; Karageorghis 1989.
24 Museum of Fine Arts, Boston, inv. 28.49. Diameter 21.5 cm. Images can be found in Nelson 1989.
25 See https://collections.mfa.org/download/151573.
26 Nelson 1989: 455.
27 See, for instance, an Apulian hydria painted at the beginning of the fourth century BCE (British Museum, F94).
28 This is why Tavenner (1933: 120) is not convinced by the identification and argues persuasively that these birds might be doves. But we can also mention the decoration of a Paestan vase, with the bird's cross stripes picked out on tail and wings (Bohr 1997, fig. 1).
29 See also the Athenian red-figured hydria from the end of the fifth century BCE held in Florence (Museo Archeologico Etrusco, 81948), on which both the *iunx*-bird and the *iunx*-wheel have been identified; for other examples, see Nelson 1946: 454.
30 *Greek Anthology*, 5.205 (transl. W. R. Paton, slightly modified).

31 Faraone (1993: 152) suggests that Nikô was probably a successful courtesan, 'who at the end of a long career dedicated this valuable device to Aphrodite, the patron goddess of her profession'.

32 Fifth-century BCE Athenian playwright Aeschylus calls the goddess *aiolomètis*, 'dappled-minded' (*Libation Bearers* 1037).

33 Sappho, fr. 1 Page. The poem has been brilliantly studied by Privitera (1967), who shows that the use of the epithets *poikilothronos* and *doloplokos* is part of the device created to guarantee the efficacy of the prayer. The author supports the traditional view that *poikilothronos* has the meaning of 'ornate-throned', whereas other scholars have argued that it might refer to the flowery garment of the goddess: see Vickers 1999: 22; Scheid and Svenbro 1993: 51–55.

34 A parallel was already drawn by Pirenne-Delforge (1993: 283).

35 Homer, *Iliad*, 14. 214–21 (transl. A. T. Murray and W. F. Wyatt, slightly modified).

36 See Grand-Clément 2011: 458–59.

37 On the agency of the garment and the meaning of *thelkteria*, see Carastro 2006: 95–98.

38 Pironti 2007: 97–98.

39 *Il.* 2.447–49.

40 *Il.* 15.307–10.

41 On Athena's aegis, see Vierck 1991.

42 Detienne (1974: 164, 168), who draws a comparison between two mythical young women (Mintha and Iunx), also establishes a connection with perfumes. According to him, seduction may play with visual, sonic and olfactory devices.

43 Another good example of the agency exerted by a *poikiloi* artefact, blurring the frontier between craftsmanship and living beings, is provided by the round shield of Achilles in the *Iliad*. I thank David Konstan for drawing my attention to this example. I will not develop this point further here since it goes beyond the scope of the present chapter.

44 On the Greek imagery of snakes, see Sancassano 1997; on the Greek taxonomy of snakes, Bodson 1981; on the role played by snakes in mythology and cult, see Ogden 2013.

45 Theognis, I, 601–2 (transl. D. E. Gerber modified).

46 With regard to textiles, the use of black dots, circles and stars was also a means of conveying the image of variegated, colourful garments for the vase painters, who did not have a great range of colours at their disposal due to the firing process involved in vase production.

47 In this paper, I will not discuss Athena's colourful and elaborately woven *peplos*, which also conveys the notion of *poikilia* but which, I think, works in a quite different way.

48 Other traditions claim that it was forged by Hephaistos: Deacy and Villing (2009: 111).
49 Red-figured cup by Douris, c. 480–470 BC. From Cerveteri (Etruria). Museo Gregoriano Etrusco, inv.16545: https://fr.wikipedia.org/wiki/Fichier:Douris_cup_Jason_Vatican_16545.jpg.
50 For two of the more recent updates on the polychromy of ancient Greek sculpture, with full bibliography, see Østergaard 2018 and Brinkmann 2007. Among the many catalogues of exhibitions held on the topic, see Brinkmann and Wünsche 2007; Østergaard and Nielsen 2014.
51 Herodotus, *Historia,* 7.61 and 65. For the link between *poikilia* and Barbarians, see Grand-Clément 2013: 249–53.
52 For the details of the pigment analysis and painting process, see Brinkmann and Koch-Brinkmann 2010: 115–20.
53 See Brinkmann and Koch-Brinkmann 2003. Since then, they have proposed two other experimental colour reconstructions: one in 2006, with a slightly different colour-scheme, and another in 2019, with golden flecks added to the clothing (https://buntegoetter.liebieghaus.de/en/).
54 The great deal of interpretation involved in this colour reconstruction has been criticised by modern scholars (see, for instance, Schmaltz 2009).
55 See the sensational discovery in 1994 of the mummified remains of ancient miners who worked in the fifth and fourth centuries BCE.
in the opencast salt mine of Douzlakh, in north-western Iran. The woven trouser worn by salt mummy no. 4, now in the Archaeological Museum Zanjan, was rather loose and made of plain wool: Grömer 2016.
56 Paris, Musée du Louvre, inv. Sb 14426. Image: http://www.achemenet.com/fr/item/?/musee-achemenide/categories-d-objets/architecture/decor-architectural/3018977
57 For an analysis of the geometric patterns in ancient Scythian and Chinese textiles, see Berczi 2009.
58 Deacy and Villing 2009: 117.
59 His book was translated into English in 2001 with the title *The Devil's Cloth: A History of Stripes*.
60 Euripides, *Cyclops,* 182–85. See Harlizius-Klück, this volume.
61 See Euclides, *Elements,* 1.22; Ps-Aristotle, *Mechanics* 854b16).
62 The noun comes from the verb *rhembô,* meaning 'to turn round and round', 'to roam, rove, roll about', according to Liddel, Scott and Jones 1996.
63 Pindar, *Olympians* 13.94; *Isthmians* 4.47 (3.65).
64 The bullroarer is considered to be the earliest and longest surviving among artefacts that can be termed musical instruments. Its use has been widespread all over the world,

but its ritual and symbolic significance have varied from one culture to another. For a few bibliographical references, see Oliver and Johnson 2003.

65 See Liddell, Scott, and Jones 1996: 1574 and suppl. 271 (the word might even designate a tambourine or a 'kettle-drum', used in the worship of Rhea and of Dionysus: Aristophanes, fr. 303; Apollonius Rhodius, *Argonautica*, 1.1139). A Hellenistic epigram mentions a *rhombos* among the playthings dedicated to Hermes by a young man on becoming an adult: *Greek Anthology*, 6.309.

66 Tavenner (1933) thinks that *rhombus* and *iunx* are both tops. Moreover, he challenges the common view that the so-called *iunges* depicted on vase-paintings are magic wheels, contending that the objects are rather playthings or love gifts, such as wreaths.

67 According to Gow (1934: 6), followed by Johnston (1995), the *iynx* was a wheel on a loop of string, whereas the *rhombos* was rather a bullroarer, but in the ancient texts the difference is not so clear. It seems that, in contrast to the *iunx*, we do not have any depiction of a bullroarer on a Greek vase.

68 Beekes 2010: 1280; Chantraine 2009: 935–36 (who suggests that the etymological root is possibly **wer*, to turn).

69 Chantraine 2009: 935. Archimedes uses the term 'solid *rhombos*' to designate two right circular cones sharing a common base.

70 See Lissarrague 1990. Regarding the Thracians, more specifically, it must be stressed that, on vase paintings, their long cloak (the *zeira*) quite often featured patterns, stripes, and sometimes dots. However, this garment is never depicted with lozenges. I suggest that the reason for the difference between Persian tops and trousers is that the *zeira* is not regarded as being tight-fitting. We may add that the Thracians (especially women) are also depicted with tattoos on their skin, which is another way of suggesting the *poikilia* of Barbarians.

71 See the reconstruction in Brinkmann 2004: 120–21.

72 Deacy and Villing 2009: 117.

73 Harlizius-Klück and Fanfani 2016: 95.

REFERENCES

Arnott, W. G., *Birds in the Ancient World from A to Z* (London; New York: Routledge, 2007).

Beekes, R., *Etymological Dictionary of Greek* (Leiden; Boston: Brill, 2010).

Berczi, S., 'Geometry of Royal Tomb Art of Ancient Eurasia: Scythian, Xiongnu and Chinese Ethnomathematics from Ukraine, Russia, Mongolia and China', *Pollack Periodica*, 7 (2012): 199–211.

Bodson L., 'Les Grecs et leurs serpents. Premiers résultats de taxonomique des sources anciennes', *L'Antiquité classique*, 50.1–2 (1981): 57–78.

Bodson, L., 'Introduction to the Ancient Greek System of Snake Naming: the Ophionym *dipsas* and its Synonyms', *Anthropozoologica*, 47.1 (2012): 73–155.

Bohr, E., 'A Rare Bird on Greek Vases: The Wryneck', in J. H. Oakley, W. D. E. Coulson and O. Palagia, eds, *Athenian Potters and Painters* (Oxford: Oxbow Books, 1997), pp. 109–23).

Brinkmann, V., 'The Polychromy of Archaic and Classical Greek Sculpture', in J. S. Østergaard and A.-M. Nielsen, eds, *Transformations: Classical Sculpture in Colour* (Copenhagen: Ny Carlsberg Glyptotek, 2014), pp. 80–115.

Brinkmann, V., and U. Koch-Brinkmann, *Der prächtige Prinz* (Munich: Biering & Brinkmann, 2003).

Brinkmann, V., 'Il Principe e la divinità: La riscoperta della policromia sulle sculture del Tempio di Egina', in P. Liverani, ed., *I Colori del Bianco. Policromia nella Scultura Antica* (Roma: De Luca, 2004), pp. 107–32.

Brinkmann, V., and U. Koch-Brinkmann, 'On the Reconstruction of Antique Polychromy Techniques', in V. Brinkmann, O. Primavesi, and M. Hollein, eds, *Circumlitio: The Polychromy of Antique and Mediaeval Sculpture* (Munich: Hirmer, 2010), pp. 114–35.

Brinkmann, V., and R. Wünsche, *Gods in Color: Painted Sculpture of Classical Antiquity; Exhibition at the Arthur M. Sackler Museum, Harvard University Art Museums, in Cooperation with Staatliche Antikensammlungen and Glyptothek Munich and Stiftung Archäologie Munich, September 22, 2007–January 20, 2008* (Munich: Stiftung Archäologie Glyptothek, 2007).

Carastro, M., *La cité des mages. Penser la magie en Grèce ancienne* (Grenoble: Millon, 2006).

Chantraine, P., *Dictionnaire étymologique de la langue grecque: Histoire des mots.* Avec Supplément (Paris: Klincksieck, 2009).

Deacy, S., and A. Villing, 'What Was the *Colour* of Athena's *Aegis*?', *Journal of Hellenic Studies*, 129 (2009): 111–29.

Derlon, B., and M. Jeudy-Ballini, 'L'art d'Alfred Gell', *L'Homme*, 193 (2010): 167–84.

Déléage, P., 'Les répertoires graphiques amazoniens', *Journal de la société des américanistes*, 93.1 (2007): 105–26.

Descola, F., *Par-delà nature et culture* (Paris: Gallimard, 2015).

Detienne, M., *Les Jardins d'Adonis: La mythologie des aromates en Grèce* (Paris: Gallimard, 1972).

Detienne, M., and J.-P. Vernant, *Les ruses de l'intelligence: La* mètis *des Grecs* (Paris: Flammarion, 1974).

Drinkler, D., 'Tight-Fitting Clothes in Antiquity – Experimental Reconstruction', *Archaeological Textiles Newsletter*, 49 (2009):11–15.

Faraone, C., 'The Wheel, the Whip and Other Implements of Torture: Erotic Magic in Pindar Pythian 4.213–19', *Classical Journal*, 89 (1993): 1–19.

Faraone, C., *Ancient Greek Love Magic* (Cambridge, MA: Harvard University Press, 1999).

Gell, A., *Art and Agency: An Anthropological Theory* (Oxford: Clarendon Press, 1998).

Gell, A., 'The Technology of Enchantment and the Enchantment of Technology', in J. Coote, ed., *Anthropology, Art, and Aesthetics* (Oxford: Clarendon Press, 1994), pp. 40–63.

Génière, J. (de la), 'Une roue à oiseau du Cabinet des Médailles', *Revue archéologique,* 60 (1958): 27–35.

Gombrich, E., *The Sense of Order: A Study in the Psychology of Decorative Art* (Oxford: Phaidon, 1979).

Gow, A. S. F., 'ΙΥΓΞ, ΡΟΜΒΟΣ, Rhombus, Turbo', *Journal of Hellenic Studies*, 54 (1934): 1–13.

Grand-Clément, A., *La fabrique des couleurs. Histoire du paysage sensible des Grecs anciens (VIII*e*–début du V*e *s. av. n. è.)* (Paris: De Boccard, 2011).

Grand-Clément, A., 'Poikilia. Pour une anthropologie de la bigarrure en Grèce ancienne', in C. Bonnet, P. Payen, and E. Scheid, eds, *Anthropologie de l'Antiquité. Anciens objets, nouvelles approches* (Turnhout: Brepols, 2013), pp. 239–62.

Grand-Clément, A., 'Poikilia', in P. Destrée and P. Murray, eds, *A Companion to Ancient Aesthetics* (London: Blackwell, 2015), pp. 406–21.

Grömer, K., 'Durchdacht gemacht: Die Kleidung eines Salzmannes aus Chehrabad Iran', *Universum Magazin*, 3 (2016): 108–9.

Harlizius-Klück, E., and G. Fanfani, '(B)orders in Ancient Weaving and Archaic Greek Poetry', in G. Fanfani, M. Harlow, and M.-L. Nosch, eds, *Spinning Fates and the Song of the Loom: The Use of Textiles, Clothing and Cloth Production as Metaphor, Symbol and Narrative Device in Greek and Latin Literature* (Oxford & Philadelphia: Oxbow Books, 2016), pp. 61–99.

Johnston, S. I., 'The Song of the Iynx: Magic and Rhetoric in Pythian 4', *Transactions of the American Philological Association*, 125 (1995): 177–206.

Karageorghis, V., 'Two Votive *Iynx*-Wheels from Cyprus', in *Architecture et poésie dans le monde grec. Hommage à Georges Roux* (Lyon: Maison de l'Orient et de la Méditerranée Jean Pouilloux, 1989), pp. 263–68.

Lagrou, E., 'Le graphisme sur les corps amérindiens: Des chimères abstraites?', *Gradhiva*, 13.1 (2011): 68–93.

LeVen, P., 'The Colours of Sound: Poikilia in its Aesthetic Contexts', *Greek and Roman Musical Studies*, 1 (2013): 229–42.

Liddell, H. G., R. Scott, and H. S. Jones, *Greek-English Lexicon, with a revised Supplement* (Oxford: Clarendon Press, 1996 [1946]).

Lissarrague, F., *L'autre Guerrier: archers, peltastes, cavaliers dans l'imagerie attique* (Paris: La Découverte, 1990).

Nelson, G. W., 'A Greek Votive Iynx-Wheel in Boston', *American Journal of Archaeology*, 64 (1946): 443–56.

Ogden, D., *Drakon: Dragon Myths and Serpent Cult in the Greek and Roman World* (Oxford: Oxford University Press, 2013).

Oliver, P., and B. Johnson, 'Bullroarer', in J. Sheperd, ed., *Continuum Encyclopedia of Popular Music of the World* (New-York; London: Continuum, 2003, vol. 2), p. 412.

Østergaard, J. S., 'Polychromy, Sculptural, Greek and Roman', in *The New Oxford Classical Dictionary*, Oxford: Oxford University Press, 2018 https://doi.org/10.1093/acrefore/9780199381135.013.8118 [accessed 11 November 2023].

Østergaard, J. S., and A.-M Nielsen, *Transformations: Classical Sculpture in Colour* (Copenhagen: Ny Carlsberg Glyptotek, 2014).

Pastoureau, M., *L'Étoffe du diable. Une histoire des rayures et des tissus rayés* (Paris: Seuil, 2008).

Perrot, S., 'Le sifflement du serpent: du son inarticulé à la mise en musique', *Anthropozoologica*, 47.1 (2012): 345–61.

Pirenne-Delforge, V., 'L'Iynge dans le discours mythique et les procédures magiques', *Kernos*, 6 (1993): 277–89.

Pironti, G., *Entre ciel et guerre. Figures d'Aphrodite en Grèce ancienne* (Liège: CIERGA, 2007).

Privitera, G. A., 'La rete di Afrodite. Ricerche sulla prima ode di Saffo', *Quaderni Urbinati di Cultura Classica*, 4 (1967): 7–58.

Rinaudo, M., 'Sviluppi semantici e ambiti d'uso di *poikilos* e derivati da Omero ad Aristotele', in E. Berardi, ed., *Poikilia: Variazioni sul tema* (Acireale: Bonanno Editore, 2009), pp. 25–64.

Sancassano, M. L., *Il serpente e le sue immagini: Il motivo del serpente nella poesia greca dall'Iliade all'Orestea* (Como: Edizioni New Press, 1997).

Scheid, J., and J. Svenbro, *Le métier de Zeus: Mythe du tissage et du tissu dans le monde gréco-romain* (Paris: Errance, 2003).

Schmaltz, B., 'Die Kore Akropolismuseum inv.682. Versuch einer Rekonstruktion', *Jahrbuch des deutschen archäologischen Instituts*, 124 (2009): 75–134.

Tavenner, E., 'Iynx and Rhombus', *Transactions of the American Philological Association*, 64 (1933): 109–27.

Thompson, D'Arcy W., *A Glossary of Greek Birds* (London: Oxford University Press, 1936).

Vickers, M. *Images on Textiles: The Weave of Fifth Century Athenian Art and Society* (Konstanz: University Press Konstanz, 1999).

Vierck, S., 'Die Aigis: zu Typologie und Ikonographie eines mythischen Gegenstandes', Diss. Münster, 1991.

Williams, D., and J. Ogden, *Greek Gold: Jewellery of the Classical World* (New York: Abrams, 1994).

9

EPISTEMIC, SOCIAL AND MATERIAL ORDERING THROUGH WEAVING THREADS

Annapurna Mamidipudi

STARTING WITH WORDS: THE CLOTH-BODY-POEM

This is fine, this is fine cloth.
It is been dipped in the name of the lord
The spinning wheel, like an eight-petal lotus, spins,
With five *tatvas* and three *gunas* as the pattern.
The Lord stitched it in ten months
The threads have been pressed to get a tight weave.
It has been worn by gods, people, and sages
They soiled it with use.
Kabir says, I have covered my self with this cloth with great care,
And eventually will leave it like it was.

KABIR, WEAVER SAINT 15TH CENTURY

DRAWING ON FAMILIAR EVERYDAY TERMS FROM HIS HAND WEAVING PRACTICE, Kabir translates deep and abstract philosophies of existence into poetry still sung today. Interpreting the poem above, scholar Linda Hess says, 'the subtle and fine body-cloth is woven with the inhale and exhale as warp and weft, animating the fabric of the body-self. Rather than stain this fine cloth with neglect and violence, my aim is to live a life that would leave the cloth-self in pristine condition.'[1] The weaving terms that Kabir uses in his poetry are readily decipherable as metaphors for deep and abstract metaphysical philosophies. Yet, for the weaver Kabir, the material cloth and weaving practices are critical for understanding the metaphorical reading. Taking Kabir's poetry as a practice of transmission of knowledge, Linda Hess notes that Kabir is always sung – the text is always oral. Such texts that are performed she suggests 'entail a certain fluidity of text, a certain unpredictability of content and interaction' (Hess 2015: 212).

FIG. 9.1 The poet Kabir with Namdeva, Raidas and Pipaji. Jaipur, early nineteenth century, National Museum New Delhi (Public Domain, Wikimedia.org)

Bodies and their memory – particularly the ability to remember text-song – are of central importance. Orality implies sociality – the making of communities. On the one hand, Hess argues that music has a transformative effect on how we receive and understand text; on the other, she argues that texts sung as music, combined with sound, physical presence and social interaction are constituent of oral performative cultures. Rather than using the words and terms as metaphors whose primary significance is to explain cosmological order, Kabir's poetry could now be read as referencing the practices – of weaving, of singing – themselves, as the basis for producing epistemic, social and material ordering.[2]

STARTING WITH OBJECTS: THE LOOM-BODY-CONCEPT

The handloom is a technological object that is used to produce cloth. Yet, following contemporary norms of technological progress, since the Indian handloom itself is not constantly being innovated, it struggles to maintain its status as a technological object of the present.[3] As a counterpoint to the deterministic narrative that frames the handloom as a backward technology – especially within innovation discourses that equate technological newness with progress – activist-weaver Gopi Krishna[4] recalls an episode from a 1998 meeting in the village of Chinnur, Adilabad, which instead highlights the technological creativity of the Indian weaver. His weaver colleague Nazeer Kamaal had brought as gifts for the honourable guests bags woven from two-inch-wide tape normally used to weave the base of the traditional 'charpoy' or four post bed. When a local dignitary specifically asked an extra one to be made for her, his weaver colleague, unfazed by the absence of his loom, wound threads around the fingers of the upheld hands of two people and set up a warp for weaving the necessary length of tape needed to make a bag. Gopi, in recounting this story, showed that the loom was not an artefact of the past, but a flexible concept that could be materialised as the weaver wished: 'the loom is not just a material technological object, in the mind of the weaver it is an abstract technical concept that can be used to order threads and to produce a weave using any available resources' (Mamidipudi 2016). Indeed, as demonstrated, it was a concept that could be creatively deployed as needed, as it was stably embedded as routine practice in the weaver's body and mind.

This might well explain how the loom played a similar role – as a concept that could be the basis for knowledge exchange – among 300 weavers gathered in the weaving village of Chirala in 2018, for a ten-day conference on 'Anchoring innovation in handloom weaving,' organised by the union leader Macharla Mohan Rao. The conference drew weaver participants from Gujarat, Jammu and Kashmir, Chattisgarh, Triura, Manipur, Nagaland and Sikkim, Karnataka, Tamil Nadu, Kerala and Andhra Pradesh and Telangana, and scholar participants from all over the world. Special guests were weavers and dyers from Thailand, Taiwan, China and Laos. Some weavers journeyed over four days and nights, carrying their looms, since that was a prerequisite for participation.

FIG. 9.2 The conference 'Anchoring Innovation' in Chirala, attended by 300 weavers, activists and scholars (photo by S. Gopinath in 2018)

The craft activist organisers had a mandate for the conference that brought them all together – there would be no tired talk of diminishing markets and inadequate state aid, berating the industry for its real and imagined woes. Instead, weavers would be treated like delegates at a conference, their travel paid for, their stay accommodated by local weavers of Chirala who opened their homes to the travellers, and most important, what would be spoken would be the language of the loom.[5]

A weavers' camp of 72 looms, with exhibition and workspaces, was set up under trees and shelters at a local school, drawing the local community into

FIG. 9.3 Weavers in Chirala, Bandaru Gangadhara Saibaba from Chirala and Chanhsouck Phommalin from Laos (photo by S. Gopinath)

what was perhaps the first time they had seen such a festival of looms: of weavers coming together from all over India to share knowledge. Translators were at hand, yet workshops and discussion reflected the capacity of artisans to communicate and absorb from one another across barriers. Weaver-to-weaver interactions offered a 'reality show' context to two days of discussions that followed, engaging scholars and weavers from around the globe around issues of craft and pedagogy, law, labour, livelihoods and future directions.

More than 70 women weavers from the north-east of India set up their very simple loin looms at the front of the meeting space. At the other end of the spectrum of handlooms, an exhibit of looms with elaborate Jacquard mechanisms had been set up by experts from the Weavers Service Centre. Generally seen as the brokers of new technology to the sector, the male technologists were used to getting all the attention from weavers at whichever venues they exhibited their looms. Here though, since the focus was not on technological progress, but the knowledge of the weaver, male weavers from Chirala flocked to the loin looms to watch the women weave complex patterns using the simplest looms. Later, in the discussion sessions, when the same male weavers complained about how high-speed mechanised power looms copied their innovative handloom patterns, the north-east women weavers took the argument to its completion. They could now confidently argue that when weavers used Jacquard and dobby attachments on their looms to make complex patterns, the men were doing to the women's loin loom techniques[6] exactly what the men were accusing the power looms of doing to them.

STARTING WITH PEOPLE: LIVELIHOOD-COMMUNITY-ECOLOGY

Social relations are the backbone of handloom weaving economies in India (Mamidipudi 2016). These relationships are the living source of an ecology made up of material skills, tools, songs, memories and spaces. For example, the nomadic Kunche Erukula community (primarily living in Telangana and Andhra Pradesh) made the brushes used by weavers to starch cotton warps, a technique called sizing, which made India famous for its cottons. Fearing theft while travelling, they wove their savings, converted into gold nuggets, into the brushes that they repaired, and left them behind in the weavers' homes for safekeeping. Yet, no weaver ever broke open a brush to steal their gold, for fear that they had no way of putting it together again, and would lose the means of sizing their warps and the trust of the brush makers.

The skill of the brush maker was in knitting the *kunche*, or brush, using the bark of a particular tree. According to the medieval text Manasollasa, an early 12th-century Sanskrit text composed by the Kalyani Chalukya king Someshvara III[7] on the art of living, rope made of this anajan tree bark was so strong it was used to capture elephants. One of the toughest woods of India, its trunk could serve as the base of an oil mill, *ganuga*, the oil collecting in the hollowed out middle, around which bulls would traverse in circles, grinding the oil seeds. The bulls would be fed on the stalks of the native *jowari* (*sorghum*) plant that used to grow seven feet tall, full of sugary sap that gave them the strength to work the mill.[8]

With the steam engine, the tractors, the motors and the hybrid seeds, the *jowari* plant became shorter, the bulls weaker and the communities poorer. The reed for the handloom was no longer made by the local carpenter out of the jowari plant, but was mass produced in metal in a factory. When knowledge is performed by bodies, and is embedded in the ecology of social relationships, rather than written in books, it can only be transmitted from person to person. Family and social relationships thus become the backbone of accumulation of any kind of capital in this community, financial or social. Social capital is the currency of both pedagogy and performance. Today, for there to be gold in the brushes of the Kunche Erukula, all these complex relations would have to be reinvented.

This is hardly the business of policy makers today: Macharla Mohan Rao, union leader and handloom activist does not have much positive to say about government policy towards handloom weaving in India. Even as it has a market share of 10% in the domestic market, and is the second largest rural employer after agriculture, the government considers it a 'sunset industry.' Yet he has only good words for one particular Textile Minister in the 1990s, and his championing of a policy that was referred to as 'house-cum-workshed' that constructed houses for weavers, designed by weavers. This was partly seen as welfare work, but for the weaving villages in Andhra Pradesh, it became the impetus for a new generation of young weavers to take up weaving. For example, weavers from Odisha, a neighbouring state, visiting the weavers' conference in Chirala, Mohan Rao's hometown, exclaimed over how well the streets were laid out as well as the spaces for all the different tasks of weaving. The houses are clearly ordered around the loom that was located prominently in view in the front of the sheltered veranda, so the weaver could be seen at work. Houses are also ordered in straight rows, with streets in the front that could be used for sizing long warps. The houses themselves were airy and well lit, and quite modern. The rows of houses are arranged back-to-back; that is, two rows of houses would meet at the back, where the different generations of women could meet, to mind children, wind bobbins or share cooking tasks. Seeing such infrastructure for weaving for the first time, the Odisha weavers enviously named it a 'five star weaving village'.

Mohan Rao contrasts this to the current largest policy intervention in the Indian Textile Ministry, the 'technology upgradation fund'. Based on the assumption that upgrading textile technology would always include the purchase of new machine technologies, this policy fund provided capital at low rates of interest to textile entrepreneurs for purchasing new machines.[9] This fund did not provide any support for handloom weavers. Rather than acquiring new looms or new technologies, handloom weavers would have gained from acquiring new techniques for using their familiar looms. Such techniques could range from training in more complex weaving methods, to improve the skills of the weavers, to ancillary techniques for using different materials of, for example, dyeing techniques. However, for the mechanised industry, the Technology Upgradation Fund worked very well, since machinery could now be cheaply purchased, and mills increase their spinning and weaving capacities.

In addition to offering an unfair pricing advantage to the mechanised industry over handmade products, this policy further displaced the social relations between producers of cotton and producers of textiles in the village ecology. When linked mutually in terms of scales of production, the production ecology had to grow at an even pace, keeping in mind all the different producers involved. Instead, when the large integrated mills increased spindle power by thousands with no constraint on cotton that could now be imported as a global commodity, it ceased to be a local resource. Since policy makers see textile and cotton production as separate silos, a policy to export cotton yarn was then made to create market for the surplus yarn being produced. But now it had to be aggregated in large quantities for spinning for export, and only middlemen who had capital profited from the policy, rather than the farmers. The result was that cotton farmers lost their local markets, and were at the mercy of exploitative middlemen and fluctuating global demand. Weavers lost access to yarn that was now being exported out of the country. What did not feature in any of these policy decisions is that cotton growing used the maximum of pesticide and fertiliser of all crops in India, causing huge environmental impacts.

Reflecting on the detrimental effect of this fragmentation of the village ecology, craft workers, in their recommendations to the Ministry of Textiles in 2021, advocated for a different attitude to handloom weavers by the State. Using results from the PENELOPE project, they showed the value of the unitary nature of social, material and epistemic ordering in handloom weaving, at once benefitting communities, economies and knowledge cultures. In the submitted policy note to the ministry, they claim:

> The creative capability of the hand loom in India expands outwards from seed, spinning wheel, loom, home, street, village, local environment, state, country to global civilisation, like concentric circles radiating from the hand, heart and mind of India's weavers. In consultation with weavers, co-operatives, handloom service providers, we propose a radical shift in policies for handloom weaving that recognises its special contributions to our economy, society, and knowledge culture. Focusing on their deep embedding in the flourishing cultures of India's villages and cities, we propose that *our weaver ecologies and their innovative knowledges – not just their products – are living traditions that generate sustainable futures.* Rather than classifying handloom weaving separately as process, product, skill, economics, culture, livelihood, heritage, through our fragmented policies, we propose that using a knowledge lens will help us define handloom weaving in a way that we instinctively take for granted, as *more than a sum of all its fragmented parts.* In doing so, we will learn again to recognise and value handloom knowledge that weavers as part of Indian civilisation carry forward from generation to generation.[10]

ORDERING TIME/SPACE: OCCUPATION-LEISURE-TECHNOLOGY

The Telugu term *kaala kshepam* generally refers to leisure activity; a weaver in the village of Ponduru used it to explain how he felt about time spent on the loom.[11] Historically, since there was always demand for yarn in areas that supported handweaving, spinning too was such an occupation of leisure and at the same time of economic value. Moreover, it could be taken up seasonally by Dalit peasants when there was no agricultural work, or by women of all castes in between household chores. In most weaving villages of coastal Andhra Pradesh, weaving is a household activity; in Ponduru particularly it is combined also with hand-spinning of local cottons, mostly by women, in both weaving

FIG. 9.4 Spinners from the North East and Kutch, Chirala conference (photos by Gopichandin 2018)

and non-weaving households still today. As such, yarn could be exchanged in the market for money, records from even the late eighteenth century show that it was from earnings of women through spinning that households used to pay tax (Wielenga 2020).

In the face of competition from yarn produced by machine, the women spinners of Ponduru seem an anachronism. Asked why she continued to spin when she might prefer to spend time in leisure, an octogenarian spinner replied 'it is what I do with my leisure'.[12] Going against the wisdom of technological determinism that threatens handwork of any kind as productive activity, Poludas Satish, a cotton activist, decided to teach spinning to women as means of generating livelihood in Bihar. Initially attempting to learn to spin at home, young women quickly exchanged their wages for bicycles and lipsticks, cycling into the women's spinning centre working alongside mothers and mothers in law, to earn, socialise and learn from each other. As a mode of social ordering, spinning technology reproduced familiar community spaces of leisure activity, as well as occupations and technology.

The skill of a hand spinner lies in their being able to spin finer counts, with an even twist that ensures that the yarn does not break apart while weaving. Generally, cotton handloom weavers categorise thickness and fineness of yarn based on 'counts'.[13] The count of the yarn is a number; it expresses the number of weight units in one length unit, so if a unit length of 1000 meters is weighed, then the count is weight divided by unit length, assuming that the weight is evenly distributed across the yarn. Thus, the lower the count, the thicker the yarn. This same number communicates staple length to the farmer, weight to the trader of cotton, and thickness to the spinner. It is used to calculate weight in units of lengths (called hanks) across the chain of production and consumption. Further in the chain, the 'count' converts to 'reed' and 'pick' (i.e., yarn density per inch on the warp and weft) as an indication of the time needed and therefore of the required labour in weaving. The number translates into colour absorption for the dyer, resolution of the motif for the designer and weight and drape for the consumer.

Local production of fabric through the introduction of organic cotton varieties is first and foremost a change in count, as local cottons tend to be short staple and thicker. Initially, this seems a mere numerical change: from 60 to 20. However, in order to be set at work, this change has to be negotiated back and forth at every stage; between cotton trader and dyer, dyer and warper, warper and sizer, sizer and weaver, and so on. As the new number travels across each stage of the work and part of the network, the object it describes takes form and shape, until finally the consumer identifies and chooses it as a textured, local, organic fabric, setting off the next cycle of production and consumption. When this point is reached there is an agreement on the number of the count that will circulate in the ensemble, and organic cotton as a handloom technology is stabilised.

But this is not the complete story of the change involved. At each stage, as the count is being negotiated, another judgment is called for that each actor has to make in parallel. The yarn trader has to judge the quality of the yarn, in terms of its lustre; the warper on what kind of differentiation in warp texture it can take; the sizer in terms of what the smoothness of yarn would do for texture of the final fabric; the dyer for whether colour matching could be achieved and to what extent; the weaver for density of weaving, and the resulting visual and tactile quality of the fabric; the designer for suitability of surface ornamentation – what kind of motif, or print, for example, and so on. These judgments are clearly aesthetic; it is these capabilities that will come into play across the ensemble to construct the design of a new product. These judgments are made from experience, from aesthetic capability as well as by drawing on the historical repertoire that each group carries; colour palettes, motifs, design and product samples and so on. When craftspeople make this evaluation, it also evidences their deep engagement with the material that they work in, and their innate capability of manipulating it. This capability of creating products that are consistent in meeting quality parameters from inputs that are less consistent is seen by skilled craftspeople as part of their expertise.[14]

In a system fraught with such complex negotiation, one may understand that a person seeking to manage the production and marketing chain of hand weaving would think of the count as the most stable standard to coordinate quality. New to a project that sought to connect vulnerable cotton farmers to hand weavers, using small-scale machinery that could spin cotton in small quantities, the manager of the spinning unit found himself in a rather peculiar situation. The weavers who wove the yarn advocated a very specific count – a count of the number 27. This meant that across the chain of production, this number had to be negotiated – in the reed, in the pick, to the buyers, and so on. Talking to Satish, an expert in spinning, the manager explained his puzzlement at the seeming sacredness of that number, when weavers refused his offer to use the much easier-to-manage yarn counts of 25 or 30. 'What would happen', he asked, 'if I were to insist on changing the count to 30, for example?' Satish's response 'You can't do it, unless the weaver accepts it' only elicited further puzzlement from the manager, since after all he supplied the yarn that the weaver must weave.

Satish explained that the 27 pointed to an invisible instability in the nature of the yarn supplied to the weaver.[15] Since the yarn was made on experimental small-scale machines, the weaver would encounter varying thickness and thinness in the yarn while he wove, which he would need to manage. This is unlike mill yarn, which is uniformly of the same thickness, stably of the same count.

Thus, it is only for the count of 27 that the number of weight units in one length unit varies across the thread. If the count changes to 25 or 30, the weaver expects uniform threads. Keeping to the peculiar number of 27 as count is how the weaver codes the information of the material instability into the count. This serves the purpose of conveying an instability to be managed during weaving. However, this instability is not a problem for the weaver but a specific quality of the supplied yarn that allows for a specific texture. Therefore, the number 27 as count, not completely abstract, but also not entirely material, travels through the chain of production and marketing, stabilising the ensemble without itself being stable.

Embedding numbers in material practices of counting, manipulating and timing requires an understanding of the material being manipulated. Still, it is not the material form that is being manipulated, but the number in its material form; thus, the units of analyses are algorithms made up of operational possibilities in the material – the threads in this case –, rather than the geometric forms of design. Abstracted numbers cannot maintain their claim to provide a superior form of manipulation, unless they are able to take the challenge that such material orderings of numbers pose. Numbers in weaving show that numbers unitarily attached to material realities are manipulated according to the rules of that material – numbers in threads relate as density, thinness, weight, spin in space; while musical numbers relate to each other along the octave in time. Thus, patterns abstracted from one material to another become different mathematical entities, even if they retain the same form. For example, a woven meander is an arithmetical algorithm combining structure and colour in threads, but a painted meander on a vase is a geometrical expression.[16] When the pattern is represented through abstract mathematical numbers, it ceases to be material, and becomes symbolic – and completely inadequate as a weaving number.

CODING A COLOUR: BODY-ALGORITHM-MATERIAL

The construction of a weave is an algorithmic movement included in the making of things, particularly fabric, song, music, dance and colour. However, the algorithm performs with the material and not with notation or wording. Mohammad Salim, a master dyer, evaluating a film made on dyeing Indigo,

FIG. 9.5 The traditional fermentation vat using natural Indigo (photo Moody Chetananand in 2015)

comments, 'I don't trust what the dyer in the film says, because the colour of the dye water is green, where at that stage of dyeing, it should be blue'.[17] From the perceived lack of visual authenticity in the practice of dyeing in relation to the spoken word, he questions the veracity of the film as performing dyeing knowledge. The traditional fermentation vat that Salim is an expert in requires bacteria to break down the Indigo dye over a period of fifteen days, so that it can be applied on cotton yarn. During this process, the liquid in the vat turns green, before it turns blue, and green again once the blue dye is exhausted. To keep up continuity in production, the vats are started a day apart from the previous one, thus each is in a different stage of fermentation. The vats perform in tandem to each other, as a continuous source of colour, yet can advance only with the interventions that we could describe as decision making, framed by Salim as the dyeing process.

We could consider the procedural authenticity he refers to as the algorithm that is embedded in the action of dyeing Indigo blue. In a sense, this kind of framing of an algorithm could be thought of as the opposite of the formal algorithms of computer programming – the strictly structural 'formal unchanging entity (…) that prescribes steps made one after the other, depending on one another' (Rohrhuber 2018: 1). At one level, Indigo dyeing as algorithm breaks down the opposition of mixture and solution; at another it addresses the predictive and prescriptive functions of algorithms as opposition of process and outcome. Weaving, as well as the procedures that Salim refers to, unfold in time but perform only on the basis of the material ingredients and their effects on each other in space – the perfect presentation of time, in the unfolding of the process in time, and in its perfect vanishing as the performance at once unfolds in the space of a generative process (Rohrhuber 2018: 20).

Hylemorphism, the splitting of a process of generation into plan and implementation in time and space, requires first that such a split be possible. In complex knowledge practices that demand constant decision-making, such a split becomes impossible. Yes, there is a plan, and yes, there is implementation, but

FIG. 9.6 Weaving household in Vellasavaram village showing household engaged in different activities around the loom (photo by Margriet Smulders in 2012)

it collapses into the same moment. There is a time/space line operating – of memory, weave, outcome. The weaver's memory is constantly accumulative, through the current iteration of his memory, of the past in the present; the weave is indivisibly both plan and implementation, the outcome is the pattern of decisions made regarding paths taken and paths not taken. Once made, the pattern is a record of the decisions taken. When programmed into a machine, it is exactly implementation, now separated from the plan. What takes time for the weaver, the careful attention to decision making, is exactly what is removed from the machine's agency. Yet once copied, there is no difference between the weaver's fabric and the machine-made fabric. The process of decision making that is so critical to one, completely disappears in the other. Worse, this disappearing of decision-making is then projected back onto the weaver, who then only seems to be performing labour, rather than using technology.

As in this case, this has effects on what possibilities craftspeople are allowed in the imagination of the majority in Indian society who do not understand this as a technical mode of existence.

READING A TEXTILE: TEXT — TECHNIQUE — PLACE

Throughout Indian textile history, cloth made for common use was the mainstay of livelihoods, crossing caste barriers in what was thought to be mainly a hereditary occupation. '*Saudagiri'* in Gujarati alludes to the propensity of a person to trade, or make a sale. It is also the name given to an Indian textile from the mid to late 1800s, made solely for the 'use of the Siamese', characterised as 'a coarse fabric with poor block registration, where the dyes are chemical' (Guy 1998). The handwritten label affixed on a sample of this textile from the V&A claims that it was dyed at Peethapur, on the banks of the river Mahee – the Mahee Kanta. Such labels are generally understood to be descriptions of the origin of the artefact. The technical claim this label is inscribed with is lost to the eye of the scholar who overwrites its history and describes it as coarse and of common use. This technical claim can be read from the label – a craft technique is named after the place of its use; thus to describe its place of origin is to also describe a print technique – Peethapur – and the colour palette and fastness can be distinguished by the waters of the river where it is dyed – the Mahee Kantha river. The colours wrought from the solutions in this river by the printer dyers of the past continue to draw one's eye to their simple appeal, recognisable even through the glossy mis-representation of their commonness. Key to the textile pattern is the mordant, which when dissolved in solutions made of the water from the Mahee river infused colour onto cloth. Yet, once the colour is fast, the mordant is washed out. It is these remainders of knowledge gleaned from material traces found in museums, as well as the material absences, that we can read from the textile itself. Thus, craft is twice memory – once as remembered in its material form, and then again in the replication of it, using the techniques, place and skill of the weaver as he weaves them again every day.

What is also at stake here is the representation of complex knowledge – knowledge that is inextricably at once embodied practice, reflexive decision-making and material agency. In particular, the challenge is to highlight non-propositional knowledge and illuminate the conditions of intelligibility of such knowledge (Knorr-Cetina and others 2001: 10), to grasp it as social phenomena and at the same time reconsider dichotomies between human and non-human entities.

Theory does not always exist as text. Particularly when theorising what the weaver knows, but not in words, text loses its ability to represent such knowledge except partially. How then to understand what words can do for understanding weaving if not theorise? What does the form offer? What then is theory, if it cannot be abstracted in words from bodies, objects, which are not seen as knowing, but doing and being? This text is an attempt to describe weaving as unitary and ubiquitous knowledge that orders social, material and epistemic domains. Yet, in this form, it is at best a collection of stories. Retold from experiences of working with craftspeople and activists in the last three decades, it holds within it the hope that these are stories that weavers too will find interesting to hear and bear being told about them.

Towards the goal of scholarship, this text only presents an unfinished description of weaving knowledge. We are left with more questions than answers. What does it mean to talk about epistemology, with reference to hand weaving? Why do we need a frame that the 'actors' themselves don't use, when talking of what they know? The reality of weavers' knowledge is mediated by the frame by which it becomes visible – thus to the market it is labour, to the designer it is skill, to the connoisseur it is art, to the STS scholar it is tradition recast as innovation. We see what we are trained to see, in the terms that we are trained to use. What does this do then, to the weaver and her way of knowing? There are two issues at stake here. The first, the hierarchy between the epistemology of the viewer, and the epistemology of the weaver. Historically, any claim to epistemology is made only in terms of the viewer; typically, this is the dominant discourse. The effort here is to make visible what would count as epistemology to the scholar, in the weaving practice of the weaver, and there could be two outcomes – one that the epistemology eludes scholarly vocabulary, and therefore the scholar infers that it is absent, or the scholar realises the gap in her own epistemic framework and works to repair it.

The second, much more elusive, task is to grasp the epistemic practice of the weaver in the weavers' own terms. Yet in order to capture this epistemic practice, assuming that starting from the dominant framing is counter-productive, the endeavour is to start from experiencing as much as possible of the weavers' reality, suspending at least temporarily one's own epistemic frame. Particularly if a diverse set of people immerse themselves in a collective experience, and seek to reflect on it as fulfilling epistemic goals, then a common frame may emerge between them that reflects the epistemic frame embedded in the weavers' experience of his or her reality. Such a collective frame shimmers into existence like a mirror turning into a pane of glass, now offering a view from the eyes of the weaver. Held securely and refracted through multiple perspectives, easily perceived patterns turn into complex code; much as the fabric patterns of the past turn into a frame holding craft knowledge of decision making, both literally and as knowledge.

ENDNOTES

1 http://ajabshahar.com/songs/details/58/Chaadar-Jheeni-Rang-Jheeni&title=Chaadar-Jheeni-Rang-Jheeni [accessed 11 November 2023].

2 See the contribution of Harlizius-Klück, this volume, chapter 2.

3 Harlizius-Klück and Mamidipudi 2024.

4 Meeting of Dastkar Andhra for inaugurating indigo vats, 1998, co-ordinated by Annapurna Mamidipudi, recounted by Gopi Krishna.

5 Preparation meeting of the Handloom Futures Trust, March 2018, attended by Macharla Mohan Rao, Uzramma, Poludas Nagendra Satish, Vivek Oak, Manisha Kairaly, Shaila Nambiar, Shruti Mahajan, Annapurna Mamidipudi.

6 Field notes of Poludas Nagendra Satish, Chirala 2018.

7 From the Kannada translation https://archive.org/details/Sachidanandendra_Swamiji_Sureshwaracharya_-_Manasollasa [accessed 13 May 2024].

8 Private communication of Author with Uzramma, October 2021.

9 Interview Mohan Rao, January 2020, Chennai.

10 Policy Note submitted to the Ministry of Textiles January 2020, Handloom Futures Trust, Hyderabad. The Handloom Futures Trust is a trust set up to focus on handloom weaving in India as a knowledge culture, particularly as historically it has been perceived as either cultural heritage or vulnerable livelihood. The aim is to build value for weaving ecologies by focusing on the knowledge aspect, bringing together textual research and experimental practices on the field. The Handloom Futures Trust mainly raises resources to provide fellowships for researchers, activists and experimental practitioners who advance knowledge in handloom weaving.

11 Muppena Appa Rao, weaver, Ponduru, Interview 2010.

12 Interview, Poludas Satish January 2020 Chennai.

13 For an analysis of textile production in early modern India, using counts ('Cotton was sold in candies; thread was sold in bundles; cloth pieces had diverse thread-counts and dimensions; bales or packs of cloth contain different numbers, sizes and weights of cloths') see Wendt 2005: 4.

14 This brings to focus another important difference between craft and mechanised production. The window of variation in inputs is much less for machines, which cannot handle such variation, compared to craftspeople who are inured to it. But again, if the productivity value overtakes the ensemble, then craftspeople with the capability to deal with non-standard material will demand standardised material in order to meet the productivity demands.

15 Meeting of Malkha Marketing Trust, January 2020, Hyderabad.

16 See Harlizius-Klück, chapter 2.

17 Meeting of dyers on representation by Handloom Futures Trust, October 2019 Hyderabad.

REFERENCES

Guy, J., *Woven Cargoes: Indian Textiles in the East* (London: Thames and Hudson, 1998).

Harlizius-Klück, E., and A. Mamidipudi, 'Reconstructing Knowledge in the Museum: Using the Handloom as Technology', in T. Boone, E. Haines, A. Dubois, and K. Staubermann, eds, *Understanding Use: Objects in Museums of Science and Technology* (Washington: Smithsonian, 2024), pp. 109–35. https://smithsonian.figshare.com/articles/book/Understanding_Use_Objects_in_Museums_of_Science_and_Technology_Artefacts_13_/25444927 [accessed 13 May 2024].

Hess, L., *Bodies of Song: Kabir Oral Traditions and Performative Worlds in North India* (Oxford: Oxford University Press, 2015).

Knorr-Cetina, K., T. R. Schatzki, and E. von Savigny, eds, *The Practice Turn in Contemporary Theory* (London, New York: Routledge, 2001).

Mamidipudi, A., *Towards a Theory of Innovation for Handloom Weaving in India* (Maastricht University, 2016).

Rohrhuber, J., 'Algorithmic Music and the Philosophy of Time', in R. T. Dean and A. McLean, eds, *The Oxford Handbook of Algorithmic Music* (Oxford: Oxford University Press, 2018), pp. 17–40.

Wendt, I. C., '400 Years of Decline? Understanding the Changing Structure of the South Indian Textile Industry', *Global Economic History Network Conference,* Padua, Italy, 2005.

Wielenga, K. D., *Weaving Histories: The Transformation of the Handloom Industry in South India, 1800–1960* (Oxford: Oxford University Press, 2020).

10

COMPARATIVE REFLECTIONS ON ANDEAN WEAVING AS SCIENCE

Denise Y. Arnold

INTRODUCTION

AS AN ANTHROPOLOGIST WITH AN ARCHITECT'S TRAINING, I WAS FASCInated by Andean weaving from the start of my fieldwork in Bolivia in the 1980s, but far from understanding its scientific and philosophical implications.[1] My early questions to weavers were politely brushed aside as not technical enough. They did not resort to the Greek *technē*, in the sense of *epistemē*, as a principle of knowledge, craftlike or not. I soon learned that knowing (*yatiña* in Aymara, the regional language), in an epistemological sense, was not a generalised and abstract idea, but applied to a particular place with defined limits, such as the loom space, or a field (Arnold with Yapita 2006: 113–15). In weaving, the weaver clears the ground, giving thanks to the Earth, then she proceeds to weave life on her loom. In practice too, this is not knowledge in the abstract, derived from an empty universe, but knowing about life, and building on what is already there.

From 2005 to 2012, I worked closely with weavers in the South-central Andes, in partnership with Elvira Espejo, a weaver from the same region, and the linguist Juan de Dios Yapita, on two long projects. The first was more practical, and responded to local demands to improve textile quality by adjusting aspects of the existing productive chain; the second was more academic, aimed at researching weaving structures and techniques in the weavers' own language. The title of the book that I wrote as a result of these projects, *The Andean Science of Weaving* (2015), with the collaboration of Elvira Espejo, came from a comment by some local weavers during a workshop we held about recovering finishing techniques with their own weaving terminology. They had heard about these techniques from their grandmothers, but never applied them in practice: they commented that this study of Andean weaving terms and their revival in practice was 'women's science.'

A first step in my wider argument is to clarify what I mean by 'science,' and then what an 'Andean' science might mean, comparatively speaking. In comparing Western science and traditional or indigenous knowledge systems (some call it 'ethnoscience'), the Austrian philosopher Paul Feyerabend, in his book *Against Method* (1975), concludes that these distinct approaches reflect different ways of knowing, given clout or not by the more formal institutions, such as universities, according to the paradigms which hold sway at any particular moment. But importantly, for Feyerabend, it is precisely the dynamic interrelation of these interacting traditions that might challenge on occasion these dominant paradigms and lead to new levels of scientific understanding.

Other important comparative studies by Sandra Harding (1996–7), David Turnbull (1997), Wim Van Binsbergen (2007), and Isabelle Stengers (2017), as well as a wealth of essays on what is now known as 'Traditional Ecological Knowledge' by M. M. R. Freeman (1992), Douglas Nakashima and Marie Roué (2002) and Fulvio Mazzocchi (2006), among others, often conclude, like Harding herself, that Western science is itself an 'ethno'science, based on a system of beliefs.

Bruno Latour and his colleagues, in their Actor Network Theory, take a more pragmatic approach, arguing that science is a collective activity, a complex, dynamic network in which scientists, institutions, concepts, physical entities and forces 'knit, weave and knot' together into an overarching scientific fabric (Latour 1987, 2005; Latour and Woolgar 1986). Tim Ingold, developing similar ideas, prefers the more organic term 'webs' to the technological stance of 'networks' (Ingold 2011: 64).

Taking up these ideas, the young scientists Feng Shi and colleagues (2015) conclude that science is a 'complex system,' built up from strong interactions between diverse, differentiated components, which manifest emergent and often unexpected collective behaviour, at all scales. For them, the networks described by Latour not only trace the past politics of science, but act as a substrate for future scientific discovery. Their perspective extends the definitions of classic network-oriented human problem-solving, although it still presents this activity in a rather objective and unsituated way. But at least their observations confirm how the nature of woven fabric, explored by Ingold (2011: chapter 7), and feminists such as Sara Ruddick (1995, see also Confortini and Ruane 2013), lends itself to thinking about the world in ways that re-link that torn asunder by modernity, where a woven 'morphology' actually enables thinking connectively between and among things, from a life-centred perspective.

THE 'GREAT QUESTION' APPLIED TO THE ANDES

Another entry into these debates was to examine the factors at play in asking the 'Great Question': of why modern science developed in the West, and not in China, as explored by the English biochemist Joseph Needham, with Wang Ling, in their series of books on *Science and Civilisation in China* (1956–2016), and more recently by the French philosopher and sinologist François Jullien (1999 [1996], 2000 [1990], 2010 [2009]).

Heather Lechtman, too (1993), a scholar on Andean metallurgy, familiar with weaving technology, applies this 'Great Question' to define differences in technological developments, and hence of scientific knowledge, between Europe and the Andes. She notes how Andean technological developments, mainly those under the Inka, were not oriented towards 'hardware,' in the sense of developments in tools and machines (swords, ploughshares or wheels), as in the West, but towards 'software' that would facilitate coordinations in agricultural and herding production between diverse populations living at different altitudes. So for her, Andean technologies had to do with relations between and among human groups and their sources of survival. Here, Lechtman views weaving as part of a wider normative technology of fibre manipulation, widespread and vital to Andean civilisations. But, she leaves the wider issue of science and its definitions there.

Here I take up Andean weaving practices as 'science' in the collaborative and relational sense offered by Ingold, Latour, Van Binsbergen and Lechtman. These practices certainly concern regional explorations into the socio-political and economic interrelations between people. But weaving practice also entails human interactions with the biological domains they engage with, in wider multispecies relations, as well as human relations with material domains, in technological and technical interactions, and in the plays of forces involved in making things, of which Ingold has made us aware (2011: chapter 18). I sense we are dealing with relations among things, of what the Argentine archaeologist Alejandro Haber (2007) calls 'relations between relations,' where Andean weaving practice plays a vital part in creating emerging biocultural spaces, as argued by the Argentine ethnobotanist Verónica Lema (2014).

Working with weavers in the South-central Andes affirms that these wider relations involve more than technological developments in looms and instruments, or in weaving structures and techniques. I have suggested that it was the historical integration of these developments into 'social' sequences, followed by the cascade effect of these wider 'social' activity streams, that articulated the elements of these broader Andean territories into an evolving whole (Arnold 2018: 240). The cascade effects of biological and material activity streams must have articulated these elements in a similar way.

THE *CHAÎNE OPÉRATOIRE* OR PRODUCTIVE CHAIN OF WEAVING AS AN ORGANISING TEMPLATE

These wider scientific coordinations between diverse groups of social actors (herders, dyers, instrument makers, loom-bar carvers, weavers, finishers), with their epistemological and ontological characteristics, coincided with developments in the *chaîne opératoire* or operative chain of weaving, the term originally coined by Leroi-Gourhan, in 1943, to describe a normative chain of operative sequences in artefact making. As in our first project with local weavers, I refer to this operative or productive chain to organise this chapter, beginning with planning before moving on to weaving production.

The characteristics of these productive chains operate at a local community level in Qaqachaka, the rural *marka* with its six *ayllu* communities, located within the municipality of Challapata in Southern Oruro in Bolivia, where we worked over decades. But these characteristics are also evident in the wider and more 'radical' communities of practice (so named by Chantal Conneller 2011: 16–18), where the integration of their technological and human characteristics creates what Lechtman (1977) calls the 'technological style' of a regional sense of identity, with its expression of common technical values, cultural symbols and ideas. Qaqachaka's regional identity is rooted in its history, as a former part of Charkas-Qharaqhara and later of Killakas Asanaqi, two of the great pre-Conquest Aymara federations of the region. However, the practices which help perpetuate this common identity nowadays manifest mainly through dress and fashion, shared visually at festive events, which consolidate, or differentiate, local communities of practice within these wider regions. I propose that these points of articulation are comparable to the modern scientific sharing of ideas, common trends in thinking and forging alliances, achieved in conferences like HOMO TEXTOR, in which we participated together.

PLANNING WEAVING ACTIVITIES

I start with textile planning, with its far-reaching demands in terms of access to materials, labour and technological supports, which have many qualities of a scientific enterprise. Here, the epistemological focus is not on an abstract or objective 'making as knowing,' but on a more encompassing idea of going with the flow of energy in the world, and how to harness this energy constructively, without controlling it directly. This phenomenon is similar to Needham's focus on *wu wei* in ancient China as 'going with the grain' (Needham 1964: 401) or Jullien's comments on Taoist philosophy as the basis for the drive to achieve efficacy by working with energy flows already in motion (Jullien 1999/1996).

In achieving and perpetuating this flow, historical evidence suggests that the Inkas, a common point of historical reference in the region, estimated the relative human energy (in Aymara *ch'ama*, or in Quechua *kallpa* or *qama*) and biological time available within regional populations, taking into account sex and age criteria, in terms comparable to our notions of 'labour force' or 'man-power' (Rostworowski 1993; see also Arnold 2012: 180–87). Information obtained though the Inkas' five-year census accounts of human and camelid populations was collected and articulated through the widely disseminated decimal system of measurement, documented on knotted *khipus*, then used to calculate and plan large-scale tasks, some aspects of which still survive in the region. The territorial reach and jurisdictional limits of these tasks were set by

FIG. 10.1 Selection of Guaman Poma's 'streets' (*calles*), for women, drawn in his early seventeenth century *Nueva corónica y buen gobierno* (ca. 1615), showing the first, second, fourth, fifth, sixth and seventh streets. Source: Royal Danish Library, GKS 2232 kvart: f.215 [217]), f.217 [219]), f.221 [223]), f.223 [225]), f.225 [227]) and f.227 [229]. http://www.kb.dk/permalink/2006/poma/info/en/frontpage.htm

the *khipus* themselves, associated not only with water-related rites (Bennison 2019; Bennison and Hyland 2021), but with specific territories under the domain of particular mountains and their water flows (Arnold and others 2000: 345; Pimentel 2005; Arnold with Yapita 2006: 212, 218–19).

Evidence of this practice can be seen visually in Guaman Poma's early seventeenth century drawings of what he calls the streets (*calles*) of these age and sex groups, focused in the female case almost exclusively on weaving practice, which illustrate the obligations of different groups to collect raw materials (dye plants, water, kindling, fibre), prepare thread and then make specific products (thread, slings, ropes, mantles) (Rostworowski 1993; see also Arnold 2012: 180–87) (figure 10.1 A–F).

Other scientific developments in the Andes were oriented towards managing the physical environment through skilled engineering feats, in extensive terraces and irrigation systems, building productive networks connected by road and bridges, and along them intermittent waystations (*tampu*) or administrative centres (*kallanka*) for storing supplies or distributing them in incipient markets.

FIG. 10.2 Contemporary knotted *tupu* used to standardise sizes of weavings (photo by the author, Collection of the Instituto de Lengua y Cultura Aymara (ILCA), La Paz, Bolivia

Along these productive hubs, units measured in *tupus* (figure 10.2) were used to calculate the expected yields of different cultigens in physical units of land measurement, depending on the kind of land (often defined by its soil colour, and hence its degree of fertility), and in terms of the retribution in work owed to the state by specific social units (families, *ayllus* or the relocated *mitimay* groups) (Rostworowski 1993; Arnold 2012: chapter 4).

Tupus were standardising measures relating work to an area of agricultural land and pasturing activities (as well as to road lengths, and mineral veins in mining), and were important in textile making (figure 10.2). In return for intermittent corvée labour tasks to make textiles as a form of tribute, the Inka provided weaving families with fibre from the royal herds, food and drink for collective festivities, and security through the storage of items of tribute to be redistributed in cases of food or clothing shortages. Provincial families were also absorbed into Inka kinship systems, to consolidate this royal control over labour power.

This relational pattern of knowledge in calculating and planning work and energy flows, lubricated with reciprocal exchanges, was disseminated through, and accounted for, on *khipus* at community levels, mainly under the control of men (to be passed upward to higher levels of state administration). For their part, women controlled the production of larger textiles in the making (when knotted *tupus* measured width and warp length), and finished products, associated with the household economy (see again Arnold 2012: chapter 4).

THE USE OF MODELS AND STANDARDISING PROCEDURES

As in modern science, Andean weaving practice as a form of science drew on model making in the archaeological past. Small portable models called *salta waraña*, like those used in the past, are still commonly lent between weavers, especially older women, for learning techniques and designs they are not familiar with (Arnold and Espejo 2012). Similarly, for applying new colour combinations, they use *musa waraña*, in the form of thread-wrapped rods, which are also used to standardise patterns in group activities. We reinstated the use of these *musa waraña* into our second weaving project, and they worked very well at a planning stage and as standardising devices (figure 10.3).

FIG. 10.3 Archaeological (upper left) and modern (lower left) examples of the thread-wrapped rods, called *musa waraña*, used to standardise colour combinations, for example in the counts of the striping options shown in the scheme to the right. Source: British Museum Collection, London (Am1909,1207.150), and scheme by the author, Collection of the Instituto de Lengua y Cultura Aymara (ILCA), La Paz, Bolivia, respectively

Bruno Latour (1986: 19) has criticised the use of models in Western science, mathematical and otherwise, as evidence of the objectivity and distancing of modern scientists from the real world. François Jullien (1999/1996: 22) is similarly negative about this use of models. And Ingold (2011: chapter 17) has critiqued Aristotle's hylomorphic model, where such activities are thought to be conceptualised first in the mind and then in reality, or where organic form is thought to precede its development in the real world. However, Andean weaving practice really does involve a number of prior planning decisions, many modelled on small supporting devices (such as thread wrapped stones or corn cobs to aid coordinations in colour use), before the loom is even set up (Arnold 2018: 252–56). Ed Franquemont, an accomplished weaver himself, calculated that, as a weaver plans her work on the loom in places around Cusco, some 80 decisions of this kind are made (personal communication).

These Andean models were highly situated and contextualised, and, as in their Mesoamerican counterparts (Pitrou 2014), most probably used to scale up planning procedures into household, community or landscape-wide applications, relationally. Apart from resorting to models, there was the deliberate state application of standardising procedures, similar to those described by Latour (1986) in the West. The Inka state developed such procedures to ensure the quality of fleece and other basic materials, the forms and sizes of particular garments (Julien 1999), the range of structures and techniques used by certain social classes, and the content and meaning of certain motifs in weaving iconography. The state imposed these norms in the immense territory they conquered, in mobile objects (textiles and *khipus*) to which the State could refer constantly.

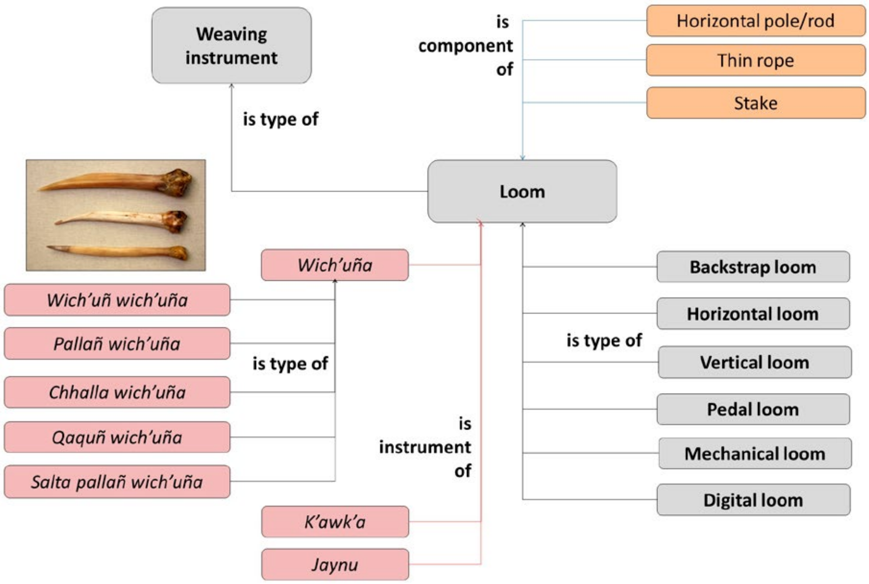


FIG. 10.4 Diagram of regional looms and weaving instruments, with their terminology, organised ontologically. Source: Scheme drawn by the author, Collection of the Instituto de Lengua y Cultura Aymara (ILCA), La Paz, Bolivia

The presence of a standard set of weaving instruments, with agreed names, is yet another reminder of these Inka standardisation measures of the past to improve cloth quality (figure 10.4). The design of contemporary spinning and plying instruments draws on physical entities (in the measurement and use of energy and forces), with attention to the direction and velocity of spin and ply, and relative whorl weight, depending on whether the thread is camelid fibre, cotton or another vegetable fibre. In weaving proper, pressioning techniques demand the specific tightness or looseness of a certain weave. The selection of threads in the designs of warp-patterned weaves demands more finely pointed and harder instruments such as llama bone or wooden picks, whereas tapestry can be made using blunter instruments, in a categorisation of weaving instruments already standardised under the Inkas, if not before (Rivera 2014). The use of such a set of appropriate instruments has to be planned, as they can break or get lost, and new ones take time to make, and entail visits to specialist workshops, where bone picks are smoked to become hardened.

REARING CAMELIDS WITH CERTAIN COLOURS OR DEVELOPING DYE TECHNOLOGIES

In social terms, the increasing complexity of weaving practices went hand in hand with increasingly complex networks of social actors, their technological supports and developments, and the institutions of which they formed part. Planning ahead ensured a local supply of dye materials at the right moment of the *chaine opératoire*. Weavers calculate the quantity of animal fibre they will

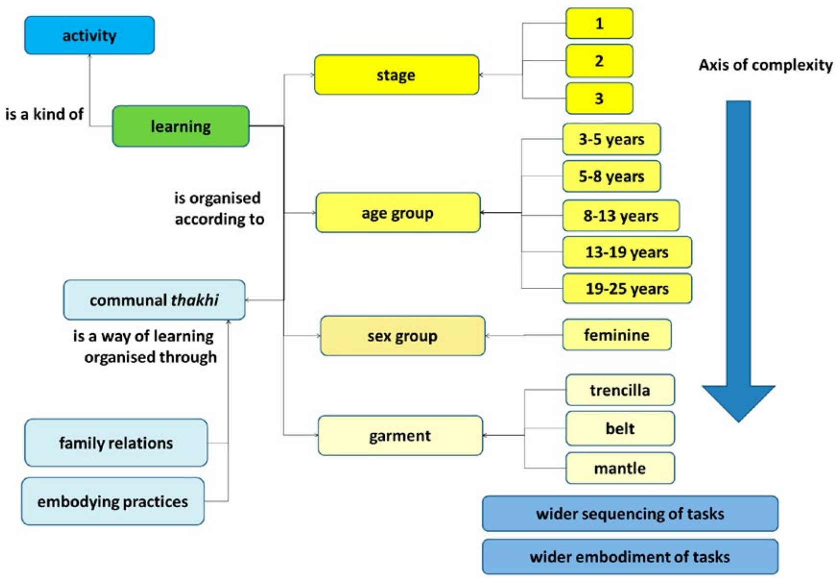


FIG. 10.5 Diagram of the learning pathways called *thakhi*, organised ontologically. Source: Drawn by the author, Collection of the Instituto de Lengua y Cultura Aymara (ILCA), La Paz, Bolivia

use to obtain thread of different colours for a certain textile, and they need to have an appropriate loom at hand on which to apply the structures and techniques to be executed, the loom poles often coming from valley trees, traded in through networks of established exchange partners, nowadays called *caseros*.

Weaving institutions formed around practice-centred local associations and their wider exchange networks, and, in the past, state institutions such as the Inka *aqlla wasi* (closed communities of selected women) and the Inka-established pathways of learning called *thakhi*, were organised through age sets and sex-gendered groups in these regional groups (figure 10.5). In their modern counterparts, young girls still pass successively from more simple to more complex loom technology, instruments, and woven structures and techniques, in three basic stages (Arnold and Espejo 2015: 64–69; Arnold 2018: 248–49).

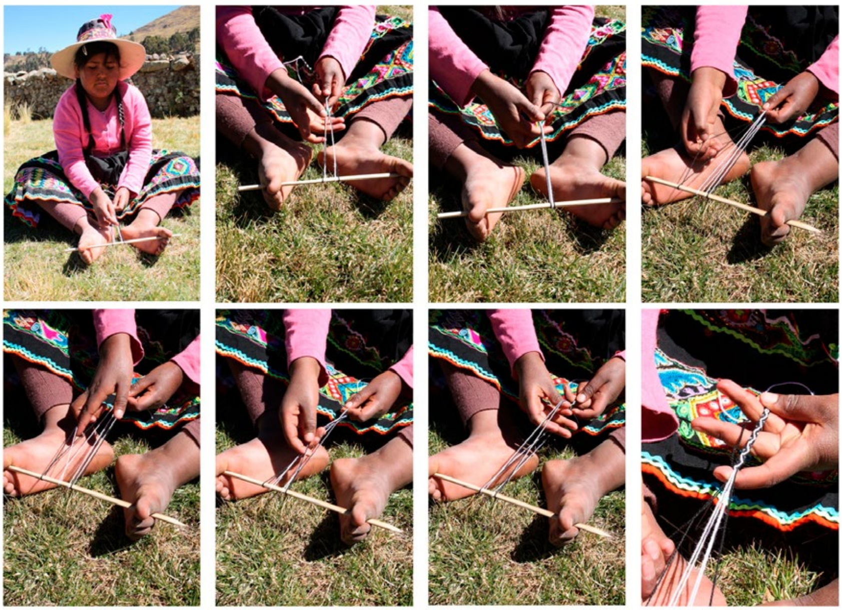


FIG. 10.6 A sequence showing the young Qaqachaka weaver Silvia Espejo weaving warp crossing techniques (photo by the author, Collection of the Instituto de Lengua y Cultura Aymara (ILCA), La Paz, Bolivia)

In these learning sequences, young girls start with warp crossing techniques on simple looms, learning to manipulate yarns in distinct directions to create zigzags and rhomboids, first with their fingers, then visually (figure 10.6). Regional technology here deals with material developments in tools, and the set of social relations in which weavers participate with others at a family level, which then extends outwards into the wider community of weaving practice.

These phases of intergenerational learning give priority to the interactive aspects of weaving practice as 'techniques' to sustain the environment and ensure its continuity, as herds have to be reared on good quality pastures and water supplies to render fine fibre. Here, weaving endeavour reaches out into the biological and material domains. The British anthropologist A. M. Hocart (1935) suggests that it was these kinds of techniques, often associated with rituals, that articulated human social activities with the bio-cosmological aspects of the regional ecology. His view was late echoed by Gilbert Simondon (1980), who held that man-made machines can resemble life and cooperate with life. For Hocart, ritual is a 'science of life,' ritual techniques an applied 'science of life,' and ritual practice 'techniques to secure life.' Hence, many so-called 'spiritual' values, even native 'worldviews' and 'cosmopolitics,' are precisely those directed at ongoing interactions between humans and non-humans in their surroundings.

Other articulations between the social and biological domains include ways of rearing herd animals and ongoing experiments in animal genetics, based on long-term empirical observations. In the past, it was the crossing of different wild camelids, the *vicuña* and *guanaco*, which led to the development of alpacas and llamas as particular species. Nowadays, during the animal mating ceremony, when species are crossed, weavers experiment with the colours and qualities of their fleeces to achieve the desired tone, length and degree of fineness, directed at their use in weaving (Arnold and Espejo 2007: 326–31). Here, conceptualisation, interpretation and prediction play their part.

Dye technology, too, achieved great advances that evolved in identifiable steps. In their open-air laboratories, Andean weavers experiment constantly with strange brews of mineral salts and other compounds, dissolved in fermented urine and other strong smelling dissolvents and mordants, in order to obtain the colours they seek in their work. Even regular dyeing processes entail continued experimentation with distinct quantities of dye plants, minerals or insect products, such as cochineal, and their reactions to specific mordants (urine, or alum as sulphate of aluminium and potassium, *millu* in Aymara) or different qualities of water. Acid mordants (lemon, vinegar or alcohol) render brighter colours, whereas a bath in metallic salts, such as ferruginous clay or iron oxide, generates oxidation to produce darker tones (Arnold and others 2019: chapter 6). Dye remains impregnated in pots on weaving sites are only now being examined in archaeological contexts such as the *aqlla wasi* on the Peruvian coast. In

FIG. 10.7 Skeins with graded tones of the natural green from the tola shrub, made in different immersions. Source: Photo in the Collection of the Instituto de Lengua y Cultura Aymara (ILCA), La Paz, Bolivia

the recent past, dyeing was a specialist task in the hands of experts, and highlanders visited their workshops, usually in the valleys where the dye herbs grew, to obtain the coloured yarns they needed (Arnold and Espejo 2011: 185–86).

These specialist dyers managed colour tones by the number of immersions, hence the dye concentrations they were working with (figure 10.7), as do weavers today. Strong colours, especially red and blue, are associated with youth and power, and washed-out colours with washed-out older people (Arnold and Espejo 2011: 185–86). Colour saturations, like colour combination preferences, were equally relational rather than determined in a vacuum.

Emerging from this practice-based experience, Andean colour theory is not based on the properties of light, as in Newtonian models and the Munsell system, but on the properties of colours in water-based transformations. So the primary colours are not the reds, yellows and blues of refracting light, but violets, oranges and greens, while the reds, yellows and blues are secondary or tertiary colours, arrived at only after previous transformations of the Andean primaries (Arnold and Espejo 2013: 170–77).

WEAVING PROPER

Turning now to weaving proper, some terms used for the emerging units of a specific garment, such as *sillku* and *suyu*, still embody former labour systems. In the central design areas, the relative width of coloured stripes (*lista*) and design bands (*salta*), in narrow intermediate and wide areas, indicate, relationally, design planning directed towards the visual expression of the quantities of possible cultigen yields (Arnold 2012: 116–21; see Silverman 1988).

In finished mantles, the distribution of borders (*t'irja*), the plain *pampas* and the blocks of figurative or geometrical designs called *salta*, document each productive process, from land at rest in the *pampas*, to fields under cultivation in the design areas, and then the rows of harvested products piled up at the sides of fields in the stripes and border areas (figure 10.8) (Arnold 2012: 116–21). This visual and conceptual design organisation applies inductive and deductive reasoning combined with theoretical knowledge, and its transmission through woven forms of inscription.

FIG. 10.8 Borders, plain pampas and the design areas (called *salta*) in a contemporary woven woman's mantle or *lliklla*. Source: Photograph of a *lliklla* from the Museo de Textiles Andinos Bolivianos, La Paz (unregistered), integrated into a diagram by the author, Collection of the Instituto de Lengua y Cultura Aymara (ILCA), La Paz, Bolivia

Ladder designs, where more elaborate designs give way to rows of coloured horizontal lines, or alternating colours in a checkerboard effect, are not just techniques used to finish a weaving. Through their pick-up counts, ladder designs document the potential uses of agricultural products, either destined for household storage and consumption, or to be sent back into regional exchange circuits. Ladder designs, in a household's food bags, also register the series of transformations undergone in a domestic setting between a raw agricultural product, for example the root crops oca or maize, with the distinct colours of their outer skins or pericarps, and flour ground from these, of a much lighter shade (Arnold and Espejo 2014). So again, the underlying epistemological significance of these designs reaffirms transitions and transformations, in the dynamic flow of the world.

These kinds of practices are articulated visually and conceptually, in the region-wide language of weaving structures, in terms of warp levels, and techniques, in terms of pick-up counts, each of these being organised from simplicity to complexity (see also Arnold in press). One and two warp levels are considered simple (*ina* in Aymara, *siqa* in Quechua), whereas three to eight are considered complex (*apsu* in both languages). In the past, these technical differences were used to create distinctions at a social level, whereby ordinary commoners (*ina jaqi*) were restricted to wearing simple cloth made with undyed fleece colours, whereas the regional elites (the 'selected ones' or *apsu jaqi*) had access to complex cloth, with strong, dyed or 'cooked' colours, notably reds and blues (Arnold and Espejo 2011: 179, 186).

Some technical differences from simplicity to complexity are articulated through the common warp pick-up counts in odd or even patterns, learnt visually and corporeally from an early age.[2]

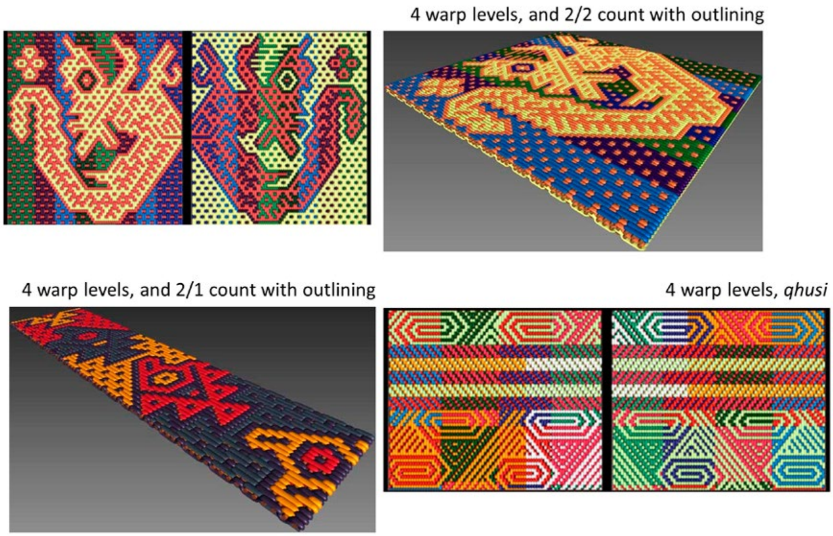


FIG. 10.9 Complex contemporary 'reselected' weaving techniques. Source: Drawn in the Sawu 3D programme developed by the Instituto de Lengua y Cultura Aymara (ILCA), in images drawn by members of the ILCA team, under the supervision of Elvira Espejo, La Paz, Bolivia

These pick-up counts are combined with colour selections and reselections to create certain techniques that present, again relationally, outlining, colour blocking, and the alternation of dark and light designs (*qhusi* and *tika*) (figure 10.9).

Odd and even pick-up counts also generate the specific patterns of figurative or geometric weaves, with their different significations. Even counts tend to give rise to figurative patterns that document agricultural and herding products in the making. Odd counts, on the other hand, give rise to geometrical patterns that document the contexts for this production (for example in terraces, or walled enclosures) (figure 10.10). Our documentation of these pick-up counts allowed us to develop our software program, Sawu-3D, to document these visually (Arnold and others 2019: chapters 1 and 7).

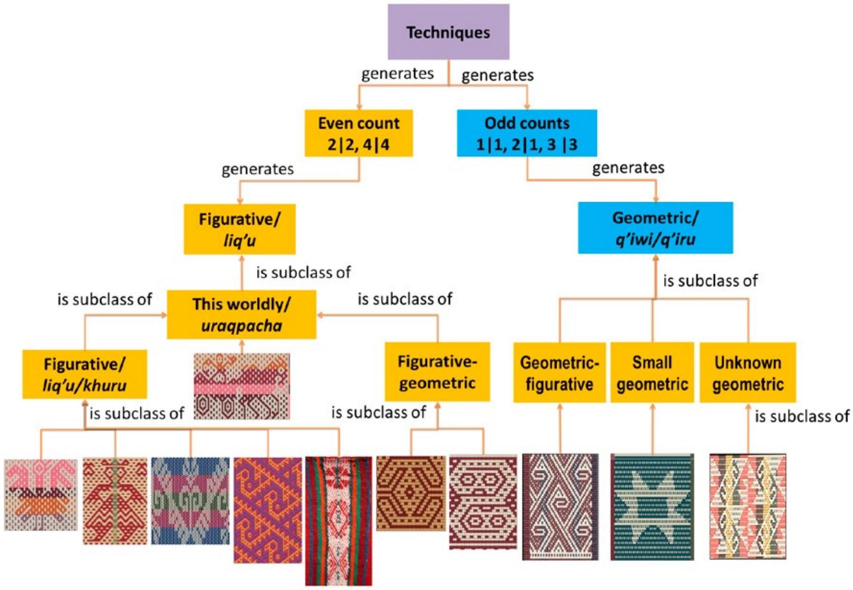


FIG. 10.10 Figurative and geometric pick up counts in warp-patterned weaves and their resulting iconography. Source: Diagram drawn by the author based on images in the ILCA Collection

These relations became consolidated through history, and more so with modern schooling when girls had a better grasp of arithmetic. We noted this in a comparison of warp count and motif type between archaeological textiles and contemporary ethnographic ones, in a corpus of 419 out of 704 museum registers, where the percentage of correspondence of odd counts giving rise to geometrical motifs increased from 69 to 72 per cent in modern examples, and of even counts from 88 to 96 per cent, respectively (Arnold, De Diego and Espejo 2011: 290–91). Thus, these iconographic and other aesthetic values arise from deep textile structures and patterns, and not from surface 'decorative' features, as Lechtman (1984) also found in the case of Andean metallurgy. This is why the weavers themselves classify these iconographic differences in a science of relations and patterns.

COMPLEXITY AND EMERGING SOCIAL-TECHNICAL INSTITUTIONS

As in modern scientific developments, identified by Latour and colleagues, the technical demands by weavers themselves to be able to apply ever more complex structures and techniques, with greater colour combinations, would have generated a cascade of increasing technological complexity in looms and instruments. Evidence suggests that an early development of this occurred in Early Horizon Paracas (700 BC–200 AD) when the availability of a wider colour palette coincided with contemporary loom developments to create examples of triple cloth (with three warp layers) (Doyen-Bernard 1990).

Any consideration of Andean weaving practice as science must also take into account the productive process, the finished product, and its circulation in the world. Like writing, *khipus* and weavings embodied forms of codification at different stages in their making. Then finally, like a written text, the finished product became externalised from the human body. This allowed their makers, in their communities of practice, to reflect upon the technical or aesthetic success of their enterprise, as well as to contemplate any adjustments they might make in the future. The linguist Roy Harris (1989) and the philosopher Richard Menary (2007) perceive this process of externalisation as the development of detached or 'autoglottic" spaces' for cognitive reflection (Arnold 2015: 45–46). In other words, producing inscriptions in weaving, as in writing, facilitates a way of thinking. In the productive chain, this happens first with the subproducts of different stages (spun threads, plied threads, dyed threads), then with the finished weaving product, each providing a cognitive support for their analysis by the maker, and by others.

WEAVING WIDER CONNECTIONS

In terms of the regional lifeworld, beyond the social and biological fabric of Andean living organisms and landscapes, weavers making woven artefacts 'ensoul' material form. In the productive chain, it is common for the ontological aspects concerned with this 'ensouling' of life to allude to maternal care, and to its counterparts in agricultural and pasturing productive processes, in a language of 'giving birth to,' 'growing' and 'mutually caring for' (*uywaña*), with its botanical equivalents of 'seeding,' 'sprouting' and 'blooming.' As it grows, a weaving becomes a vibrant interface for documenting and disseminating cultural ideas and symbols that express these living processes (Arnold 2018: 240–41).

Importantly, the whole process of weaving is regarded by weavers as creating living beings as 'persons' (*jaqi*), in a deliberate personalisation of the artefact which they call *jaqichayaña*: 'making persons' (Arnold 2018: 243). They identify the moments of creating its body (its 'genesis' in Simondon's terms), and of nourishing it through eating and breathing, when the warp shed opens and they introduce the weft thread. A weaver with ample ability to introduce life into artefacts is regarded as intelligent, for having developed her skills in the three-dimensional manipulation of threads, and her mental skills and those held in her heart, to understand this three-dimensional world (Arnold and Espejo 2013: 54–60).

The powerful way that weaving practice acts as inscription, and as a support for these kinds of ontological connections, contributed to its development as a manner of codifying across media, rather like mathematics in our Western tradition. In this mediating guise, the units of Andean weaving become reference points for song, dance and music, herding and agriculture. For example, the *wayñu* songs and dances of the rainy season are considered to be the unravelling of the main village plaza, perceived as a giant loom housing a colourful coca cloth, into its component elements (Arnold 1992; Arnold and Yapita 2000: chapter 2).

At an ontological level, the intergenerational transmission of this sociobiological drive to embed weaving practices in the natural world, symbiotically, occurs in the way that learning to weave privileges respect for the living nature of materials. Girls begin by learning to visualise the quantity of camelids in their herds in a practice of visual gestalt, and to count visually with their fingers. Then they learn to identify, with their fingers and palms, fibre textures, and how to differentiate between opaque fibre cut from the hides of dead animals as opposed to vibrant fibre, sheared from live ones. They recognise which part of the animal this has come from by its smell and texture (Arnold 2018: 245, 251).

Passing on to a more complex iconographic content, the girls then learn to document in their designs the regional repertory of natural and material resources (in flora, fauna and avifauna, as well as the watch faces, ships and planes of today). Some textiles document regional history, others interpret meteorological phenomena, medicinal herbs, water management, agricultural and pasturing processes and stages, biological classification systems and economic patterns of exchange and household management.

FINAL REFLECTIONS

I conclude with the French sinologist and philosopher François Jullien's comments on Needham's 'Great Question,' originally asked by Max Weber: 'Why was there science in Europe and only in Europe?' Jullien arrives at his answer in terms of language and technology. His proposal is that Greek thought, as the basis of the Western philosophical tradition, concerns the language of 'being,' linked to demands directed at determination, through *logos*, which permits developments in abstraction, to produce that which is 'truthful.' However, in practice, Jullien acknowledges that Greek thought was to proceed away from the dynamics of living in the world, with its silent transformations, towards interminable construction and abstraction (Julien 2000/1990, 2010/2009; Arnold 2022: 218).

Jullien emphasises that at the heart of these notions of being is the use of the verb 'to be,' present in Greek but absent in archaic Chinese, as it is, in an independent form, in Andean languages such as Aymara and Quechua. For Jullien, this resulted in the emergence in the West of the individualised subject, imbued with a sense of heroic agency, always intent on intervening actively in the world (2010/2009: 15). This sense of agency is absent in ancient China as it is in the rural Andes we knew, where philosophy has been more intent on going with the flow of things to participate in their efficacy.

From this standpoint, Andean weaving as science concerns an alternative worldview that seeks to replenish the living world constantly, in a communion of subjects. It does not seek to interpret reality through linear conceptions of cause and effect, or pursue heroic changes in the world, but interacts in constantly forming multidimensional cycles, in which all elements are part of an entangled and complex web.

ENDNOTES

1 Many thanks to Elvira Espejo for our debates over the ideas expressed here, and to Juan de Dios Yapita for his help with Aymara language terms. Fieldwork was made possible thanks to a grant from the Interamerican Foundation of the USA, from 2005–2009, and from the Arts and Humanities Research Council (AHRC) (No. AH/G012180/1), from 2009–2012, in a collaboration between Birkbeck, University of London, and the Instituto de Lengua y Cultura Aymara (ILCA) in La Paz, Bolivia, with colleagues including Germán Apaza, Rodolfo Velásquez, Claudia Rivera, Miriam de Diego and Efraín Yujra. See, too, the project website: http://weavingcommunities.org/.

2 Arnold and Espejo 2013: Chapter 6; Arnold, De Diego and Espejo 2014: 295–97; see also the classic essay on the theme by Mauss 1968/1934).

REFERENCES

Arnold, D. Y., 'At the Heart of the Woven Dance-floor: the Wayñu in Qaqachaka', *Iberoamericana*, Frankfurt, 16, Jahrgang, Nr. 3/4 (47/48) (1992): 21–66.

Arnold, D. Y., *El textil y la documentación del tributo en los Andes: los significados del tejido en contextos tributarios* (Lima: Fondo Editorial de la Asamblea Nacional de Rectores, 2012).

Arnold, D. Y., 'Del hilo al laberinto: replanteando el debate sobre los diseños textiles como escritura', in F. Garcés V. and W. Sánchez C., eds, *Textualidades. Entre cajones, textiles, cueros, papeles y barro* (Cochabamba: INIAM, 2015), pp. 39–64.

Arnold, D. Y., 'Making Textiles into Persons: Gestural Sequences and Relationality in Communities of Weaving Practice of the South Central Andes', *Journal of Material Culture*, 23.2 (2018): 239–60.

Arnold, D. Y., 'Reflexiones sobre el giro ontológico en la Antropología de los Andes', in D. Y. Arnold and J. de Dios Yapita, eds, *Lengua, cultura y mundos entre los aymaras: Reflexiones sobre algunos nexos vitales* (La Paz: Plural editores e ILCA, 2022), pp. 203–24.

Arnold, D. Y., M. de Diego, and E. Espejo, 'On the Relation between Andean Textile Iconography and Woven Techniques', in Denise Y. Arnold and P. Dransart, eds, *Textile, Technical Practice and Power in the Andes* (London: Archetype Publications, 2014), pp. 283–302.

Arnold, D. Y., and others, *Aprendizaje colaborativo en hacer una ontología del dominio del textil andino* (La Paz: ILCA, 2019).

Arnold, D. Y., 'Pickup counts in Andean warp-faced weaves, their iconographic implications in a practice-based numeracy', in Ernst Halbmayer and Kasia Mikulska, *Amergraphics* (Leiden: Brill, in press).

Arnold, D. Y., and E. Espejo, 'De *qeros* y constelaciones: algunas relaciones entre las prácticas astronómicas y textuales aymaras', in D. Y. Arnold, J. de Dios Yapita, and E. Espejo, *Hilos sueltos: los Andes desde el textil* (La Paz: Plural editores e ILCA, 2007), pp. 301–50.

Arnold, D. Y., and E. Espejo. 'Andean Weaving Instruments for Textile Planning: The *Waraña* Coloured Thread-wrapped Rods and their Pendant Cords', *Indiana*, 29 (2012): 173–200.

Arnold, D. Y. and E. Espejo, *El textil tridimensional: La naturaleza del tejido como objeto y como sujeto* (La Paz: IAF, Fundación Xavier Albó and ILCA, 2013).

Arnold, D. Y., and E. Espejo, 'Woven Techniques and Social Interactions in the South Central Andes: Ladder Designs and the Visualisation of Productive Output', in D. Y. Arnold and P. Dransart, eds, *Textile, Technical Practice and Power in the Andes* (London: Archetype Publications, 2014), pp. 303–26.

Arnold, D. Y., and E. Espejo, *The Andean Science of Weaving: Structures and Techniques of Warp-faced Weaves* (London and New York: Thames and Hudson Press, 2015).

Arnold, D. Y., and J. de Dios Yapita, *River of Fleece, River of Song: Singing to the Animals, an Andean Poetics of Creation* (Bonn: BAS 35, 2000).

Arnold, D. Y., with J. de Dios Yapita, *The Metamorphosis of Heads: Textual Struggles, Education, and Land in the Andes* (Pittsburgh: University of Pittsburgh Press, 2006).

Arnold, D. Y., Weaving as Writing: A Serious Omission in the Bolivian Educational Reform of 1994', in a special issue of *Cultura & Psyché: Journal of Cultural Psychology*, eds, Carlos Kölbl and Erdmuter Alber (published online 12 May 2023), https://doi.org/10.1007/s43638-023-00066-2. Online: https://rdcu.be/db1DX.

Bennison, S., 'You are What you Speak? Talking with the *Huacas* in Huarochirí (Peru)', Talk in the Workshop on Critical Language Research: Applied Linguistic and Anthropological Approaches, in the Centre for Latin American and Caribbean Studies (CLACS)/School of Modern Languages, Newcastle University, UK, 25 October 2019.

Binsbergen, W. van, 'The Underpinning of Scientific Knowledge Systems: Epistemology of Hegemonic Power? The Implications of Sandra Harding's Critique of North Atlantic Science for the Appreciation of African Knowledge Systems', in P. J. Hountondji, ed., *La rationalité, une ou plurielle* (Dakar: Conseil pour le développement de la recherche en sciences sociales en Afrique/CODESRIA and UNESCO, 2007), pp. 294–327.

Confortini, C. C., and A. E. Ruane, 'Sara Ruddick's *Maternal Thinking* as Weaving Epistemology for *Justpeace*', *Journal of International Political Theory*, 10.1 (2013): 70–93.

Conneller, C., 'Introduction: Making Materials Matter', in C. Conneller, ed., *An Archaeology of Materials: Substantial Transformations in Early Prehistoric Europe*, (New York and London: Routledge, 2011), pp. 1–23.

Doyon-Bernard, S. J., 'From Twining to Triple Cloth: Experimentation and Innovation in Ancient Peruvian Weaving (ca. 5000–400 B.C.)', *American Antiquity*, 55.1 (1990): 68–87.

Feng Shi, J. G. Foster, and J. A. Evans, 'Weaving the Fabric of Science: Dynamic Network Models of Science's Unfolding Structure', *Social Networks*, 43 (2015): 73–85.

Freeman, M. M. R., 'The Nature and Utility of Traditional Ecological Knowledge', *Northern Perspect*, 20 (1992): 7–12, www.carc.org/northern_perspectives.php (inaccessible in November 2023).

Haber, A. F., 'Arqueología de *uywaña*: un ensayo rizomático', in C. Aschero and others, eds., *Producción y circulación prehispánicas de bienes en el sur andino,* (Córdova, Argentina: Brujas, 2007), pp. 13–36.

Harding, S., 'La science moderne: est-elle une ethnoscience?', in R. Waast, ed., *Les sciences hors d'Occident au XXe siécle, Vol. 6. Les sciences au sud: état des lieux,* (Paris: Orstom, 1996/1994), pp. 239–60.

Harris, R., 'How Does Writing Restructure Thought?' *Language and Communication*, 9.2/3 (1989): 99–106.

Hocart A. M., 'The Purpose of Ritual', *Folklore*, 46 (1935): 343–49.

Hyland, S., S. Bennison, and W. P. Hyland, 'Khipus, Khipu Boards, and Sacred Texts: Toward a Philology of Andean Knotted Cords', *Latin American Research Review*, 56.2 (2021): 400–16. https://doi.org/10.25222/larr.1032 (accessed 12 November 2023).

Ingold, T., *The Perception of the Environment: Essays on Livelihood, Dwelling and Skill* (London and New York: Routledge, 2000).

Ingold, T., *Being Alive. Essays on Movement, Knowledge and Description* (London and New York: Routledge, 2011).

Julien, C., 'Spanish Use of Inca Textile Standards', *Indiana*, 16 (1999): 57–81.

Jullien, F., *Las transformaciones silenciosas* (Barcelona: Edicion Bellaterre, 2010 /2009).

Jullien, F., *Tratado de la eficacia* (Barcelona: Ediciones Segucia, 1999/1996).

Jullien, F., *La propensión de las cosas. Para una historia de la eficacia en la China*. Trans. by A. Sucasas (Rubí /Barcelona: Anthropos Editorial, 2000/1990).

Latour, B., 'Visualisation and Cognition: Drawing Things Together', in H. Kuklick, ed., *Knowledge and Society. Studies in the Sociology of Culture Past and Present* (Greenwich, Connecticut: JAI Press, vol. 6, 1986), pp. 1–40.

Latour, B., *Science in Action: How to Follow Scientists and Engineers Through Society* (Milton Keynes: Open University Press, 1987).

Latour, B., *Reassembling the Social: An Introduction to Actor-Network-Theory* (Oxford: Oxford University Press, 2005).

Latour, B., and S. Woolgar, *Laboratory Life: The Construction of Scientific Facts* (Princeton University Press, 1986).

Lechtman, H., 'Style in Technology: Some Early Thoughts', in H. Lechtman and R. S. Merrill, eds., *Material Culture: Style, Organization, and Dynamics of Technology*, Proceedings of the American Ethnographical Society, 1975 (St Paul, MN: West, 1977): 3–20.

Lechtman, H., 'Andean Value Systems and the Development of Prehistoric Metallurgy', *Technology and Culture*, 25.1 (1984): 1–36.

Lechtman, H., 'Technologies of Power: The Andean Case', in P. J. Netherly and J. S. Henderson, eds, *Configurations of Power in Complex Society* (Ithaca, NY: Cornell University Press, 1993), pp. 244–80.

Lema, V. S., 'Criar y ser criados por las plantas y sus espacios en los Andes Septentrionales de la Argentina', in A. Benedetti and J. Tomasi, eds, *Espacialidades altoandinas. Nuevos aportes desde la Argentina*. Tomo I (Buenos Aires: Editorial de la Facultad de Filosofía y Letras de la Universidad de Buenos Aires, 2014), pp. 301–38.

Leroi-Gourhan, A., *Evolution et techniques: l'homme et la matière* (Paris: Albin Michel, 1943).

Mauss, M., 'Techniques du corps', *Sociologie et Anthropologie* (Paris: Presses Universitaires de France, 1968/1934): 364–86.

Mazzocchi, F., 'Western Science and Traditional Knowledge: Despite their Variations, Different Forms of Knowledge Can Learn from Each Other', *Viewpoint. EMBO (European Molecular Biology Association) reports*, 7.5 (2006): 463–66.

Menary, R., 'Writing as Thinking', *Language Sciences*, 29 (2007): 621–32.

Nakashima D. J., and M. Roué, 'Indigenous Knowledge, Peoples and Sustainable Practice', in P. Timmerman, ed., *Encyclopedia of Global Environmental Change. 5: Social and Economic Dimensions of Global Environmental Change* (Chichester, UK: Wiley, 2002), pp. 314–24.

Needham, J., 'Science and Society in East and West', *Science & Society*, 28.4 (1964): 385–408.

Needham, J., with Wang Ling, *Science and Civilisation in China*, 7 vols., (Cambridge: Cambridge University Press, 1956–2016).

Pimentel, H. Nelson. *Amarrando colores: La producción del sentido en khipus aymaras* (La Paz: CEPA, Latinas Editores, 2005).

Pitrou, P., 'Life as a Process of Making in the Mixe Highlands (Oaxaca, Mexico): Towards a "General Pragmatics" of Life', *Journal of the Royal Anthropological Institute*, 21.1 (2014): 86–105.

Rostworowski, M., 'Mediciones y cómputos en el antiguo Perú', in M. Rostworowski, ed., *Ensayos de historia andina. Elites, etnias, recursos, segunda parte,* (Lima: IEP, 1993), pp. 171–97.

Rivera C. C., 'Prehistoric Textile Production in Highland Bolivia: Instruments for Spinning and Weaving Processes', in D. Y. Arnold and P. Dransart, eds, *Textile, Technical Practice and Power in the Andes* (London: Archetype Publications, 2014), pp. 233–57.

Ruddick, S., *Maternal Thinking: Toward a Politics of Peace* (Boston, MA: Beacon Press, 1995).

Simondon, G., *On the Mode of Existence of Technical Objects*, ed. J. Hart, trans. N. Mellamphy. Unpublished manuscript, University of Western Ontario [translation of *Du Mode d'existence des Objects Techniques*. (Paris: Aubier Montaigne, 1958)], 1980.

Silverman, G., 'Significado simbólico de las franjas multicolores tejidas en los wayakos de los Q'eros', *Boletín de Lima*, 57 (1988): 37–44.

Stengers, I., *Another Science is Possible: A Manifesto for Slow Science* (London: Polity Press, 2017).

Turnbull, D., 'Reframing Science and Other Local Knowledge Traditions', *Futures*, 29.6 (1997): 551–62.

PART III

ON MISSING AND SEIZING TEXTILE OPPORTUNITIES

11

STRING: REWIRING WOMEN AND ELECTRONICS

Ebru Kurbak

INTRODUCTION

> In Ersilia, to establish the relationships that sustain the city's life, the inhabitants stretch strings from the corners of the house, white or black or gray or black-and-white according to whether they mark a relationship of blood, of trade, authority, agency. When the strings become so numerous that you no longer pass among them, the inhabitants leave: the houses are dismantled; only the strings and their supports remain (Calvino 1997: 68).

STRING, ONE OF THE OLDEST TECHNOLOGIES ON EARTH, HAS BEEN BUILDING spider webs of intricate relationships in the world for more than 20,000 years, both physically and metaphorically, as Italo Calvino illustrates in one of his fictional *Invisible Cities*. Prehistoric peoples discovered that by twisting short and weak plant and animal fibres together they could form long and strong threads, inventing 'the unseen weapon that allowed the human race to conquer the earth' (Barber 1995: 43). String enabled humans to bind objects together and make tools, to create ropes and go down into caves, to make nets and catch fish, and to weave sails and discover new lands – an invention so powerful that it sparked a 'String Revolution' in the Upper Palaeolithic comparable to the Industrial

Revolution of the second millennium (Barber 1995: 45). It is argued that today string is being recovered as a new tool, making a comeback not only materially but also in shaping ways of thinking, reappearing in many areas including modern art, chemistry, physics, mathematical modelling and information technology (Küchler 2007). Contrary to previously dominant classification systems that celebrated distinctions, thinking through string suggests linking, connecting, associating, bonding concepts, people and things (Küchler 2007).

This text investigates string as a means to reveal a concealed kinship between two seemingly disparate fields: textiles and electronics. Over the past two decades, research areas such as e-textiles and smart textiles have increasingly presented the innovative integration of textiles and electronics. Most works developed in these fields – despite differing in intention, form, scale and function – commonly demonstrate interchangeability between wire and threads. Such work is commonly read as the novel discovery of electrical potentials of historical metal threads and the appropriation of these long-existing materials to reproduce electrical functions. In this text, I will argue that it is the other way around. String, being the first technology of its kind, is the source of the very imagination of the electrical wire. And the affordances of string have inspired the invention of many electrical applications that form the foundations of the electronic technology of today. By puncturing the history of electrical experimentation, I intend to unearth this ever-existing link between textiles and electronics, and show that the perceived rupture between the two fields is clearly not due to their materialities, but has been the mere enforcement of social, cultural, political and economic segregating forces. Through this lens, I will discuss present-day investigations of 'textile futures' as manifestations of 'unrealized pasts.'

TEXTILES AND ELECTRONICS: TWO WORLDS APART?

Textiles have been around for so long that they are often perceived as closer to nature than to the manufactured world – or, the 'technosphere,' as Peter Haff calls it (Haff 2016). Electronics (including early electrical applications), on the other hand, have epitomised what has been considered technology for more than a hundred years. Works that merge the two fields have discussed textiles and electronics as two fields that 'employ very different toolsets,' 'consist of very different people,' and are 'starkly contrasting' in their gender compositions (Buechley and Hill 2013: 148). The social and spatial segregation of the two fields in question largely owes to the historical societal gendering of both practices and the associated gender stereotyping, especially in the Western industrial world.

Textiles have mostly been associated with women – born or made. In *Women's Work*, Elizabeth Barber suggests that since prehistory it has been 'virtually always women' who have undertaken textile work. Textiles were '*their* craft par excellence,' although men have occasionally been involved in the crafts at different times, circumstances and intensities in different parts of the world (Barber 1995: 29). Referring to Judith Brown's 'Note on the Division of Labour by Sex,' Barber suggests that the assignment of textiles to women in prehistory was due to women's usual habit of taking up works that are compatible with childcare (Barber 1995: 29). Spinning and weaving were crucial tasks but also relatively repetitive, easily interruptible (for instance, for breastfeeding), and could be carried out simultaneously while taking care of infants within the boundaries of the home. In preindustrial times, women were enslaved by textiles as making textiles required an exhausting amount of manual work from growing and harvesting the raw material, to combing, spinning, plying, weaving and tailoring the end product – be it clothing for the family, bedding, curtains, or sails for ships. After the Industrial Revolution, when textile mills replaced cottage industry in the Western world, textile making in and around the home continued with socially and culturally imposed tasks.

Arguing that this division of labour was not an entirely innocent splitting of routine tasks, second-wave feminist discourse paid special attention to textiles as instruments of both oppressive patriarchal ideology and women's resistance to it. Profound studies such as Rozsika Parker's *The Subversive Stitch*, in which the art historian focused on the history of embroidery *as* the history of women in Britain, demonstrated the complexity of the relationship between women and textiles. According to Parker 'embroidery and a stereotype of femininity have become collapsed into one another, characterized as mindless, decorative and delicate; like the icing on the cake, good to look at, adding taste and status, but devoid of significant content.'[1] The construction of femininity reproduced historically and women used textiles in different ways as means to negotiate the changing roles imposed on them. With the women's liberation movement in the second half of the twentieth century, some women entirely rejected textiles as part of their overall refusal of the culture of submissiveness, while others kept on elaborating textile skills as part of their maternal culture. Although feminist theory distinguished gender as socially constructed, and poststructuralist thought proposed even sex as a product of discourse, the conventional view that textile making and mending is a more natural domain for women still persists in some parts of the world today.

Electronics and electrical engineering, on the other hand, has been considered a white male occupation in the Western world. The field has a long history of increasing levels of exclusion, as shown by Carolyn Marvin in her book titled *When Old Technologies Were New*. Claiming 'technological literacy as social currency,' Marvin studied the early Anglo-American electrical culture through the electrical journals of the late nineteenth century and disclosed how 'electrical insiders and outsiders' were formed in the writing. The usual targets of the puns and jokes published in the journals were the women, non-Europeans, Indians, blacks, criminals, and the poor (Marvin 1988: 62). Women's ignorance, however, was ignorance beyond the level of all other outsiders, 'even of the extent of their electrical incapacity.' (Marvin 1988: 22) And, such technical ignorance as a form of worldly ignorance was a virtue of 'good' women. Women did not learn from their mistakes in using technology, or have their misconceptions corrected. Their use of men's technology would come to no good end and would cause a lot of frustration and inconvenience for their male protectors (Marvin 1988: 23). They were simply 'the parasitic consumers of men's labor.' (Marvin 1988: 24)

Not only the field of electronics but also the overarching term 'technology' is intrinsically gendered, as Ruth Oldenziel shows in her book *Making Technology Masculine*. Oldenziel implies the existence of a two-way relationship between gender and technology, in which they constructed each other (Oldenziel 1999: 11). Oldenziel gives Thorstein Veblen the most credit for initiating the view that engineers were the actual producers of technical knowledge, but claims that the social scientists of 1930s were the ones that stabilised this view (Oldenziel

1999: 48–49). Finally, when the word technology appeared for the first time in Encyclopaedia Britannica in 1978, the lexicographers privileged the branches of mechanical and civil engineering in their historiography and rendered the domain of technology 'even more exclusively male-coded than before' (Oldenziel 1999: 186). 'In this construction,' the historian underlines, 'women who enter the male-defined technical stage always look like amateurs' (Oldenziel 1999: 12). It should be noted here that this first Encyclopaedia Britannica entry slightly trivialised the textiles industry by stating, 'its importance in the history of technology should not be exaggerated.'[2] Domestic textile work had been exclusively done by women; however, most industrial textile machinery has been invented by men – intrinsically linked to the establishment of tinkering with machines as a male pursuit, which provided men with the time and space for tinkering and the rights for patenting their inventions. Despite the role textile machinery played in the Industrial Revolution, even industrial textiles were categorised at the margins of technology from early on.

In exploring the histories of diverse practices, Rozsika Parker, Carolyn Marvin and Ruth Oldenziel do in fact make a clear point in common. Gendering of practices is not the simple assignment of genders to already established practices. The elaboration of what the practice is, what it entails, where it begins and where it ends, its insides and outsides as well as its significance and meaning, are negotiated simultaneously as genders are socially constructed and attributes such as femininity and masculinity are shaped and assigned to sexes. What separates gendered fields such as textiles and electronics are not natural boundaries merely set by the nature of their subjects, but assigned borders. And 'the idea of a simple definition of what constitutes a border is, by definition, absurd,' as the philosopher Étienne Balibar puts it. '[T]o mark out a border is, precisely, to define a territory, to delimit it, and so to register the identity of that territory, or confer one upon it. Conversely, however, to define or identify in general is nothing other than to trace a border, to assign boundaries or borders' (Balibar 2002: 76). It is through a process of this sort that textiles and electronics had become the isolated practices that they were in the previous century, representing binary divides such as the decorative and the functional, the familiar and the innovative, and women's work and men's domain.

TWO RECORDERS, ONE STRING

Although textiles and electronics might appear as two opposing cultures from a distance, carrying out even the most basic hands-on experimentation at the intersection of the two fields reveals considerable compatibility between them at the material level. Drawing on my own experience, I would describe exploring the space between textiles and electronics as somewhat working with the 'strangely familiar.' I will briefly present two exemplary objects, namely two resembling sound recorder/player devices that were invented 130 years apart, to discuss some of the conditions that, I believe, create that favourable ambivalence.

The *Yarn Recorder* (2018) is an artwork that was created by the media artist So Kanno and myself within the scope of the arts-based research project 'Stitching Worlds.'[3] (figure 11.1) The object/device is a sound recorder/player that uses yarns containing steel fibers as a magnetic recording medium. In line with the objectives and approach of the overarching 'Stitching Worlds' project, the *Yarn Recorder* was clearly conceived as a discursive object rather than a practical invention. The device not only proposes a method of recording that is virtually obsolete at birth, but also employs an alternative techno-aesthetic by visually resembling two different sets of artefacts at the same time. On the one hand, the device hints at hand-made textiles by employing original parts from traditional wooden yarn winding mechanisms, which are normally used in the process of preparing handspun yarn for hand weaving. The 'reels' of the device are ordinary looking wooden bobbins, with thick, chunky, textured hand-spun yarn wound on them. On the other hand, the device is reminiscent of electronic media technologies of the mid nineteenth century. A built-in loud speaker is visible on the back panel in the middle of the symmetric placement of the two winders. The hinged wooden cover of the device supports its resemblance to portable reel-to-reel magnetic sound recording media. The object was intended as a commentary on the hidden link between the ancient spindle and contemporary rotary technologies (Kanno and Kurbak 2018: 122–25). The link is re-established not merely by means of visual appearance: the device is fully functional. Audiences are welcome to test the workings of the piece by winding the yarn at a constant speed and playing the audible sound that had been recorded on the yarn.

FIG. 11.1 Yarn Recorder (2018); So Kanno, Ebru Kurbak (photo by Elodie Grethen ©Stitching Worlds)

The second example is an 'imaginary media,' which was 'sketched, modelled, and diagrammatized, but never really born.'[4] Oberlin Smith, an American mechanical engineer and inventor who paid a visit to Thomas Edison's laboratories in New Jersey in the 1880s, published a theoretical paper titled 'Some Possible Forms of the Phonograph' on 8 September 1888 in the journal *The Electrical World*. Published about eight years after his visit to Edison's lab, Smith's paper proposed a number of improvements to Edison's phonograph and the intriguing, novel idea to record sound magnetically. Smith's paper came before the Danish inventor Valdemar Poulsen actually patented the first magnetic recording device (the telegraphone) in 1898, and is therefore considered the first appearance of magnetic recording, albeit only in theory. Interestingly, unlike Poulsen's telegraphone, which recorded sound on steel wire, Oberlin Smith proposed using cotton thread that 'would be spun (or otherwise mixed) hard steel dust, or short clippings of very fine steel wire, hardened' (Smith 1888).

The very first magnetic recording medium, then, was really imagined to be thread, a fact unknown to us at the time of the conception of the *Yarn Recorder*.

Unlike the *Yarn Recorder*, Oberlin Smith's device was never actually built. Smith filed a caveat that shows he was engaged in making experiments and wanted to secure the rights of a potential future patent (Engel 1990: 16). In his published theoretical paper, too, he refers to having made some experiments. Unfortunately, the extent of Smith's experiments and what results he achieved are unknown, as most of Smith's documents and experimenting equipment were destroyed in a fire at his factory building in 1903 (Engel 1990: VII). It is therefore difficult to know what the object would have looked like had it been built.

In one of the schematic drawings provided in the original paper, Oberlin Smith notably illustrates the recording medium (cord C) as spun thread by hatching it diagonally (figure 11.2). Unfortunately, all the diagrams in the paper are shown from above; however, some written comments of the inventor shed light on the spool size and thickness of yarn he had in mind. 'The cotton thread above mentioned would seem to be preferable to anything else on account of its cheapness, lightness and flexibility,' states Smith, who adds that this cord must be rather thin, since if it 'approached a clothes line rather than a piece of sewing silk in its general proportions it would be utterly useless as a practical recording

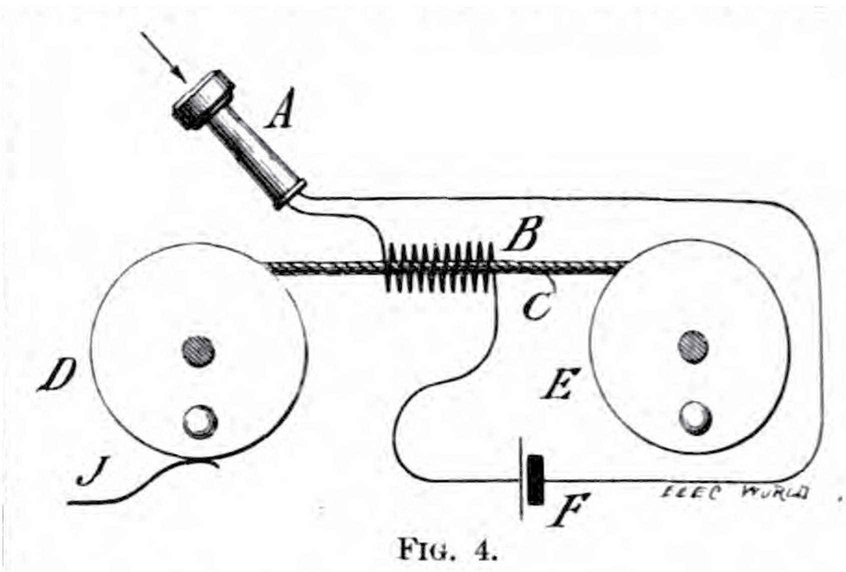


FIG. 11.2 Oberlin Smith's initial illustration in Smith 1888: 116

medium' (Smith 1888). In another statement, Smith hints at a concrete type of thread while simultaneously acknowledging it as women's material. 'The Lord's Prayer could be written upon a few feet of thread or string,' states Oberlin Smith, 'while a young lady receiving a small spool of cotton from her lover would think herself abominably neglected if it was not "warranted 200 yards long"' (Smith 1888). The mysterious pun here, which Smith placed in quotes, was transcribed in an article by Jentery Sayers. The inventor apparently refers to the crochet and darning cotton threads of the Clark Thread Company and others (Sayers 2013: chap. 1). Each of Clark's 'Our New Thread' ('O.N.T') spools held exactly two hundred yards of fine cotton thread. However, since the spools were small and tightly wound, the length of wrapped thread was impossible to determine by the buyer. Thus, the company placed the tag line 'Warranted 200 yards long' on printed labels placed on the cotton spools to assure the buyers. Not in the original publication, but in a caveat Oberlin Smith submitted to the Commissioner of Patents on 4 October 1878, three figures in perspective view were provided. The spools in the illustrations clearly resemble the typical late nineteenth-century wooden sewing thread spools of Clark Threads (figure 11.3).

The *Yarn Recorder* and Oberlin Smith's sewing thread recorder are two different manifestations of the very same idea, although they were conceived

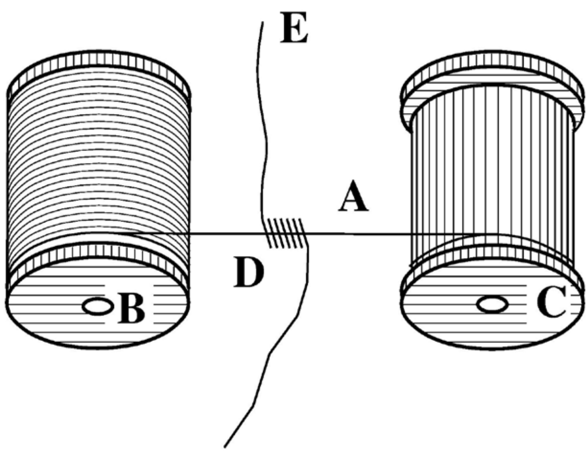


FIG. 11.3 CAD reproduction of drawing by Oberlin Smith first published in The Caveat of 4 October 1878 (reproduction by Friedrich Karl Engel (Engel 1990:14))

in different times and circumstances and with very different intentions. Both devices simply replace the wire in Poulsen's telegraphone with yarns and threads with electrical properties. Despite the perceived peculiarity, from today's perspective, of the idea of yarn as a recording medium, the devices do not seem entirely out of place. They are capable of creating a special sense of dissonance, I would argue, similar to what Tharp and Tharp refer to as 'productive dissonance' in design theory, or what Darko Suvin calls 'cognitive estrangement' in science fiction criticism (Tharp and Tharp 2018: 195; Suvin 2016: 8–9). The devices cannot be simply dismissed as nonsensical or as purely speculative fantasy, but they rather oscillate between the peculiar and the familiar continuously. The source of the peculiarity can clearly be located in the perceived rupture between the gendered worlds of textiles and electronics. The familiarity, I would propose, lies in the archetypical nature of the string and hence the eternally existing link between the two fields.

THE STRING AS ARCHETYPE

'The yarn is neither metaphorical nor literal, but quite simply material,' states Sadie Plant in *Zeros and Ones*, 'a gathering of threads which twist and turn through the history of computing technology, the sciences and arts. In and out of the punched holes of automated looms, up and down through the ages of spinning and weaving, back and forth through the fabrication of fabrics, shuttles and looms, cotton and silk, canvas and paper, brushes and pens, typewriters, carriages, telephone wires, synthetic fibers, electrical filaments, silicon strands, fiber-optic cables, pixeled screens, telecom lines, the World Wide Web, the net, and matrices to come' (Sadie Plant 1998: 12). In his comparative anthropology of the line, Tim Ingold suggests 'threads' as one of the two major categories of the line along with 'traces.' (Ingold 2007: 41) '[A] ball of wool, a skein of yarn, a necklace, a cat's cradle, a hammock, a fishing-net, a ship's rigging, a washing line, a plumb-line, an electrical circuit, telephone lines, violin strings, the barbed-wire fence, the tightrope, the suspension bridge,' according to Ingold, are all examples of threads (Ingold 2007: 41). The anthropologist refers to the writings of architect Gottfried Semper, who also famously argued that first came the thread, and then everything else in human manufacturing history was derived from the most ancient human art of threading, twisting and knotting of fibres (Ingold 2007: 41; Semper 2011: 254). Invented more than 20,000 years ago, string is the first linear element formed by humans known in history, and therefore the archetype of electrical wire and all other imaginable derivations.

Poulsen's wire recorder, Smith's thread recorder, and our *Yarn Recorder* were all materially conceivable because conductive metallic threads and yarns, wires and cables, all 'afford' similar things to humans in the Gibsonian sense. In his theory of affordances in *The Ecological Approach to Visual Perception,* Gibson defines affordances as what an environment offers to the animal (Gibson 1986: 127). Affordances are not properties that can be objectively identified through physics, but are qualities that are relative to the animal. And different objects in the environment have different affordances for the same animal. In his study, the psychologist establishes 'fiber' as a separate category of objects that is 'an elongated object of small diameter, such as wire or thread' (Gibson 1986: 35). Just like sheets, sticks, containers that afford distinct types of manipulation, 'an elongated elastic object, such as fiber, thread, thong, or rope, affords knotting, binding, lashing, knitting, and weaving' (Gibson 1986: 133). Through these kinds of behaviour, manipulation leads to manufacture, which eventually transforms the environment to offer new affordances. It is through the affordances of string that were first explored in textile making, I would argue, that many early inventions in electrical and electronics engineering could be conceived.

String affords *binding* two points in space with each other, for instance. A poem written by the American poet John Greenleaf Whittier, for the occasion of the development of the transatlantic telegraph cable in 1850s, exemplifies the perceived interchangeability of thread and wire as binders in early electrical investigations. Whittier's poem was published in the Atlantic Monthly in October 1858 and reads: 'The atlantic cord as thread. / What saith the herald of the Lord? / "The world's long strife is done! / Close wedded by that mystic cord, / Her continents are one"' (Byrn 1900: 399). Written about two months after the first electric communications between the two continents had occurred, the poem celebrated the interlocking of the two continents by means of a cord both physical and electrical. The binding string, moreover, allows *transmission* along its length. '[W]hether encountered as a woven thread or as a written trace,' states Tim Ingold, 'the line is still perceived as one of movement and growth' (Ingold 2007: 2). The process of spinning already suggests growth along the yarn. Spun yarn, furthermore, suggests movement along its length through its capacity to transmit liquid matter and fire in that very direction. From cotton wicks of candles and oil lamps to fuses in pyrotechnics, the transmitting property of the string had been utilised in many inventions long before electrical technology came along. 'The string phone,' which is an invention attributed to the English natural philosopher Robert Hooke, mechanically transmitted spoken words over a distance long before the invention of the telephone.

Human experience with string over thousands of years inspired the very discovery of the electrical conductivity of metal wire for establishing electrical connections between two points in space. The astronomer Stephen Gray discovered electrical conductivity in experiments he carried out in 1729, in which he transferred electricity from a glass tube to an ivory ball over a distance. Gray suspended an ivory ball from his balcony by means of a long line of 'pack thread' – a coarse hempen fibre – that measured 26 feet from end to end. He attached a glass tube to the top end of the thread, and observed that the ivory ball on the other end of the thread strongly attracted pieces of leaf brass when he rubbed on the glass tube. In trying to reconstruct the experiment horizontally, Gray hung the pack-thread horizontally across his flat with the help of a number of silk threads that attached the thread to the ceiling at intervals. The electrical transfer between the glass tube and the ivory ball functioned horizontally as well; however, the silk threads were not strong enough and therefore broke mid-experiment. To achieve a mechanically stronger system, he tried to hang the pack-thread with brass wire instead of silk, and realised that electrical transmission did not happen in this version of the experiment. Following these observations Gray concluded that materials can be classified as 'electrics' and 'non-electrics.' The pack-thread – especially when it was wet – could transmit electricity; however, silk did not carry electrical charge and therefore could not conduct it from the pack thread to the ceiling (Corrigan 1924: 106–07). It took another five years before Stephen Gray finally discovered metallic wire conductors in 1734.

String does not only afford electrical conduction, but also resists the flow of electricity. The material of the string determines its electrical conductivity and resistance. When Stephen Gray experimented with pack-thread, the capacity of the ivory ball was so small that it must have not mattered for the inventor that the resistance of the thread was probably as high as 10 mega ohms per foot. It was only after Gray discovered metallic conductors that textile threads were classified as poor conductors (Hearle 1952: 2).

The electrical resistance of threads became a subject of investigation in Edison and Swan's experiments with light bulbs. Their first electric light bulbs were made of carbonised, off-the-shelf, ordinary cotton sewing threads. During Thomas Edison's early experiments, the person who was responsible for mounting the small filaments was apparently the British mechanic Charles Batchelor, who was Mr Edison's principal assistant at the time and had moved to America to set up the thread-weaving machinery for the infamous Clark thread factory (Dyer 1910: chap. 12). Edison reportedly recorded a wide range of materials that he carbonised and tried with Batchelor's assistance, including all kinds of threads, fish-line, threads rubbed with tarred lampblack, fine threads plaited together in strands, cotton soaked in boiling tar, lamp-wick and twine, as well as various kinds of paper, wood shavings, vulcanised fibre and around six thousand different species of vegetable growths (Dyer 1910: chap. 11). When Edison and Swan finally came up with the idea of nitrocellulose, Swan reportedly prepared some particularly fine thread for his wife, crocheted into lace doilies, to be exhibited in 1885 as 'artificial silk' (Atherton 1984: 132). Despite Edison's records of the fibre types that he employed, and the occasional appearance of threads in electrical experiments, studying the electrical properties of textile fibres was not of much interest to textiles researchers up until the 1950s, when J. W. S. Hearle carried out his doctoral research on the subject (Hearle and Morton 2008: 643).

The length of the string determines the distance over which electricity can be conducted and the total amount of resistance that the string will present to the flow. The string can be extended in length through *knotting,* and *splicing*. Prehistoric evidence shows the importance of the technique of splicing already in ancient Egypt. North of the Mediterranean, yarns were made through draft spinning, which produces a cohesive and continuous yarn by carefully feeding the thread with fibres, little by little. Ancient Egyptians, however, did not employ draft spinning. Instead, they pre-prepared 50–100 centimetres-long flax fibre bundles, overlapped two bundles at the ends by a few centimetres, and spliced the ends together by twisting the overlapping part to hold together temporarily. They then used the spindle to combine the extended strand of yarn with another strand by adding a little twist in order to create long workable threads (Barber 1991: 47). Variations of the ancient technique of splicing were used in extending solid and stranded electrical wire soon after they became a standard for electrical applications. By the late nineteenth century, the method of splicing for connecting two threads mechanically started to be used extensively in extending telegraphy lines. Techniques such as the Western Union splice and the rat-tail joint, for instance, are typical adaptations of the prehistoric technique of connecting two cables together not only mechanically but also electrically (Sharp 1916: 13–14). The ways in which multiple wires were bundled and organised also eventually resembled applications in textiles, especially embroidery techniques such as couching share principles with the techniques of 'cable lacing,' which were largely used to bundle cables together before cable ties, or to guide groups of cables on surfaces.

The possibility of *wrapping* one string on another has long been explored in textiles, particularly in manufacturing metal threads to be then used in weaving or embroidery. Passing, for example, is a metal thread that is widely used in embroidery (Textile Research Centre Leiden 2018). It is made by winding a thin strip of metal around a cotton or silk thread core. Crinkle cordonnet, similarly, is made by wrapping a cotton core with a very fine metal wire to achieve a wavy structure. Flat worm is made by loosely wrapping a strip of metal around a cotton core and then slightly flattening the thread. The opposite form of such threads, in which metal cores are wrapped with cotton or silk, can be found in early electrical applications. In early nineteenth-century electrical experiments, mainly on telegraphy, this technique was used to insulate wire. In fact, it was milliners who typically did this job; just like they did in preparing the bonnet wire in making hats, they wrapped wire with cotton or silk threads in requested lengths to be used in electrical applications (Blake-Coleman 1992: 141–42). Examples of this type of wire, with cotton-wound insulation at different gauges, survive from Faraday's experiments. These experiments with 'silken wire' led him to many groundbreaking inventions. For example, by continuing to wind the silk wire around various objects, he discovered the electromagnet. 'When a little helix containing twenty-two feet of silken wire wound on a quill was put into the circuit, and an annealed steel needle placed in the helix,' Faraday wrote in his notes, 'the needle became a magnet' (Faraday 1844: 6).

By *winding* the string, one can form coils or store the string on spools. Wrapping the string around an object for storing the string in a compact and stretched form is an idea that goes back to the very invention of spinning. A spindle (or stone or twig) that is rotated around its own axis helps short fibres form continuous yarn by twisting, but at the same time functions as the holder for the already spun yarn (Barber 1991). Invented before the wheel, the spindle constitutes the first prototype not only for spools and reels but also wheels, gears, pulleys, all sorts of winding systems and all rotary technologies (Hochberg 1980). In early electrical experimentations, the principle of the spindle led to the invention of electronic components such as wire-wound resistors and coils, which eventually led to the invention of motors, transformers, generators, loudspeakers and microphones, and much more.

During the industrialisation of textile production, inventors in the textiles industry sought better ways of winding yarns so that they could be unwound without trouble. This brought about the principles of winding threads traversely across bobbins, winding multiple threads together in parallel for preparing warp threads for weaving, as well as winding thread in spaced spirals to form balls (English 1958: 171–83). The electronics industry appropriated similar principles and brought about new methods not only in the plain spooling of wire but also in alternative methods of coil winding such as basket winding, bifilar coil winding, and the winding of spider web and honeycomb coils to mitigate problems such as energy loss, proximity effect and parasitic capacitance in coils. As in the aforementioned experiments by Valdemar Poulsen and Oberlin Smith, the principle of the spool as storage for string appeared in a new form for storing data, with the invention of magnetic recording at the end of the nineteenth century. Another industry that developed in parallel, cinematic motion pictures, appropriated the same principle to store film on reels in various formats.

'Threads have a way of turning into traces, and vice versa,' suggests Tim Ingold. 'Moreover, whenever threads turn into traces, surfaces are formed, and whenever traces turn into threads, they are dissolved' (Ingold 2007: 2). One of the greatest affordances of the string has been weaving. This ancient technique can construct surfaces from threads, on which threads transform into traces. The 2008 documentary video *Moon Machines* describes the much-referenced occasion of the direct use of weaving in electrical engineering. The documentary exposes the creation process of the Apollo Guidance Computer, developed by the MIT Instrumentation Lab for the Apollo program for lunar missions in the 1960s. In order to make a reliable memory for the rockets, the computer scientists had to hire retired factory weavers to fabricate them, by literally weaving the structure of core memory and threading software into core rope memory. Commenting on this, Dick Battin, Director of the MIT at the time, says, 'We called it the LOL method, the little old lady method,' before swiftly adding 'Not very nice. Today you couldn't say those [words].'[5] The way the story is told in the documentary conveys a view that has been prevalent until the turn of this century: MIT labs are not perceived as typical settings for women's handcrafts.

However, despite the perceived oddness of women's involvement in the process shown in the documentary, weavers *were* the ideal candidates to make those devices, simply because both the core rope and the magnetic core memory *were* textile memories, even if not woven in the fullest sense. The manufacturing processes resembled weaving, while simultaneously also utilising the string's affordance of beading. Both types of memory utilised two distinct elements: wires and magnetic cores. In the read-only rope memory, the program was hard-coded through the very process of threading a wire through the centre hole of the core (or not). Threaded through the hole, the core represented a one, and an empty core represented a zero. Magnetic core memory, on the other hand, showed further resemblances to woven fabric, although the wefts were merely laid on the warps rather than alternating over and under. The hardware was made of magnetic cores held together in a grid structure of multiple wires threaded through the holes in the centers of the cores. The cores then could be magnetised either in a clockwise or counter-clockwise direction by electric signals sent through particular wires to represent the zeros and ones. Stephen

Monteiro, in *The Fabric of Interface*, points out the similarities between magnetic core memory and the popular women's weaving handloom kits of the time (Monteiro 2017: 43–47). There is a great resemblance between the two, except the threads in the home handloom are replaced with conductive wires in the core memory, and the decorative beads with magnetic cores. In other words, knowingly or unknowingly, it was upon the principles of women's work that the devices of the MIT researchers were conceived in the very beginning.

'All weaving is the interlacing of two distinct groups of threads at right angles,' explains Anni Albers, 'Wherever a fabric is formed in a different manner, we are not dealing with a weaving' (Albers 2017: 23). *Twining* can be considered a type of weaving in which a double weft thread crosses the stretched warp threads at right angles, and locks one warp thread between the twists of its two strands (Albers 2017: 36). In *coiling*, which is a technique also often seen in basketry, the fabric is formed by wrapping a single thread continuously around a core. If the threads are intersecting 'diagonally in relation to the edge of the fabric, or radially from the center,' we are looking at *braiding*. If only one thread is used to construct the whole fabric, the technique may be *crocheting* or *knitting*. If threads are intertwining or looping around each other, the fabric might have been constructed by *lace making*, *knotting*, *looping* or *netting*.

The potentials of constructing dense surfaces or coarse meshes out of string were not fully explored in historical practices of electrical engineering, except for instance the occasional use of woven or knitted wire meshes in the construction of Faraday cages, or the braiding of thin copper wire to achieve the production of flexible coaxial cable. The construction of electronically functioning components and devices through techniques such as weaving, knitting, crocheting, braiding and twining, among others, has only recently begun to be explored in investigations in the space between textiles and electronics from artistic, DIY, educational and engineering perspectives.[6]

UNREALISED PASTS

If the conceptions of and with the electrical wire can be traced back to prehistoric string, it can be argued that the fields of textiles and electronics could have been intrinsically fused from the very beginning. Affordances that are offered by objects are always there, according to Gibson, regardless of whether the observer can perceive them or not:

> The affordance of something does not change as the need of the observer changes. The observer may or may not perceive or attend to the affordance, according to his needs, but the affordance, being invariant, is always there to be perceived. An affordance is not bestowed upon an object by a need of an observer and his act of perceiving it. The object offers what it does because it is what it is (Gibson 1986: 138–39).

Metal threads had already been in use for over 2000 years by the time electricity became a field of research in the nineteenth century. Thus, some of today's electronic-textile experiments could technically have been done back then.

In other words, textiles and electronics practices had been regarded as incompatible with each other not due to their materialities, but rather because of social processes. The two practices were carried out strictly by different people at different places, and interactions between them were greatly hindered by gender stereotyping for a very long time. As shown through historical examples, there have been some crossovers due to the archetypical nature of string. Yet the potential of string was not fully explored, not only because women have been mostly excluded from the electronics scene, but also as the educated, white, male electricians have abstained from learning textile handcrafts. Through this lens, the increased interaction between fields of textiles and electronics today can be considered a natural result of the lifting of those social segregating forces. Thus, some of the current inventions, despite how 'futuristic' they might seem today, are in fact manifestations of 'unrealised pasts.'

At this point, revisiting the examples of the *Yarn Recorder* and Oberlin Smith's thread recorder can help develop this argument. In an article within the project book of 'Stitching Worlds', I have discussed the *Yarn Recorder* and inventions alike as 'lost possibilities' (Kurbak 2018: 117), and referred to the 'possibilities cone,' which is a model that is widely referenced in future forecasting and Dunne and Raby's theory of speculative design (Dunne and Raby 2014: 5) (figure 11.4).

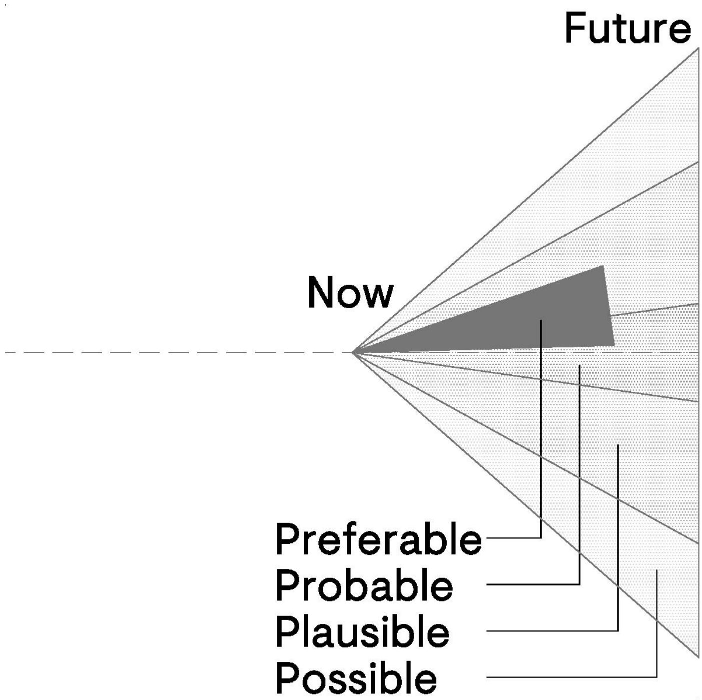


FIG. 11.4 The possibilities cone based on the illustration 'PPPP' in Dunne and Raby 2014: 5

The cone represents the idea of multiple 'futures' as opposed to 'a future.' The model is of course a limited one, unable to account for the multiplicity of situated perspectives because it relies on a singular vantage point. Yet it can be a useful tool if considered as a representation of a dominant, widely circulated view from a position of power in a given time and context. Consisting of four nested cones of possible, plausible, probable and preferable futures, the model renders design and invention as political acts due to the role they play by influencing which of these endless possibilities will become 'the future.' I have proposed drawing a second cone, an exact mirror reflection of the possibilities cone, towards the past (figure 11.5). This 'lost possibilities' cone represents the possibility for one to 'see things in history that could have happened, but did not, not always because they were not preferable, but because they were not imaginable' (Kurbak 2018: 117). The purpose of the cone of lost possibilities, by highlighting what had been 'unimaginable,' is to reveal the limitedness of human imagination. Affordances of things that have always been there but had not been seen by observers of the past, can be seen an observer of today in the light of their current experiences, knowledge, desires and capabilities.

Thinking of Oberlin Smith's invention in discussion with the *Yarn Recorder* opens an additional line of thought. The possibilities cone that was projected from where Oberlin Smith stood in the 1880s suggested an endless number of linear rays (paths to different futures) spreading from one point and filling up the conic volumes. As Jentery Sayers proposes, Smith's ideation of recording audio on thread 'demands faith in the medium – a faith that thread would store sounds naturally, authentically, and exactly as they existed prior to their mediation' (Sayers 2013: chap. 1). The inventor obviously had the necessary faith in thread and saw a sound recorder that utilises thread as a 'probable' and even 'preferable' future technology for his audience. The *Yarn Recorder* however, 130 years later, was designed *precisely because* we, as its designers, anticipated that

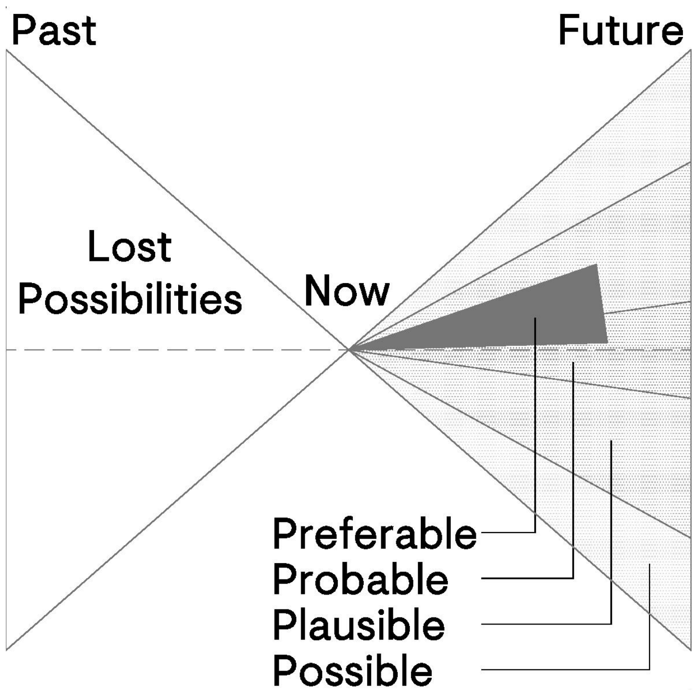


FIG. 11.5 The lost possibilities cone (illustration by Ebru Kurbak)

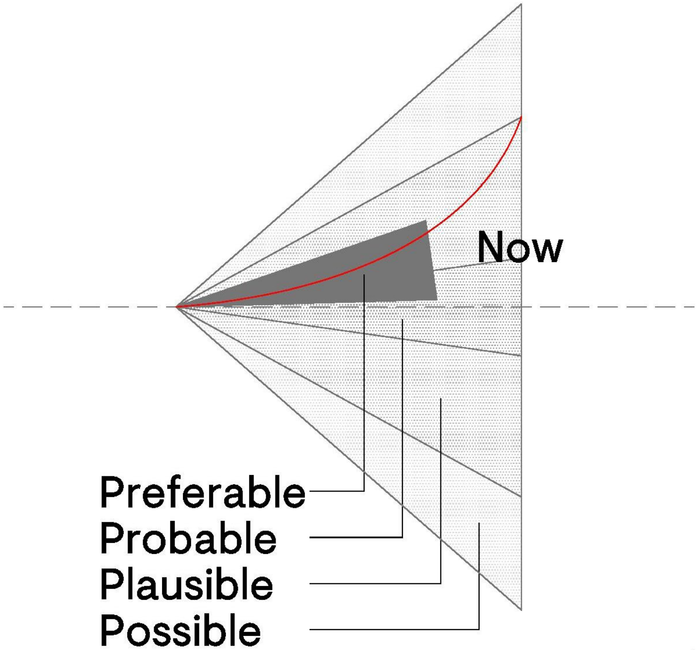


FIG. 11.6 Drifting futures (illustration by Ebru Kurbak)

the technology would be 'barely plausible' to a contemporary Western audience due to the perceived rupture between the two worlds of textiles and electronics.

Technologies that once seemed probable from a certain viewpoint can become implausible, or vice versa, due to social, cultural and economic influences. Some paths are in fact curves, or even parabolas, instead of straight rays, which slip through the different cones of possibilities over time, back and forth, in different directions (figure 11.6). Looking into the past through today's lens, one can see those ups and downs, inclusions and exclusions of people, things, knowledge and practices throughout history. But also today, with intentional and sustained efforts, the slipping between cones can be influenced; from positions at their margins, possibilities can be moved into visibility, unsettling boundaries and hopefully gradually shifting dominant views.

CONCLUSION

Techniques of textile making can be considered the 'high-tech' of prehistory. During the Industrial Revolution the 'technicity' of textiles was once more highly celebrated for a period. However, for most of the last few centuries in the Western world, textile crafting techniques, categorised as women's work, have been carried out and cultured in the confinement of the home, perhaps resulting in a loss of the imagination of 'technical' possibilities. By puncturing through the histories of what happened in textiles and electronics by means of string – and this chapter has barely scratched the surface of these possibilities – I have tried to inspire an impression of what *could not* happen. Knowledges that were once placed at the centre in the imagination of futures slowly drifted to the far edges of the possibilities cone over a long period of time. As an artist, I believe that working with such knowledge and abruptly pulling it from that far edge to the very centre in an artwork is only one way of revealing the politics involved. Eventually the pulls will influence the drifts, however small.

ACKNOWLEDGEMENT

This research was funded in whole or in part by the Austrian Science Fund (FWF) [10.55776/V795].

ENDNOTES

1 Parker 2010: 4–5; see also Parker and Pollock 2013 for an expanded discussion on the role of the feminine stereotype in art historiography.
2 Quoted by Oldenziel 1999: 49.
3 The *Yarn Recorder* was developed as a continuation of the 'Magnetic Recording on Fibers' workshop (2014) carried out by So Kanno, Ebru Kurbak and Irene Posch with the engineering assistance of Matthias Mold within the scope of the 'Stitching Worlds' project.
4 Siegfried Zielinski, rephrased in Parikka 2012: 50.
5 First aired on TV in June 2008, *Moon Machines* is a documentary series directed by Christopher Riley, Duncan Copp and Nick Davidson. See *Moon Machines* 2008: part 3: The Navigation Computer, 22:43.
6 See for instance Kurbak 2018 (*Stitching Worlds*).

REFERENCES

Albers, A., *On Weaving* (Princeton, NJ: Princeton University Press, 2017).

Atherton, W. A., *From Compass to Computer: A History of Electrical and Electronics Engineering* (San Francisco, CA: San Francisco Press, 1984).

Balibar, É., *Politics and the Other Scene* (London: Verso, 2002).

Barber, E. W., *Women's Work – The First 20,000 Years: Women, Cloth, and Society in Early Times* (New York: W. W. Norton, 1995).

Barber, E. J. W., *Prehistoric Textiles: The Development of Cloth in the Neolithic and Bronze Ages, with Special Reference to the Aegean* (Princeton: Princeton University Press, 1991).

Blake-Coleman, B. C., *Copper Wire and Electrical Conductors: The Shaping of a Technology* (Chur: Harwood Academic Publishers, 1992).

Byrn, E. W., *The Progress of Invention in the Nineteenth Century* (New York: MUNN & CO Publishers, 1900) Project Gutenberg EBook.

Buechley, L., J. Jacobs, and B. Mako Hill, 'LilyPad in the Wild: Technology DIY, E-Textiles, and Gender', in L. Buechley and others, eds, *Textile Messages: Dispatches from the World of E-Textiles and Education* (New York: Peter Lang, 2013), pp. 146–57.

Calvino, I., *Invisible Cities* (London: Vintage Books, 1997).

Corrigan, F. J., 'Stephen Gray (1696–1736): An Early Electrical Experimenter', *Science Progress in the Twentieth Century (1919–1933),* 19.73 (1924): 102–14. https://www.jstor.org/stable/43430616.

Dunne, A., and F. Raby, *Speculative Everything: Design, Fiction, and Social Dreaming* (Cambridge, MA: MIT Press, 2014).

Dyer, F. L., and T. C. Martin, *Edison: His Life and Inventions* (New York: Harper & Brothers, 1910). Project Gutenberg Ebook. https://www.gutenberg.org/files/820/820-h/820-h.htm.

Engel, F. K., *Oberlin Smith and the Invention of Magnetic Sound Recording: An Appreciation on the 150th Anniversary of the Inventor's Birth* (Bensheim: Oberlin Smith Society, 1990).

English, W., 'A History of Winding', *Mather Lecture* 1958, 168–94. Taylor & Francis Online. https://doi.org/10.1080/19447015808688362.

Faraday, M., *Experimental Researches in Electricity*, VOL II (London: Richard and John Taylor Printers and Publishers to the University of London, 1844).

Gibson, J. J., *The Ecological Approach to Visual Perception* (Hillside, NJ: Lawrance Erlbaum Associates Publishers, 1986).

Haff, P. K., 'Technosphere and Technoecology', Interview by E. Hörl, *Technosphere Magazine*, 15 November 2016. https://technosphere-magazine.hkw.de/p/Technosphere-and-Technoecology-qzjFDWgzxX2RDEDg9SN32j.

Hearle, J. W. S., '*The Electrical Resistance of Textile Materials*', PhD Thesis, University of Manchester, 1952. ProQuest (27529578).

Hearle, J. W. S., and W. E. Morton, *Physical Properties of Textile Fibres* (Cambridge, UK: Woodhead Publishing, 2008).

Hochberg, B., *Handspinner's Handbook* (Santa Cruz, CA: B. & B. Hochberg, 1980).

Holland, R. S., *Historic Inventions* (Philadelphia, PA: George W. Jacobs and Company, 1911). Kindle.

Ingold, T., *Lines: A Brief History* (Abingdon: Routledge, 2007).

Kanno, S., and E. Kurbak, 'Yarn Recorder', in E. Kurbak, ed., *Stitching Worlds: Exploring Textiles and Electronics* (Berlin: Revolver Publishing, 2018), pp. 122–25.

Kurbak, E., 'Fiberpunk: Inventing Feminine Pasts', in E. Kurbak, ed., *Stitching Worlds: Exploring Textiles and Electronics* (Berlin: Revolver Publishing, 2018), pp.114–21.

Kurbak, E., ed., *Stitching Worlds: Exploring Textiles and Electronics* (Berlin: Revolver Publishing, 2018).

Küchler, S., 'The String in Art and Science: Rediscovering the Material Mind', *Textile: The Journal of Cloth and Culture*, 5.2 (2007): 124–39. doi: 10.2752/175183507X219416.

Marvin, C., *When Old Technologies Were New: Thinking About Electric Communication in the Late Nineteenth Century* (New York: Oxford University Press, 1988).

Monteiro, S., *The Fabric of Interface: Mobile Media, Design, and Gender* (Cambridge, MA: MIT Press, 2017).

Moon Machines. Directed by Christopher Riley, Duncan Copp and Nick Davidson, 2008.

Parker, R., *The Subversive Stitch: Embroidery and the Making of the Feminine* (London: I. B. Tauris, 2010).

Parker, R., and Pollock, G., *Old Mistresses: Women, Art and Ideology* (London: I. B. Tauris, 2013).

Oldenziel, R., *Making Technology Masculine: Men, Women, and Modern Machines in America, 1870–1945* (Amsterdam: Amsterdam University Press, 1999).

Parikka, J., *What is Media Archaeology?* (Cambridge, UK: Polity Press, 2012).

Plant, S., *Zeros and Ones: Digital Women and the New Technoculture* (London: Fourth Estate, 1998).

Sayers, J., 'Making the Perfect Record: From Inscription to Impression in Early Magnetic Recording', Scalar project, 2013. http://dx.doi.org/10.1215/00029831-2370230.

Sharp, J. M., *Practical Electric Wiring* (New York: D. Appleton and Company, 1916).

Smith, O., 'Some Possible Forms of Phonograph', *Electrical World*, 12.10 (1888): 116–17.

Semper, G., *The Four Elements of Architecture and Other Writings* (Cambridge, UK: Cambridge University Press, 2011).

Suvin, D., *Metamorphoses of Science Fiction: On the Poetics and History of a Literary Genre* (Vienna: Peter Lang Publishing, 2016).

Textile Research Centre Leiden, 'Metal Threads', https://trc-leiden.nl/trc-needles/materials/metal-threads [accessed 4 May 2018].

Tharp, B. M., and S. M. Tharp, *Discursive Design: Critical, Speculative, and Alternative Things* (Cambridge, MA: MIT Press, 2018).

12

ALGORITHMIC PATTERNS ON THE LIVE LOOM

Alex McLean

ALGORITHMIC PATTERN IS AN EXPANSIVE PRACTICE RUNNING ACROSS THE arts and crafts, that is ancient, yet core to the advance of contemporary creative technology (McLean 2020). In this chapter I introduce the Live Loom as a case study in algorithmic pattern, bringing together the ancient weaving technology of warp-weighted looms with the contemporary technology of computer programming languages. The Live Loom is (perhaps literally) a tangle of old and new, and by attempting to untangle its threads and wires from around its physical wooden frame and metaphysical syntax trees, I explore algorithmic pattern as an ancient, technological and developing craft tradition.

I introduce the Live Loom (figure 12.1) in terms of its many layers of physical qualities starting with the threads themselves, their warping, the crossings of warp and weft threads, then progressing into metaphysical representations of drawdowns, syntax trees and procedures. In so doing, I explain how interactive notations reveal what is normally hidden by notation – a lively world of threads that compels us to reconsider our relationship with technology as craft.

COMPUTATION IN CRAFT

Ada Lovelace, known as the first computer programmer for her work with Charles Babbage, is often cited for recognising common patterns across weaving and computing. However, her foresight carries a misapprehension that has since

FIG. 12.1 The Live Loom, a hybrid, open hardware, warp-weighted hand loom, with 16 computer-controllable warp threads (photo by James Hendy)

been continued through the history of computer science. The motivation for creating the Live Loom is to try to expose this misapprehension, by connecting computer programming directly with weaving.

Lovelace shares her thoughts on weaving and computing in her extensive notes as translator of a piece written about Babbage's Analytical Engine: 'By the introduction of the system of *backing* into the Jacquard-loom itself, patterns which should possess symmetry, and follow regular laws of any extent, might be woven by means of comparatively few cards' (Menabrea 1843: 706). This suggestion is on one hand visionary: following the technology transfer of the Jacquard punch card reader from weaving to computing, Lovelace sees how the computational procedure of looping a subset of cards could be imported back from the Analytical Engine to the Jacquard device. However, as Ellen Harlizius-Klück has previously argued (Harlizius-Klück 2017), weaving has *always* been computational, and in not recognising this, Lovelace seems to have mistaken the opportunity to *reintroduce* computation to weaving for the opportunity to introduce it for the first time (Harlizius-Klück 2024). This would not only be a misinterpretation of history, but would miss the opportunity to incorporate the advanced understanding embedded in traditional weaving practice into the development of new computational machines. Today, we still follow Lovelace's thinking in assuming that the youngest technological practice is the most advanced one, which does not stand to reason, and leads us to continually re-invent a poorer wheel.

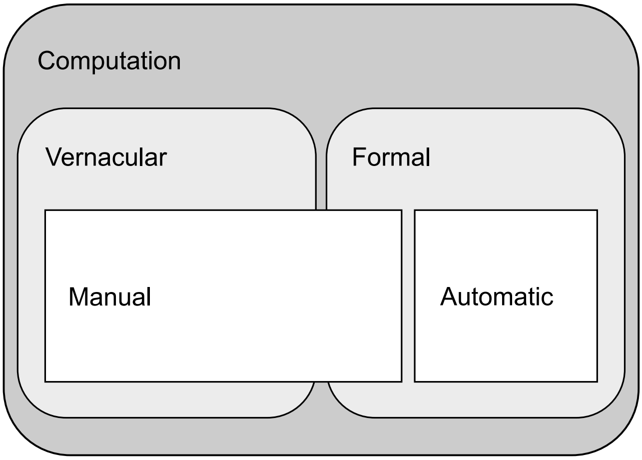


FIG. 12.2 Euler diagram showing the logical relationship between vernacular, formal, manual and automatic forms of computation

To differentiate the Live Loom from the Jacquard mechanism, the Euler diagram in figure 12.2 shows the logical relationships between different kinds of computational technology. One dichotomy drawn in the diagram is between vernacular and formal computation. Vernacular computation includes the kind often examined in the field of ethnomathematics: ways of working that are passed down by word of mouth. Formal computation is a process unambiguously notated in such forms as a computer programmer's code listing, a mathematician's lambda calculus or a weaver's draft. The other dichotomy shown is between manual and automatic computation. For computation to be automated, it must be formalised, so that it may be followed by an electronic or (in Lovelace's time) a mechanical computer. However, where a computation is manually worked through by a human, this could be done either on a vernacular or formal basis. A human is perfectly capable of following formal instructions (such as a weaver's treadling pattern, a knitting pattern, or recipe) accurately, as well as applying embodied knowledge, accrued through the vernacular-informal instruction or personal exploration. However, since the Industrial Revolution, formal computation has become closely associated with automation, and so craft practices based on manual exploration of computational, algorithmic patterns have been sidelined. What I try to show in the following, by introducing and using the Live Loom, is the generative, creative possibilities of manual, yet formal systems of computational craft.

THREADS

In the present day, we relate the zeroes and ones of binary (base two) counting with modern computing, but we know from the field of ethnomathematics that humans have always engaged with binaries (Babbitt, Lyles, and Eglash 2012). This is clear even when looking at a single thread, which has two possible spin directions – S (holding a thread vertically, we see the spin travel diagonally top left to bottom right) or Z (top right to bottom left). If you tighten the spin of a thread and hold its two ends together, it will self-ply – creating a shorter 'doubled' yarn with the opposite spin direction – a logical negation.

A thread typically comprises smaller strands, which are ultimately composed of fibres, the thread itself already being the result of a long process of production. Threads therefore exhibit fractal self-similarity (fibres within strands within yarns, and so on) all the way down to microscopic properties which still affect the visual and physical qualities of the resulting weave. Nonetheless, as a useful simplification for present purposes, in the following we treat the thread as the atomic fundamental unit of a weave. While threads are marked by discrete[1] binaries such as spin direction, they also flow continuously. Threads are therefore both discrete and continuous, or in other words both digital and analogue. In weaving, a loom is a device for focussing on binary interactions, at discrete crossing points, and therefore it is these binary and discrete qualities that we focus on here. Regardless of the presence of electricity or electronics, any loom is fundamentally a device for working with discrete crossing points and weaving is therefore fundamentally a digital craft.

For a detailed examination of the binaries of the threads themselves, we could look to Andean *khipu* makers, for example the historical practice of record keeping within the former Inka empire, and the earlier, more improvisatory use by the Wari. As far as we understand, *khipus* integrate spin direction, knot direction and several other binary properties with a decimal system of knot-tying, in order to record discrete numerical information.[2] Most textile artists deal with threads, but in many cases that is where shared understanding ends. For example, knitting, braiding and weaving are three fundamentally different families of structures, and so knitters, braiders, weavers and indeed *khipu* makers do not necessarily have much to say to each other. For the present chapter, we focus on weaving structures.

Threads are highly susceptible to disorder – drop a few threads on the floor and they will seem to tangle almost autonomously. The role of a weaver is to impose order on threads, creating structures which hold together as a fabric, starting with the warp, which we examine now.

WARPING

A core prerequisite for weaving is to order parallel threads and hold them in place under tension. These are called the *warp* threads, and in weaving diagrams they are generally conceived as running vertically from the top to the bottom of the page, with perpendicular weft threads introduced later, from side to side. These weft threads are interlaced with the warp according to a particular pattern of movement. Setting up a loom with an arrangement of differently coloured warp threads introduces rich creative constraints on what visual patterns can later be woven on that loom, and any decision about how to do so is not taken lightly; the warping process might take weeks, depending on the thread-count and complexity of the loom.[3] The Live Loom is designed for experiment and learning, and has a very low thread-count of only 16 warps, but still the process of warping the loom takes over an hour.

WARP WEIGHTS

One of the primary functions of a loom is to hold the warp under tension, using technologies that have developed over millennia. Modern looms tend to create tension between two drums, as the warp is rolled off one drum and on to another, as woven fabric. Careful warping techniques ensure that all the threads are held at the same tension. A much older (indeed ancient) approach is to add *weights* to the warp. This is how tension is created on the Live Loom, by suspending warp threads from the top of a frame, with each thread kept under tension by a weighted bobbin dangling at the bottom. Each warp is wound around the bobbin so that the length of the resulting fabric is not limited by the size of the loom, but by the length of thread that is wound around each bobbin. As the weaving progresses, it is wound onto the top bar, and more warp is released from the bobbins, so that they are near, but not touching the surface on which the loom is placed.

Warp-weighting is anachronistic technology, but nonetheless has a number of advantages over modern looms. Tension comes only from gravity, which is of course a constant, resulting in an even tension from equal weights. Therefore warp-weighting creates more reliably uniform tension than the modern drums mentioned above. Furthermore, the threads are only attached to the loom at one end, meaning that the warps may easily be rolled up for transport and storage.

The weighted bobbins used on the live loom are technologies borrowed from another ancient textile art – Japanese *kumihimo* braiding. I was introduced to *kumihimo* through tuition from braiding expert Makiko Tada, using traditional *Tama* bobbins. In *kumihimo*, each bobbin must hold itself in place at the end of its thread, while also allowing the braider to quickly and easily release more thread. Traditionally this is done with a slipping hitch, where the thread twists back on itself on the bobbin in such a way that when the braider pulls the thread in the right direction, more thread is released. I use hobbyist plastic bobbins (with metal weights incorporated), but using the same slipping hitch I learned from Tada-Sensei.

PASSING THE WEFT

With the warp held under tension from top to bottom, the weft can be introduced, from one side to the other, and back. To create a weave, the weft travels over and under (or in front of/behind) the warp. However, generally it is the warp threads which move to create the structure – for example by alternate warp threads being pulled forward. This creates a gap between the warps which have been pulled forward, and those which have been left behind, called the 'shed'. The weft is then passed through this shed. On the Live Loom, warp threads can be selected and pulled forward using wooden sticks as levers, each one attached to a single warp thread (using a 'string heddle').

Having passed the weft from left to right, the weaver then pulls forward a new selection of warp threads, creating a new shed. They then pass the weft back through, this time from right to left.[4] Creating the new shed also functions to trap the previous weft in the weave, and physically pulling the shed open will pack that weft into place. The weft can be packed in further using a flat stick known as a 'sword'. Each weft is, then, co-dependent on the weft before and after, so that the overall structure holds together as a textile weave.

WEAVE

The selection of warp threads results in a particular weave structure, with profound impact on both the behaviour and appearance of the resulting textile. The translation from binary ups and downs into physical cloth with real-world properties, is fascinating.

Weaving structure can be conceptualised and notated as a binary grid, but this is an abstraction – weaves are three dimensional. The depth of this statement can be hard to grasp, partly because we are so used to the image of Jacquard's two dimensional, binary punched cards, as well as the older two-dimensional, binary form seen in weaver's grid-based notations, known as lift plans, drafts and drawdowns. But these two-dimensional grids only notate sheds (and, for example, on shaft looms, tie-ups and treadling), and not the real-world complexity of the woven outcome.

One place that the three-dimensionality of weaving becomes clear is at either edge of the fabric, known as the selvage. For handweavers, adjustments to the structure must be made here for the weave to hold together consistently. This requires thought and agility that is hardly possible at modern machine looms, which instead simply cut off the edges as they are woven. By contrast, handweavers put thought into creating edges which hold together for consistent results, perhaps even integrating a weave with a very different structure, such as tablet-weaving around its border (Harlizius-Klück 2017). Adjustments might also be needed elsewhere, to make sure every thread is properly integrated into the weave, applying methods to avoid unwanted loose threads, known as 'floats'.

The difference between notation and weave is particularly stark in double weave. When some structures are woven, they result in two (or more!) fabrics, one lying on top of the other. This happens when there are 'binding points' with some previous wefts but not others, causing distinct layers to form, an outcome which can confuse and surprise beginner weavers such as myself. Indeed, a well-cited paper on the geometry of weaves misunderstands double weave, describing such structures as 'falling apart' (Grünbaum and Shephard 1988), but when you actually weave these structures, they do result in well structured textiles, just more than one of them. This demonstrates the danger of trying to understand weaving 'on paper' rather than at the loom. In practice, when a weaver changes from a double weave structure to another one, these different layers are able to reintegrate into a single fabric, the double weave section creating a pocket.

There is confusion, then, between the structure that we visualise, and the resulting textile we see and touch. Apart from special cases such as double weave, there *is* a direct correspondence between the grid structure on the page, and the up-down structure of the threads in the textile. However, although this structure is present it may be obscured, especially when we vary warp and weft colours. This introduces interferences where the colour pattern in the warp and weft threads interfere with the pattern of the weave structure imposed on those threads. The result of this interference is a colour-and-weave effect, emerging from the different patterns of thread colour and weave structure, as Ellen Harlizius-Klück explains in the third chapter of this collection, and I demonstrate later in the present chapter.

The woven structure not only influences the visual appearance, but also the behaviour of the textile. For example, the woven textile's strength, how it drapes, how layered the textile is and how it reflects light. We know denim for its strength and durability, and satin for its shiny front, dull back and draping characteristics – which are much more properties of the denim and satin weave structures than the material that is used. As discussed, weaving structure is generally represented using binary grids, but the Live Loom adds an additional layer in order to generate such grids – a pattern language, which I introduce next.

PATTERN LANGUAGE

We have already considered weaving drafts, above, as a form of notation commonly seen in weaving crafts and industry. This notation is used while preplanning a weave that is later put into production, and may also be created when analysing an existing weave, 'reverse engineering' its structure. Modern industrial weaving is a resource- and time-intensive process that needs careful planning and testing to arrive at an intended product. However, the Live Loom is not designed to be productive, but instead to support creative exploration and learning at the loom itself, perhaps reflecting the improvisational approaches to developing new fabrics seen in traditional weaving. The Live Loom is too small, with too low a thread-count to produce cloth in useful dimensions, but that is not its aim. It is instead intended as a platform for live coding weaves, where decisions are made and remade during the weaving process itself.

'Live coding' is a movement co-founded by the present author (Blackwell and others 2022), emerging from the digital arts and particularly the algorithmic music communities around the turn of the millennium. It began as a way of making improvised music, where a practitioner performs by creating and manipulating code, while that code generates sound, during a performance. A live coder's screen is generally projected into the performance space so that the audience can see the code being written while it generates the music that they hear. As the community has developed, other performing arts have taken on and developed live coding techniques, and live coded video and choreographic performances are now common.

As a live programmable loom, the Live Loom resonates with a particular part of live coding culture, namely 'slow coding' (Hall 2007). Slow coding eschews high-pressured 'algorave' performances where live coders work furiously on their code to keep their audience dancing; instead, each edit is considered carefully over extended periods (in sympathy with the 'slow food' movement). Whereas a live coding musician might make an edit every few seconds, a weaver on the Live Loom might change their code once every ten minutes or more.

The Live Loom language is a library of combinators for the pure functional programming language Haskell. In general terms this means that it consists of a collection of words and symbols, each of which stands for a way to construct or transform binary up/down patterns, as shown in Table 1. This is a small and straightforward library, building on the standard functionality of the Haskell language.

`up / down`	Keywords representing a warp either being up (pulled forward) or down (left behind) when creating a shed.
`[ ]`	An empty list.
`:`	Used to add an up or down to a list (starting with the empty list above).
`cycle`	Repeats a list of up/down indefinitely.
`offset n`	Successively 'shifts' each row by the given number 'n' of warp threads.
`shift`	Shifts a row by one (e.g., takes the first up/down in the row and moves it to the end of the row).
`every n f`	Selectively applies the transformation 'f' every 'n' rows.
`backforth`	Reverses every other row. Shorthand for '`every 2 reverse`'.
`invert`	Turns all the 'up's to 'down's and vice-versa.
`zipAnd`	Combines two weaves – where a warp remains 'up' only where warps on both weaves are 'up'.
`zipOr`	Combines two weaves – where a warp remains 'up' only where warps on either or both weaves are 'up'.
`zipXOr`	Combines two weaves – where a warp remains 'up' only where one (but not both) warps are 'up'.

TABLE 1. A list of the main functions available in the Live Loom language.

These twelve keywords, along with the natural numbers, are enough to produce an astonishingly wide range of weaving patterns with a very small amount of code. Each one stands either for a unit, or a simple operation on those units – the explosion of possibilities comes from the very many ways in which they can be combined into compound operations.

AT THE LIVE LOOM

Both the computing and textile industries have been overridden by automation over the past decades and centuries, respectively. Indeed, there would seem to be motivation to develop the Live Loom so that more of it is automated – the shed could be fully opened by the mechanism without hand control, or the weft could be passed automatically, using one of the machine loom techniques developed in the textile industry. However, each step taken towards full automation separates the live coder further from their weave, until they are working only with two dimensional grids rather than three-dimensional material. By keeping hands both on coding and weaving in a physical feedback loop, the weaver-coder has the maximum opportunity to learn. In the following section I step through a weaving session on the Live Loom, recounting the problems met and decisions taken.

I began with a few rows of the simplest possible weave, known as the plain weave or 'tabby', to make sure the threads were in good order and the solenoids were working. A tabby weave follows the following lift plan:

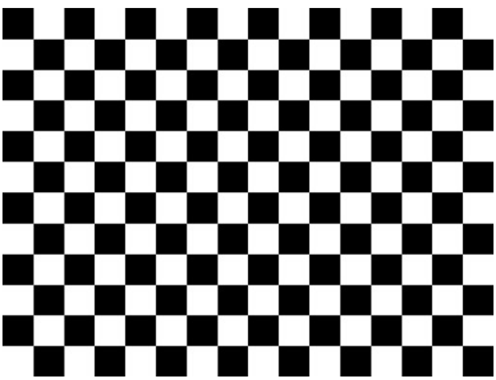


FIG. 12.3 Lift plan for tabby weave

Black stands for warp up (and therefore weft down), and white for warp down (and therefore weft up). If we were weaving with paper strips, with black warp and white weft strips, then the woven result would look the same as the above image. One way to express such a tabby weave in the Live Loom language is as follows:

```
backforth (cycle [up, down])
```

This repeats the plain weave's up-and-down structure, with the `backforth` function added in order to reverse every other row. Without applying this function, the textile would not hold together; every weft would follow the same structure, creating no 'binding points' (where weft interlaces with warp and vice-versa) from one weft to the next.

The Live Loom language has a largely mouse-operated programming interface, which is shown on the left-hand side of figure 12.4. In this interface words are dragged from a palette on the right, and arranged into a program on the left. These words are automatically connected together by the software (based on type compatibility and proximity) into a diagram representing the syntax tree of the program. This allows functions to be moved around the code playfully, to look for interesting interactions with other functions. The code generates the binary grid of a weaving lift plan, which is displayed in the interface below the word palette. The grey squares on either side of the lift plan highlight the row which was most recently woven.

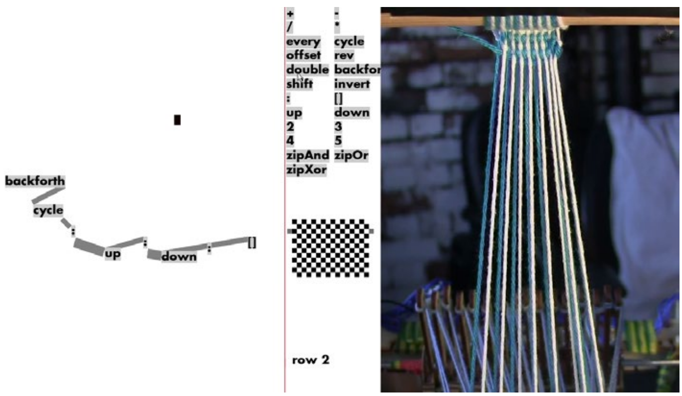


FIG. 12.4 The Live Loom interface, showing code on the left, a menu of available words (functions and values) to its upper right, and the resulting weaving lift plan to its lower right

A camera feed from the weave itself is shown to the right of the interface. Note that the camera feed shows the back face of the weave, which can look very different from the front.

When the weaver-coder is happy with their lift plan, it is time to send it to the loom. The lift plan is sent one shed at a time, by pressing the right arrow key on the computer keyboard. The same shed can be re-sent with the up arrow, and the weaver can send the previous one with the left arrow. In this way, the weaver uses the solenoid-driven heddles on the Live Loom to enact successive rows of the lift plan. This lift plan therefore represents both the binary up/down movements of the solenoids, and the structure of the woven textile that results from these movements. In some cases, the structure of the weave is readily visible in the end result. In particular, if the warps are of one colour, and the weft threads of another, then the front face of the resulting weave will often closely resemble the lift plan pattern, repeated across the fabric. However, as mentioned earlier, if different threads within the warp and/or weft have different colours, then the thread colours interfere with the structure, creating colour-and-weave effects that are surprising to the lay weaver. In the following I have warped the Live Loom with alternating white and blue threads, and also alternated between white and blue wefts. This simple set-up already provides rich ground for exploring colour-and-weave interactions.

In the case of the plain weave shown in figure 12.4, we can see that the checkerboard pattern of the lift plan has resulted in vertical stripes in the weave shown on the right. This is because the alternating blue/white pattern of the warp and weft threads means that the white weft is always under the blue warp, and the blue weft is always under the white warp, so the colours of warp and weft always match in the warp direction. However, for reasons of practicality the camera here points to the *back* of the weave. If we compare the front and the back side in figures 12.5 and 12.6 respectively, we see this section (a) appears as horizontal stripes on the front, and vertical stripes on the back. Such effects make the difference clear between a lift plan and a textile. It is often said that 'the map is not the territory', and in this case we can view the lift plan as a *map* for the textile as a *territory*. While in this case the map is used to create the territory, we can only really read and fully understand the map once we know the territory. This may seem like a paradox, but a lift plan has at least two purposes, one being as a plan for weaving, and the other as an analytical map for understanding what has then been woven. The textile itself has many properties which are not present in the abstract notation of the lift plan, and which only emerge in its making.

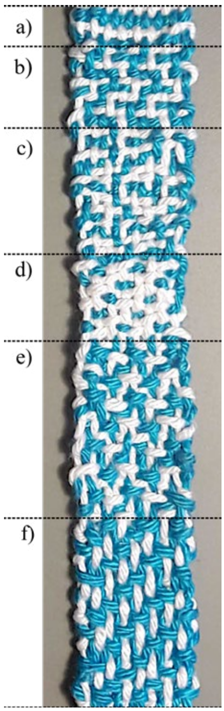


FIG. 12.5

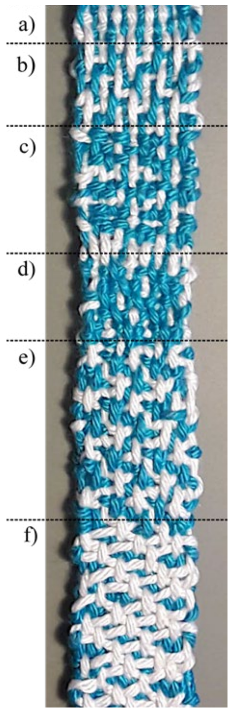


FIG. 12.6

After four rows of plain weave, I change the lift plan by adding a single 'down' instruction to the code, which now reads `backforth (cycle [up, down, down])` (for brevity, I don't include the visual representation of this code here). This produces the following lift plan.

With the structure following a back-and-forth path across the weave, the result is a wave that repeats every three warps and six wefts. Within this repeat, there are consecutive identical sheds, which in practice means that two wefts are passed through the same shed. However, I had woven this particular pattern before, and so knew this would not be a problem; these pairs of wefts are held

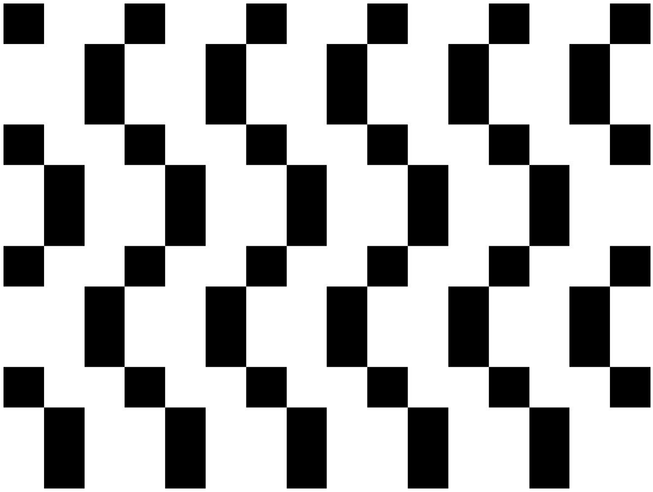


FIG. 12.7

in order by the warps, and the textile holds together well.[5] Looking at the lift plan, we can see unbroken lines formed by four white warps. This creates clear 'floating' warp threads on the back of the weave shown in figure 12.6 b), each of which travels over four wefts (if they were shown in black on the lift plan, these floats would have instead been visible on the front face). These floats occur on both odd and even warps, and because I alternate thread colours, both blue and white floats are created. Using these floats as markers in comparing the lift plan with the woven result, we can see how the structure is present in the weave. However, squinting our eyes, visually the angular repeating pattern in the weave looks very different from the wave running down the lift plan.

I should point out that while here I use the `backforth` transformation to construct the lift plan, this does not match with the reality of how I weave it. We could say that `backforth` simulates the path of a single weft, from left to right, and back again from right to left. But when it comes to weaving, I am using two wefts – I first pass the white and then the blue thread from left to right through the first two sheds, and then back from right to left for the following two sheds. This seems a small technicality but demonstrates that abstractions are at play – the language works with a model of the weaving process as a notional machine. The term 'notional machine' is borrowed from computer programming education research,[6] and is the idea that when writing software we do not address the computer we are using, but an idealised version of the computer. The properties of this notional machine are implied by the constructs of the programming language and not the hardware. When coding the lift plan I work within such abstractions, but when it comes to weaving the resulting patterns I am free to work beyond the constraints set out in the code. In this case, I introduce additional constraints in the form of colour patterning not represented in the code at all.

For my next edit to the pattern, I introduced the transformation `every 3 shift` to the existing code, so that every third row was offset by one thread in the warp direction.[7] This transformation resulted in a lift plan which I decided would not be interesting or even possible to weave – the floats in the warp direction were too long. Rather than alter this transformation I added an additional transformation on top of it – `every 2 invert`, which created an interesting-looking lift plan of tessellated, rotated 'L's:

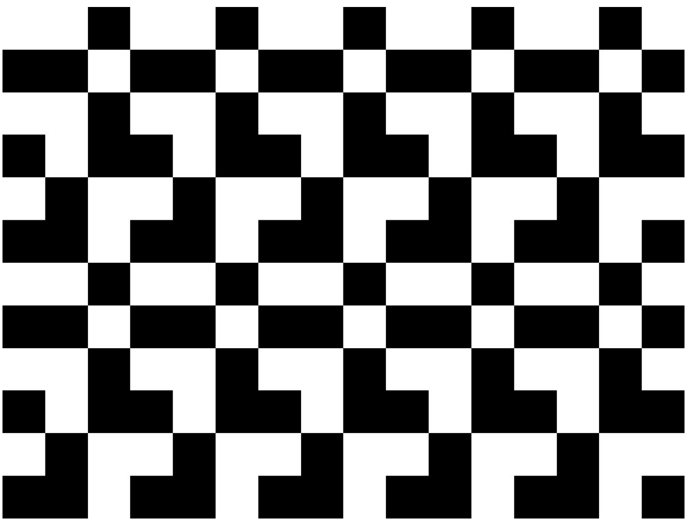


FIG. 12.8

However, when it came to following this lift plan, I had unexpected problems. The wefts would not behave in a uniform way and it took some time to begin to understand why. The results shown in figures 12.5 c) and 12.6

c) felt like a mess, without clear patterning as seen in the above lift plan. The source of my confoundment was in the pairs of sheds forming each row of tessellated 'L's. Where one row adds 'up' warps, but does *not* add any 'down' warp (or vice-versa), the previous weft is lifted up with (or left behind by) the warps. Indeed, this is how double weave is created, where wefts are lifted or left behind in order to weave on separate layers. If I returned to this pattern to weave it again, I would likely be able to produce a more consistent result, having realised that I need to pack one weft behind the other, rather than trying to work them into a clear sequence. Watching the video recording of me working, you can see where I try to pull the shed apart in order to pack the wefts in, but this does not work for double weave – they need to be 'beaten in' with a weaver's 'sword'.[8]

I continued the fabric the following day, and with a new piece of code, this time combining two patterns into one. In particular combining the repeating cycle 'down, up, up' with the repeating cycle 'up, down', using a logical 'and' operation. The code and the resulting lift plan are shown below.

```
zipAnd (cycle [up, down]) (cycle [down, up, up])
```

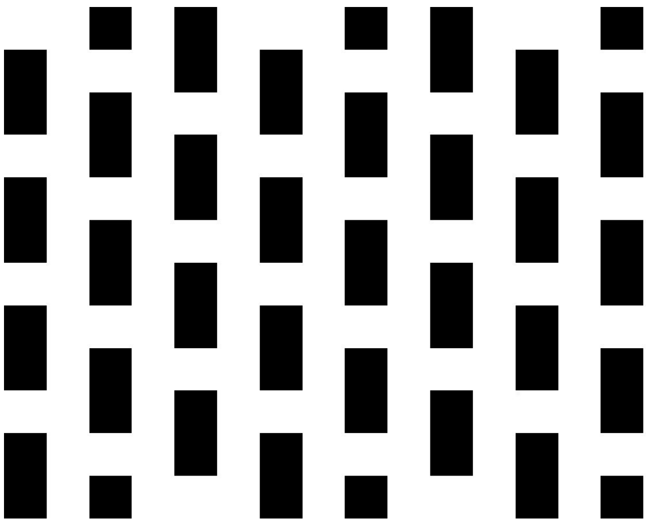


FIG. 12.9

Because these repeating sequences have differing lengths of two and three steps, the resulting repeat is the common multiple of six steps. Taking 'up' for true and 'down' for false, we then combine the sequences 'false, true, true, false, true, true' with 'true, false, true, false, true, false'. The logical 'and' returns true only for those steps which are true in both sequences, giving 'false, false, true, false, true, false'. This might seem an arcane way to produce such a short sequence of six binary values, but its usefulness is in its generative nature. Once the code is written, we can modify, add and remove elements to quickly explore a very wide range of possibilities.

Unfortunately, the lift plan resulting from this code is hardly weaveable – every other warp is not integrated into the weave, or in other words those warps float completely under the weave. So, I added an *every 2* to the logical 'and' operation *zipAnd*. This means that the 'down up up' sequence is only combined with the 'up down' sequence every other shed, and is otherwise left as a simple three-step sequence:

```
every 2 (zipAnd (cycle [up, down])) (cycle [down, up, up])
```

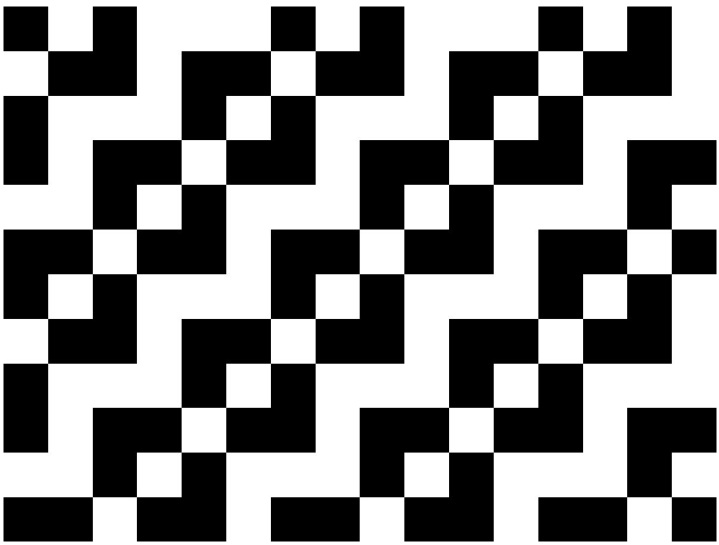


FIG. 12.10

This lift plan has an interesting diagonal twill-like structure, but after weaving 10 wefts with my usual alternating colours I did not feel inspired by the results (see figures 12.5 d) and 12.6 d)), so I looked for a more interesting pattern. I settled on adding an additional *rev* instruction, so that the *every 2* now reverses every other row, rather than operating on the logical *zipAnd* operation, which now applies to *all* the wefts.

```
every 2 rev (zipAnd (cycle [up, down]) (cycle [down, up, up]))
```

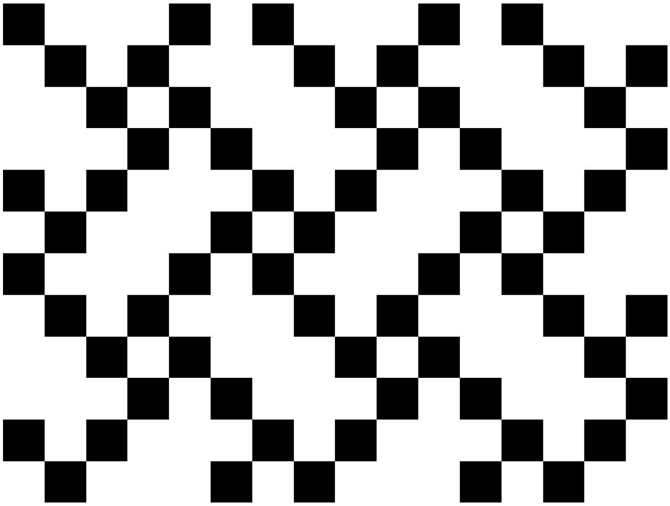


FIG. 12.11

This new `every 2 rev` code actually performs exactly the same transformation as `backforth`, just expressed in a different way, with different opportunities for being changed. The resulting lift plan resembles a diagonal brickwork-like structure, and although I persisted with it for 24 wefts this time, looking for an interesting repeat to emerge, I was still left feeling that the lift plan looked more interesting than the woven results (see figures 12.5 e) and 12.6 e)).

Finally, I made one more edit in place of the `every 2 rev`, trying a few different functions and numbers before settling on `every 3 inv`, i.e., swapping the 'ups' and 'downs' for every third weft. The result was a lift plan pattern of tessellated '+' figures.

```
every 2 rev (zipAnd (cycle [up, down]) (cycle [down, up, up]))
```

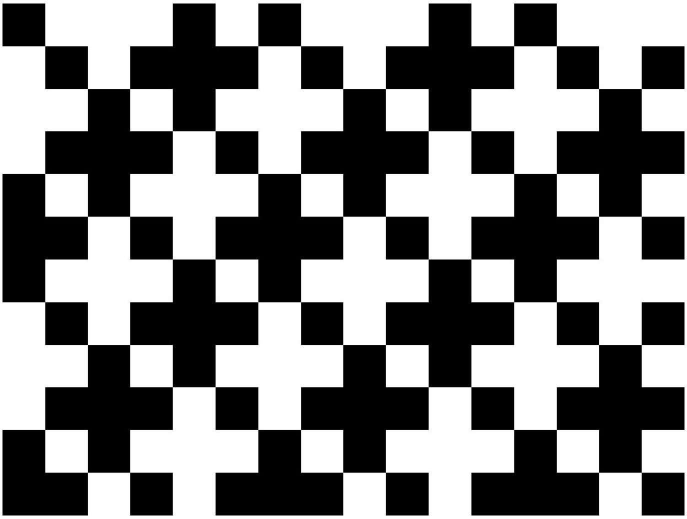


FIG. 12.12

As with my earlier experience with the unanticipated double weave effect, the wefts were again unruly, but this time in a more interesting way. This weave has floats running in both the warp and weft direction. These interact on the back face of the weave seen in figure 12.5 f, resulting in wefts which seem to run diagonally across the textile, defying the rules of the weave (where wefts can only run perpendicular to the warp). This is partly due to the warp occluding the weft, with the visual result that the paths of different wefts are joined through gestalt perception, creating the illusion of a continuous diagonal path. It was fascinating to see this interaction emerge over 26 wefts. Still, I felt the need to finish this unruly section with four tidier rows of plain weave, which I picked by hand, bypassing the code and solenoids.

Through the process of weaving the above, I move between code, lift plan and weave, building a mental model of the working threads, including double weave. From this I am able to adjust my way of working to match the mental model I built, in order to eventually produce better results. This is the process of building tacit knowledge, which (aside from the process of writing this chapter) is not written down, despite growing through interaction with live code.

DIGITAL BLINDSPOT

Colour and weave effects are an example of a computational procedure in weaving that arises from the combination of discrete, patterned elements into a more complex whole. Once we recognise this computational nature of weaving, we must also recognise that traditional weaving is a digital artform. This is, however, at odds with the usual narrative around digital arts. Normally, digital art is described as a recent development, which Christiane Paul (2003), for example, introduces as a culture of practice that grew in the 1990s, noting that the first digital computer (the ENIAC) was constructed in 1946, with theoretical foundations laid earlier. But this short-term view of digital art breaks down on close examination – digital technology is any which deals with discrete, countable elements. There are many examples of such technologies, from the abacus to the loom, which predate the ENIAC by thousands of years (McLean, Harlizius-Klück, and Griffiths 2018).

It seems, then, that the twentieth-century automation of computation through mechanical and electronic means has produced a deeply problematic blindspot. This blindspot confuses our understanding of digital art and algorithmic patterns in general. Thanks to industrial automation, we now think of computers as being separate from ourselves, whereas beforehand computing was something that humans did; indeed, a computer was a job title, often filled by women (Hicks, Aspray, and Misa 2017). The same blindspot is seen in weaving; much is made of Babbage and Lovelace's references to weaving in the design of their mechanical computer via the industrial Jacquard device, but long before the Jacquard device was attached to looms handweaving was already a computational art, just one performed by humans not machines. Indeed, we could only automate weaving by simplifying it, in the process severing the historical connection between humans and algorithms. This severing is the cause of the blindspot; where historical context is lost, digital art seems like it is new, but is impoverished without its original grounding in craft.

The live loom aims to confront this blindspot by eschewing mechanical automation in order to expose the hands-on creativity of both programming and weaving, and bring them together in a single system for exploring algorithmic patterns. It includes aspects which we more conventionally think of in terms of computing, a programming language with a software user interface. But truly, the handweaving loom interface and process is just as computational as the software interface and process.

ENCODING DOUBLE WEAVE

So far, I have explored colour-and-weave and double weave structures through naive improvisation; these structures seem magical when first encountered. Before concluding, I would like to have a closer look in order to try to understand what is really going on. Let's start with the following chart, to think about the possibilities offered by alternating colours of weft and warp threads:

```
  x o x o x o x o
x X ? X ? X ? X ?
o ? O ? O ? O ? O
x X ? X ? X ? X ?
o ? O ? O ? O ? O
x X ? X ? X ? X ?
o ? O ? O ? O ? O
x X ? X ? X ? X ?
o ? O ? O ? O ? O
```

The lowercase **x** and **o** represent the two colours alternating for the warp and weft, and the central grid shows X for crossing points which always have colour **x** on top, O where colour **o** is always on top, and ? where it depends whether the weft is over or under. This reveals a clear constraint to the motifs that may be woven using alternating warp and weft colours, revealing a grid of possibly connected points. Looking at the structure, we see a grid of X s, diagonally offset from a grid of O s. This reminds me also of double-weave, where two layers of plain weave may be produced from a simple two-dimensional pattern, one diagonally offset from the other. From this, I realised that a double weave structure with alternating thread colours should result in differently coloured layers.

To test my naive thought, I did some weaving on the Live Loom, using the following code:

```
every 2 invert (offset 1 (intersperse down (cycle [up, down])))
```

FIG. 12.13

That worked pretty well! After weaving it for a while, I wanted to try swapping the two layers. After a bit more thought, I tried simply swapping all the 'ups' with 'downs', by adding an `invert` instruction to the code:

```
invert $ every 2 invert $ offset 1 $ intersperse down $ cycle
[up, down]
```

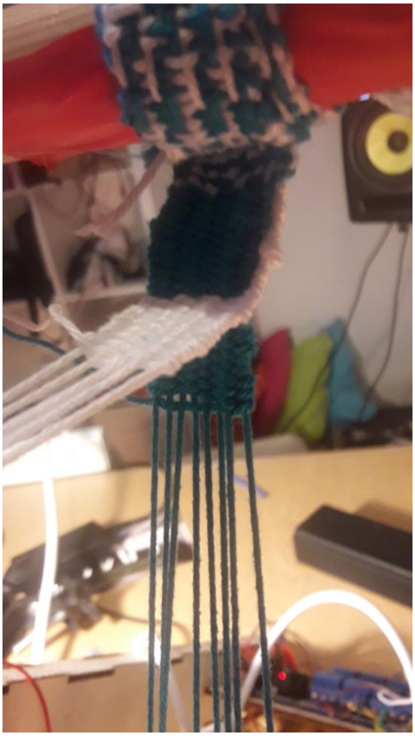


FIG. 12.14

I had some problems with my fabric unweaving, but with some adjustments, this worked very well, with the bottom layer passing perfectly through the other to become the top layer. There are no knots involved here; this is one fabric passing through the other.

Turning to the literature to try to understand this better, I came across the following from Bauhaus artist Anni Albers:

> Double weaves have a special nimbus about them for reasons not clear to me. They are thought to be intricate, hard to grasp, open only to advanced students. To my mind they are simple to understand and can be handled by anyone with just common sense – which, I admit, sometimes seems rare (Anni Albers 2017: 17).

As someone struggling to comprehend double weave, I was a little taken aback by this thought, that a structure that seems somewhat mystical for me, could be considered simple. Perhaps this is the problem with coming at weaving from the naive perspective of computer science. When looking at a binary grid it is too easy to think about weaving in two dimensional terms, and it is only at the loom that the three-dimensional interactions of weaving become simple, through embodied understanding. When dealing with such ancient technologies, much humility is required on the part of computer scientists.

Still, there is something about the code I wrote to make the double weave. Here is the lift plan created by the code:

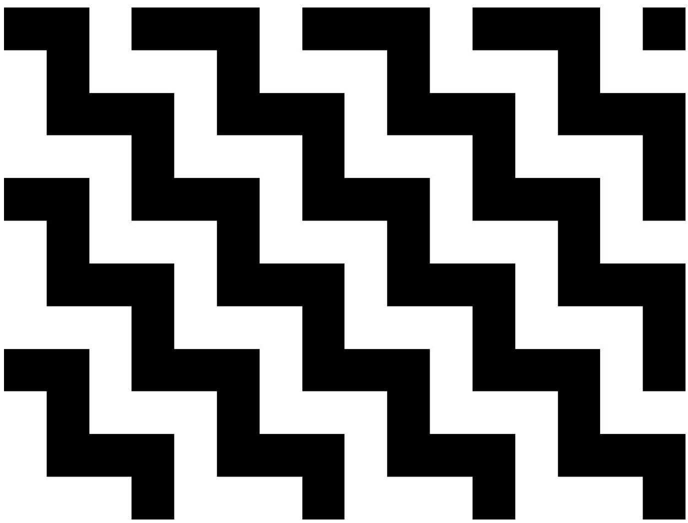


FIG. 12.15

As a naive weaver, the above structure does not, to my naive eyes, say anything about how weaving it produces two separate layers of fabric. But then I realised that the *code* does! Reading it backwards:

```
every 2 invert (offset 1 (intersperse down (cycle [up, down])))
```

`cycle [up, down]` – this is the structure that each layer ends up with – the simple repeated (cycled) up-and-down (also known as over-and-under) steps of the plain weave

`intersperse down` – this puts an additional 'down' between each step, 'making room' for the extra layer

`offset 1` – this progressively offsets each row by one step, which provides the diagonal movement in the structure. This does two things – it alternates between the upper and lower layer on the warps, and also creates the single warp offset of the plain weave

`every 2 invert` – every other row, this swaps the ups with downs, in effect alternating between the upper and lower layer on the wefts.

I find this really interesting. I wrote this line of code with an entirely practical task in mind – to produce the above binary grid of the weave structure in the clearest way I could think of.

In so doing, I've ended up with an abstract, linguistic description of the woven structure, which actually opens a window for understanding the three-dimensional, woven results.

What's also interesting is that, now I have better understood double weave, it allows me a new way of *perceiving* colour-and-weave effects. I can now imagine two layers of textile, which interweave to produce the effect. This is not of course the one true way of seeing these effects, rather one of many. But still, gaining this embodied, conceptual understanding through weaving has altered the way I perceive the world, a little bit.

CONCLUSION

In conclusion, we look back to history. What is the historical precedent for bringing together live coding in the exploration of woven algorithmic patterns? The notion of algorithmic pattern as a symbolic transformation carried out during the process of making, seems to be firmly rooted in textiles. Indeed, knitting patterns routinely contain computational operations such as logical branching and looping, with weaving drawdowns offering alternative approaches to computation based on matrix multiplication and thread-based binary logic. However, the extent to which weaving drawdowns and knitting patterns are used as tools of thought is unclear. The more visible purpose of these notations is mass communication (commercial printing and distribution of knitting patterns) or, relatedly, mass production (control of industrial looms).

The problem is that you do not need a notation in order to knit or to weave; experienced craftspeople work through memory, and by 'feel' or tacit knowledge. Indeed, ethnomathematics began as a field exploring mathematics in craft cultures that do not have a system of writing. Even if many experienced contemporary knitters and weavers make notes while designing something new, these ad-hoc notations are not for sharing but for thinking with, and so will rarely be preserved alongside the final, singular textile piece. A further reason for not preserving a notation is that, in a sense, a textile is its own notation. The structure of some textiles is much more difficult to observe than others, but where it is visible, a craftsperson can follow the threads, and in the context of their craft knowledge, 'reverse engineer' the pattern used to make them. So like the live code of the Live Loom, these pattern notations are for thinking and generally not for recording.

So while it is important to recognise that algorithmic pattern builds on ancient technology, we should also recognise what contemporary computers bring to it. By thinking with notation while it is being automatically interpreted by a computer, we are able to work with it as a live meta-material, even while physical material is being produced by that live interpretation. The design of computer programming languages for creative use is about making notations that are formal enough to be interpreted by a computer, yet flexible enough to support human expression. The software industry has been led by the strong commercial motivations of effortless mass production offered by digital media, but what we are concerned with here is not reproducibility, but the less well appreciated affordance of code as a medium for thinking through craft.

Ursula Franklin (1999) takes a historical view of technology, drawing a clear distinction between holistic technologies in craft, and prescriptive technologies in large-scale production. A handweaver is able to make decisions as they weave, in response to what they have already woven. On a production line (and Franklin gives historical examples such as ancient vase making, as well as in modern day industry), a culture of compliance is required, as individual contributions must be carefully prescribed in order to fit together in the end. This is the difference between 'growth' as a commercial imperative (potentially leading to unregulated 'overgrowth' and ultimately environmental destruction), and 'growth' as a means to follow an idea to a unique outcome. Algorithms then have a very different part to play in holistic rather than prescriptive technologies. In prescriptive technologies, the breaking down of making processes into formalised tasks is necessary for automation and mass production of quality-assured identical artefacts. In holistic technologies, algorithms instead allow us to respond to artefacts as they emerge, by working with the structures of making.

ENDNOTES

1 Something is discrete when it is countable in clear units.

2 There are also 'narrative quipus' with a different structure, and these are even less understood than the numerical ones.

3 Here we assume that the warp threads are visible in the resulting textile; this is not the case in what are called weft-faced weaves.

4 Alternatively, they might select and use a different weft, for example one of a different colour.

5 Note that if I had been weaving with a single weft, I would have had problems. A single weft would not be fixed at the edges of the fabric between two identical sheds; the first pass of the weft would be undone by the second one.

6 https://computinged.wordpress.com/2012/05/24/defining-what-does-it-mean-to-understand-computing/.

7 Looking back at this session, I realise that there was a bug in the 'shift' operation, where the final warp on the right is not shifted. This causes some corruption in the pattern at the selvedge on the right-hand side, although this does not impact the rest of the weave.

8 At the scale of the Live Loom, I use a 'lollipop stick' for such a sword.

REFERENCES

Albers, A., *On Weaving* (Princeton, NJ: Princeton University Press, 2017).

Babbitt, B., D. Lyles and R. Eglash, 'From Ethnomathematics to Ethnocomputing: Indigenous Algorithms in Traditional Context & Contemporary Simulation', in S. Mukhopadhyay and W.-M. Roth, eds, *Alternative Forms of Knowing (in) Mathematics* (Rotterdam: Sense Publishers, 2012), pp. 205–19. https://doi.org/10.1007/978-94-6091-921-3_10.

Blackwell, A., E. Cocker, G. Cox, A. McLean, and T. Magnusson, *Live Coding: A User's Manual* (MIT Press, 2022). https://doi.org/10.5281/zenodo.7383848.

Franklin, U., *The Real World of Technology*, 2nd edition (Toronto: House of Anansi, 1999).

Grünbaum, B., and G. C. Shephard, 'Isonemal Fabrics', *The American Mathematical Monthly*, 95.1 (1988): 5–30. https://doi.org/10.1080/00029890.1988.11971960.

Hall, T., 'Towards a Slow Code Manifesto', Blog. ludions, 1 April 2007. http://www.ludions.com/texts/2007a/.

Harlizius-Klück, E., 'Weaving as Binary Art and the Algebra of Patterns', *TEXTILE*, 15.2 (2017): 176–97. https://doi.org/10.1080/14759756.2017.1298239.

Harlizius-Klück, E., 'Adas Traum, oder: Die Weberei als algorithmische Wissenskultur', in U. Hashagen and R. Seising, eds, *Algorithmische Wissenskulturen* (New York: Springer 2025).

Hicks, M., W. Aspray, and T. J. Misa, *Programmed Inequality: How Britain Discarded Women Technologists and Lost Its Edge in Computing* (Cambridge, MA: MIT Press, 2017).

Mclean, A., 'Algorithmic Pattern', *Proceedings of the International Conference on New Interfaces for Musical Expression* (Birmingham, UK, 2020): 265–70. https://zenodo.org/record/4813352.

McLean, A., E. Harlizius-Klück, and D. Griffiths, 'Digital Art: A Long History', Porto, Portugal, 2018. https://doi.org/10.5281/zenodo.2556604.

Menabrea, L. F., *Sketch of the Analytical Engine Invented by Charles Babbage, with Notes by the Translator Ada Lovelace.* R. & J. E. Taylor, 1843.

Paul, C., *Digital Art* (London; New York: Thames & Hudson Ltd, 2003).

13

EMBODYING PATTERNS OF TEXTILE MACHINERY: A DIALOGUE

Caroline Radcliffe and Alex McLean

INTRODUCTION

THE FOLLOWING IS AN EDITED TRANSCRIPTION OF A DISCUSSION BETWEEN Caroline Radcliffe and Alex McLean, where the former is interviewed by the latter. Caroline and Alex have quite different backgrounds in performance practice and research: Caroline is a musician, theatre maker and clog dancer, and Alex writes code to make live music as a 'live coder'.[1] There are correspondences, however, with Caroline's clog dancing relating closely to the technology of the Industrial Revolution, and Alex's coding relating to the technology of the information revolution. The following particularly relates to Caroline's work, 'The Machinery', a multi-media performance based on a traditional dance from Lancashire, which she learned from Pat Tracey, that incorporates the movements and sounds of industrial cotton mills. In collaboration with Sarah Angliss, Caroline has aligned this dance with the equivalent modern-day setting of the call centre (Radcliffe and Angliss 2012). Approaching nine minutes, this piece centres on Caroline's clog dancing, with a focus on the repetitive, clattering movements of her feet, backed by a projection mixing footage of industrial machines with contemporary call centres and performed to the sounds of cotton machinery from Quarry Bank mill in Styal, Cheshire. For the fullest picture,

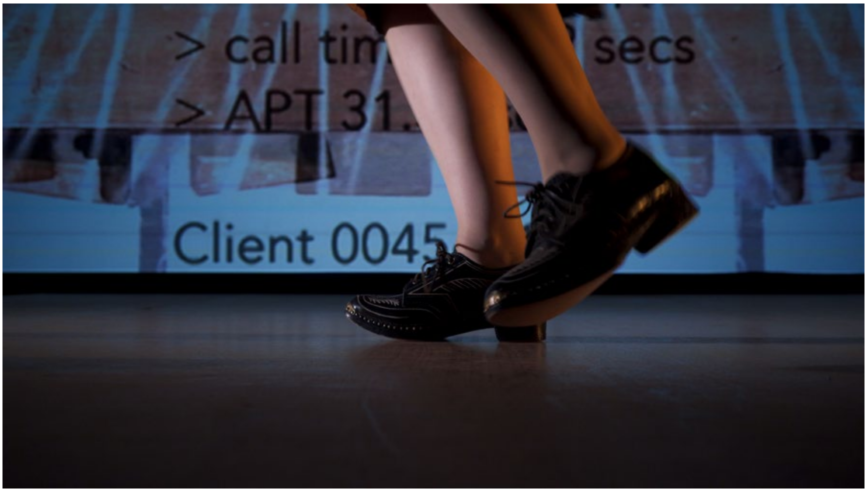


FIG. 13.1 Still from Caroline Radcliffe and Sarah Angliss' rendition of 'The Machinery', where repetitive clog dancing mimics the movements and sounds of industrial machines (photo and video by Jon Harrison in 2018)

the reader is encouraged to watch video documentation of one of Angliss and Radcliffe's performances of the machinery.[2]

INTERVIEW

The following interview took place over video conferencing during May 2020, with Caroline Radcliffe in Birmingham, UK and Alex McLean in Sheffield, UK, during the first coronavirus lockdown. It begins with reflections on their prior shared interest in making screen-based works, and how these works were reframed by their ongoing experience of COVID-19 restrictions, and wider cultural movements towards alienation.

COVID-19 AND ALIENATION

CAROLINE RADCLIFFE: With the coronavirus pandemic in mind, I've been thinking again about Marx's theories of alienation which had really framed mine and Sarah Angliss' piece 'The Machinery'. There is ongoing discussion about how working from home during the lockdown has affected labour, and it got me thinking about the transition from artisan weaving to the textile factories – the process that Ellen Harlizius-Klück describes in her article on weaving and the Jacquard loom (Harlizius-Klück 2017). I looked at the most recent film of 'The Machinery', an immersive installation work which Sarah and I made with filmmaker Jon Harrison. All of our planned work for this installation has fallen through this year, as it has for most other artists, and I was thinking, how can I not look at it now in the light of everything having to go on screen – every meeting and everything that I'm doing now being on screen – and not only on one screen? In the past I have written a great deal about Victorian drama and the windowed effect of what are called 'compartmental scenes', and how they mirror the computer windowed screen. That just seems to be even more present now, in everything that we're doing. So I watched 'The Machinery' again and in the light of what the entire art world is having to adapt to now, it seemed like this horrible premonition! I think it will completely change the meaning of the piece – one of the things that was really interesting when it was shown for the first time as an immersive installation (at Ironbridge Gorge Museums in 2018), were people's responses and emotions to the piece. Their reactions were very individual, they really applied it to their experiences of either the workplace, or how they felt in terms of their social relations with other people, how they felt about art, how they felt about movement – we got so many different responses.

As soon as I watched 'The Machinery' again in the light of this crisis, it took on a completely clear (to me) articulation of what Marx talks about when he discusses the fourth version of alienation, which is to cut the worker off from

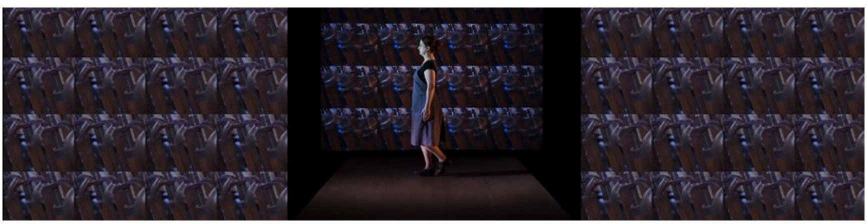


FIG. 13.2 Still from 'The Machinery' as a three-channel video installation, with Caroline Radcliffe performing the clog dance surrounded by repeated and mirrored screens-within-screens, representing repetition in labour (photo and video by Jon Harrison in 2018)

society. He talks about that being the ultimate aim of capitalism, anticipating the current neoliberal agenda to disempower the worker. In education and particularly in universities there's a lot of fear at the moment about everything going online now. Will the worker no longer be needed face to face? Does it mean that we lose even more agency over the work we produce? All these questions were all being asked by Marx in terms of valorisation; he says that once the worker is alienated, and the agency is taken away from the worker, that's when they lose the feeling of creativity that otherwise enables the human spirit to engage with work.

In her article on the Weaving Codes/Coding Weaves project, Emma Cocker challenges this, talking about how 'privileging efficiency and optimization can delimit creative possibilities, reducing the potential of human intervention and invention in the seizing of opportunity, accident, chance and contingency' (Cocker 2017: 124). So following this I stick by what I said in my original article about 'The Machinery'. It's a provocation, a challenge to Marx's statement that capitalism will destroy creativity, that capitalism will subsume the worker and alienate them, and that their life becomes meaningless. This clog dance shows that the human spirit can overcome adversity through creativity. 'The Machinery' is a really good example of how people do find creative ways to address these attempts to alienate them in the workplace. This seems particularly pertinent when I revisited the piece. It's all repeated screens, and the call centre worker is on her own, in little boxes looking at lots of other call centre workers.

I think the other significance about this piece which I hadn't fully realised, was the fact that I took it away from the group, Camden Clog, who it was initially choreographed for. So initially Pat Tracey[3] had choreographed it for six of us, and so we were machine components working together – we moved in patterns, in and out, and you got much more of the topography of the actual textile machines. If you were to look at it from above you could see those patterns working backwards and forwards, like the weft of the loom, with the six of us. I took it away from that to become an individual piece, in order to make it about alienation. I think if I was making it now, for the first time, in response to this coronavirus lockdown, it would have had to have been on my own, and I'd probably have done it on screen, with lots of versions of me – which is actually what we already did! This is what Jon and me and Sarah did with it when we filmed it in 2018. So I think that when people finally see it they'll think that it was made in response to COVID-19. Actually, one of the things I was thinking at the start of this lockdown is 'God, I hope I don't have to watch loads of theatre about isolation!' Then I watched my own piece, and it is entirely about isolation! Now I wonder whether, when we finally manage to tour it, people might actually really not want to watch it…

. . .

ALEX MCLEAN: I guess people will be hungry for what they've been missing, but it's hard to know what's going to happen isn't it? It's all up in the air.

CAROLINE: The significance about the piece is that it does seem to be timeless – we originally made it in 2007, and it just keeps popping back, creating different meanings for different people. It seems to adapt to political and global circumstances every time. So I enjoyed reading Ellen's article about how weaving went so much further back, and the ideas that are inherent in weaving don't really change – even when you bring them up to computer programmed coding and stuff.

ALEX: This makes me reflect on my own live coding practice, which is obviously very screen based as well! Of course, everyone has been staring at screens for the last few years, their phones and computers. Actually I've started using the Skype call jingle music in my performances. The Skype music is annoying because it doesn't loop properly – the steady beat jars when it loops. So it's quite nice to remix it, to take that away so it's actually got a steady rhythm. This calls back to 'The Machinery' really, taking something which has bad associations like Skype… I guess like a lot of things around the office, Skype has found its way into family life, so now we use Skype to talk to our family and friends… But still, there's something about having to be hyper-present and always online, even though you're not in the workplace… and in retrospect it's interesting that I've started working that into my music.

WORK IN THE HOME

CAROLINE: Well the thing you mention about the family – Marx also talks about that in the context of alienation. He says that during the Industrial Revolution, women and children got taken from the home and everyone moved into the workplace. They then had to start commodifying everything within the home, in order to get that hidden labour complete. I think it's Feuerbach who talks about the family as being this ideal relationship, so that the home and the family become the thing that you escape to, and they become the thing that replaces the kind of misery. I was thinking of that in relation to how, at the moment, people are rediscovering family values through this isolation; they're going back to doing things as a family, and back to nature, which Marx also foresees – he says we have to be connected to nature, and that when you lose that, you lose the human spirit. So I do think that the whole thing can be explained in terms of capitalism, and I think some workplaces will take advantage of this, in trying to outsource work to the home so that people get even more confused about these boundaries.

ALEX: Maybe that's things going back to how people were producing in the home, for example doing artisan weaving in the home. This is something that my colleague Annapurna Mamidipudi is working on – trying to come up with a certification for artisan weaving. So instead of Fairtrade, the idea is that if you buy something like a sari, and know that that was made in someone's home… and that their systems of knowledge around handmade/homemade weaving is respected… So I suppose moving away from the 'presenteeism' of being in the workplace, and working at home… There could be a nice side to that I think.

CAROLINE: I think there is, but I think in Marx's terms it's about whether or not you have ownership of your products – the idea of valorisation is whether you still have the creative input. If Annapurna achieves some kind of authentication, the question is whether we take this as being something that valorises creative work, or whether you're just doing it for somebody who will take it away, and doesn't see the end product, or the profit from it. So it has to be something that you still have control of – that's the thing that will stop you becoming alienated as a worker … it's that you're still invested in the work that you're doing, you're not just producing a commodity for somebody else.

OWNERSHIP OF ALGORITHMS

ALEX: Yes, I enjoy the message of your work that there's always resistance – whether it's electronic musicians in Detroit coming up with Techno, or clog dancers working in Lancashire mills coming up with a similar kind of noise music before that. Both are political responses to mechanisation which celebrate human creativity.

CAROLINE: Yes, I think it also creates that ownership that we were just talking about – when the machines replace what you were previously doing manually, then you still have ownership of those machines by appropriating them, and by imitating them with your body – by embodying them.

ALEX: Yes. Tim Ingold puts it this way, '… at the same time that narratives of use are converted by technology into algorithmic structures, these structures are themselves put to use within the ongoing activities of inhabitants, and through the stories of this use they are reincorporated into the field of effective action, within which all life is lived' (Ingold 2011: 62). It's this response to things being formalised and automated. But then somehow we respond by inhabiting it in some way, creating another layer on top. I was thinking about this in terms of this ongoing push to get kids to understand algorithms, the 'get kids coding' movement. Is this about giving them power or not? The book 'Data Feminism' has a nice table comparing concepts on one side which obscure power, with concepts that challenge power (D'Ignazio and Klein 2020). You'd think by helping a child understand algorithms, that would give them power, but actually it's like putting a child in a mill, really! It doesn't give them power over the machine, the machine has power over them. They're just fitting into a predefined framework about what an algorithm is, defined in terms of control structures. So we say that Facebook has algorithms that control what we talk about, and

AI is an algorithm that tells us what music to listen to. But if you actually put it in historical and cultural context, that allows you to challenge power, because you understand the history of the algorithm, and how our relationships with algorithms aren't inevitable – that we can actually define them ourselves and bring them into culture in a way that's meaningful.

ALGORITHMIC TRADITION

CAROLINE: I think that's why trans-historical work is so interesting, and is the reason why we didn't make 'The Machinery' a direct reconstruction of the nineteenth-century dance. Although I work in historical performance practice, Sarah and I deliberately didn't want it to be that. We wanted it to feel contemporary, we wanted to create a piece that was timeless that could be read both within its historic cultural meaning and a contemporary meaning. I think that's worked, because its history brings new meaning to its current position when people view it.

The table in the *Data Feminism* book notes that 'by acknowledging structural power we can work towards dismantling of it' – how do you think that would work with dancing in a nightclub, or in a school? Like you have done with live coding, pre-pandemic, I was about to go into schools with 'The Machinery', we were going to create noise music there. We were working with some students from the Argent College (run by the Ruskin Mill Trust), who do silver-smithing, jewellery making, gardening. We were going to use their tools to create music, and try to do something similar to what Sarah and I had done with 'The Machinery'.

ALEX: I think anything that puts an algorithmic structure in a historical context of textile or a musical pattern is going to give children the idea that algorithms are about patterns, and about procedures, and this is something humans have always done – it's not something that was invented in the last 50 years. It is good to also make clear that this is something that they develop by themselves – they can come up with new ways of making music. They can start with some noises, look for patterns, build things up, and start making their own traditions. I think anything that gives children the idea that nothing is fixed, that a different future can be imagined, is positive right now.

CAROLINE: This reminds me of Malke Rosenfeld teaching maths through dance – that no choreography was the same. Even though she'd only used a small set of patterns, you know, as with musical notation, it will never be the same – she found that every single mathematical combination made by the children was different, so it became something really original.

TRADITION, OWNERSHIP AND NOTATION

ALEX: This is a tension in 'The Machinery' I think. Because it is a particular dance that you've been taught, and you've also been told not to teach anyone else! So it has an identity with Pat Tracey, it's something that she's choreographed. But it's also something that's come from her ancestors, who have worked in the mills. So it's something that has been passed down, but it's also something that's fixed. But then you've changed it! So there's all kinds of tensions – you share it openly just by dancing, but not teaching it. But then you're giving talks about it, and are writing about it. There's an interesting balancing act that you have here, between respecting a composition that comes with certain constraints about what you can do with it, and also celebrating or getting across the idea of a tradition that can change. So what would be the next step for 'The Machinery', if in some way it's something which is fixed, how can the tradition continue for you, do you think?

CAROLINE: Well I think this is something that's really inherent in popular culture, and particularly popular culture that's passed on through the vernacular, that isn't written down. One of the most important elements about clog dancing was what they called originality. Clog dancing was often done in competitions, at fairs or music halls or whatever – similar to the breakdance and hip-hop battles of today. You had different categories for judging, so it might be how many beats you did, or missed, and timing – whether you were rhythmic. But then there was the category of originality. So it's given that clog dances will always change – the nature of popular culture is that it will always develop. If clog dancing stops developing, it becomes something else, it becomes a kind of museum piece that's no longer part of that evolution. So I would question the whole idea of tradition, in the way writers such as Hobsbawm have written about the invention of tradition (Hobsbawm 2012). I think, well okay, that was Pat's dance, and she created that choreography, and each dancer has a few dances where they say, this is my dance and nobody can copy it. That comes from that competition mentality that clog dancers had, because it was so much about the skill of being able to create more interesting, more original, or more technically complex steps. In fact, when she taught us she would often change things, and we'd say 'Oh but you told us it was like that last week.' 'Did I? Oh well, it's like this.' So there was a constant flux, so it was fluid, it was constantly moving. Even now, when it's written down, when it's notated, it often differs from the way we were taught. There'll be a very slight variant and it doesn't matter, because that's the nature of it. We're not trying to preserve it in amber, it's something that has to develop. So Pat knew that when she said that she didn't mind me doing the dance as a performance piece. I was very wary because I knew that she felt very strongly it was not only her dance, but a Camden Clog dance (our clog group that I danced with). We were the only ones that could perform it. She said, well okay, yes you can do this, this sounds good. But she said, 'Don't teach it, don't teach it.' So I said I wouldn't, but this is tricky now because people have started filming it. It will obviously never be the way that Pat danced it because I'm not Pat. Actually, I missed out a step, and I can't remember whether I did that deliberately or whether I'd just forgotten.

NOTATION AND MEMORY

CAROLINE: Today, because I was thinking about what you'd asked me to consider, I looked up the notation that she'd given me and that's all I've got – so that's it, that's the whole dance *(shows AM a list of steps and numbers)*

ALEX: Notations are often there just to jog your memory, aren't they?

CAROLINE: Well that one certainly is because unless you knew the basic elements of those steps, there's no way anybody could replicate that, the only people who could translate that would be Camden – the clog group –or myself. Whereas these are her most complete notations… *(shows AM a more detailed version of step notation).*

ALEX: Wow that's really interesting, and so I guess this is quite particular to her, this style.

CAROLINE: Yes, but again, if you didn't know her style, there's no way you could translate that really is there? When I take that to my group I say, 'Look it's really easy, it's written down, here it is.' And they say, 'I find it really difficult to understand', and I say 'But it's simple, look, it's left, right, tap.'

ALEX: Yes! I suppose they're just like way-markers, these little things, they're just to help you remember.

CAROLINE: Another example of clog notation is Newcastle notation; it was made by somebody who wanted it to be really readable. He created a much more complex system so that you got more nuance about things like the angle of the foot. Maybe because I don't dance that particular clog style I find it totally incomprehensible – as have others I've met. So I think really there has to be an element of … what's the words when you pass it down, when you relay?

ALEX: Oral culture is how you described it in your talk at the HOMO TEXTOR conference, but it's also tacit knowledge I think, knowledge that you can't write down. That's something that's come up a lot in our PENELOPE project – how to value and understand knowledge that can't be written down. During my PhD I got very interested in Scottish bagpipe notation, Canntaireachd, where you can 'speak' the bagpipes in the same way you can speak drums. But once you write that down as words you lose the rhythm, so it's very much a vocal tradition. If you read out those clog instructions to do the steps, there'd be information in the intonation and the rhythm of the way that you're describing the steps, I'm sure, that wouldn't translate to the written page. But we're so used to writing as a form of transcription now, especially Western staff notation.

ARTISAN VS ARTIST, VISIBLE KNOWLEDGE

CAROLINE: Another interesting thing that came up through the HOMO TEXTOR conference was this idea of the artisan versus the artist. I've just been reading Diderot's *Encyclopédie*, where he talks about what the artisan is, and what the artist is. Actually he dismisses the role of the artisan because, he says, it comes down to the idea of 'technê' (which kept coming up in the conference), this idea of technical skill and repeated skill. Diderot said, basically, that that's just repetition – it's not artistic because there's no thinking behind it.[4] Artisans were subservient to rules for the pursuit of profit, that there was a lack of education, and that it was done through habit. Artisans don't require intelligence. So that's really the distinction he makes, and that we now suffer from – artists have genius and intelligence, and artisans don't – they're literally just users of tools (Diderot and d'Alembert 2017). I mention this because you said that we're so used to notating everything. A lot of what I study is to do with popular culture, and not the written word, not the text. So I think that popular culture is still persistently invalidated because it hasn't ever been written down, actually you can't write it down. The notation is something that becomes just part of an 'insider knowledge', isn't it? People talk about insider and outsider knowledge. If you're a member of Camden Clog you're an insider, and you can read this notation. If you're an outsider you can't. So Diderot doesn't take into account this idea of insider knowledge, which certainly, in terms of something like dancing or Canntaireachd, is embodied knowledge. You may not be able to write it down or articulate it, but your body's articulating it.

ALEX: The interesting thing with Canntaireachd is that it *has* been written down, but then it's useless once the practice has died, because only the words have been written, and not how they are articulated.

CAROLINE: Which is exactly the same for clog notation. Complete notation of mechanisation vs incomplete notation as waymarkers in embodied knowledge.

ALEX: Yes, my Mum wanted to make a jumper for my son, so I sent her a pattern that I downloaded and she just couldn't understand it. She couldn't go to the local knitting circle due to COVID-19. So she's had to email the creators of the pattern to try and work out how to do it. They've been very helpful, it was a pattern I paid for. But the problem is that the pattern is American, and so there's all kinds of embodied knowledge. The pattern on its own isn't useful because you don't know the language behind it – you don't know the bodily movements you have to do. You need the knowledge in your fingers. But then when it comes to mechanisation, things change. Because that notation of the weaving pattern is then complete. When you punch those holes in the cards that are fed into the Jacquard device, that's exactly what the machine does – it just reproduces the notation. There's nothing extra.

CAROLINE: That's different from what we were talking about, about whether 'The Machinery' would change – in that it won't evolve, that punch card. That's not going to evolve or change. Whereas with 'The Machinery', I've recently seen Camden dancing it, and it's very different to how Pat did it. But then they would never claim it was exactly the same, because it never can be, you know, we're not Pat!

ALEX: But I think people don't recognise that once you mechanise, once you reproduce notation… Like, you must have heard MIDI files where you transcribe some music onto a computer, and then play it back. There's no articulation or interpretation, it's just reproducing the notes and it sounds very mechanistic and empty of life.

CAROLINE: But that goes back to ideas about the dualism between mind and body. I'm thinking about doing a project about Descartes and music. In the seventeenth and eighteenth centuries there was a whole movement of musical instruments that were regarded as mechanical. So you had the hurdy gurdy, the bagpipe, the organ, the harpsichord… They were really a kind of pre-Enlightenment recognition of dualism – between the emotional instruments which came from breathing – like the flute, or the violin where you could alter the bow – emotional instruments that expressed thought and feeling, and then you had the mechanical instruments. So they were thinking about mechanisation – how much emotion can it convey and whether it can convey the anima or the soul, or expressiveness… whether you can convey it through a mechanical instrument. It's interesting that they were trying to link those with things like electricity, even at that time, like the electrical harpsichord which they wrote about in the eighteenth century.

MECHANICAL MOVEMENT AND LABOUR

ALEX: I think it's different for mechanised music and for mechanised weaving though. Because on the hurdy gurdy you still have the expression through how you turn the handle. With weaving it's completely automated by a machine, and people look at it and think that's all that weaving is. But there's so much missing – it's treating weaving as a two-dimensional structure when it is a three-dimensional one, and artisan weavers have so many techniques which a Jacquard machine isn't able to do. A machine loom isn't even able to weave the edges of textile, so it just cuts them off. There's all kinds of weird three-dimensional things you can do on a hand loom that you can't do on a machine loom. But when you look at machine looms, you think that's all weaving is, and then you see a human weaver work, and these structures are invisible to you, so you just see the repetitive labour, and you just see the human weaver as being a kind of machine themselves. So the aim of the PENELOPE project I suppose, is to bring out and make visible the tacit knowledge and understanding that a hand weaver has.

In music, like with Techno, it's very mechanised, it's made by a sequencer. But still there's movement in it in how the effects are controlled, and the music is shaped to do that. Also when you are listening to it, you're not just listening, it's a very active listening where you're actually dancing, or at least thinking about dancing to it. It's the kind of music you dance to for hours on end, in the dark.

CAROLINE: Yes and with clog dancing, you've got a whole dimension that will never be written down, things like volume, crescendos and diminuendos, emphasis of beats. You can't possibly get any of that from the notation. You can really differentiate between a dancer who dances 'heavily', where all the beats are the same, or somebody who brings out the integral rhythm of the piece.

ALEX: Yes it's almost as if the notation just gives you the ground, and the actual figure is the movement – this kind of shaping of the building of anticipation, the crescendos. But that all comes through the interpretation of the notation. I mean, the similarity between the results of the clogging you do and Techno is really really striking. With the kind of noise music aspect that you're taking something industrial, working within that mechanical repetition, and creating something astonishing. To me it's just exactly the same process as Techno.

CAROLINE: I worked a bit with a Kathak dancer in Leeds (Jyoti Manral), and she said that the roots of Kathak came via Spain from flamenco. We found once she put clogs on it seemed like a clog dance. It was so similar – Kathak is very percussive. She said that flamenco in turn came from blacksmithing and ironwork. It's another dance form that comes out of labour. Flamenco imitates the percussive noise of that labour. There are all sorts of similar examples.

ANALOGUE VS DIGITAL

CAROLINE: One thing I wanted to ask you, because I also read your paper about 'what is digital', and it makes me realise how ignorant I am, because not only do I not know what the Jacquard loom really did, but I realised I didn't know what digital really means either (McLean, Harlizius-Klück, and Griffiths 2018). I was interested in this idea of it being basically binary. Not just something that's computed. I wonder if you see anything digital – apart from algorithms – is there something digital about 'The Machinery' that you can identify, or not.

ALEX: Yes definitely. I think digital is a word with an increasingly confused meaning. There's no clear definition, unless you take it down to first principles, and talk about digital being the opposite of analogue, where analogue is a smooth shape – like that crescendo you were talking about – and the digital is like an impulse, a kind of discontinuity like a clog dance move. So I think there is digital and analogue in everything. In music it's clear that digital just means discrete notes or discrete steps, and analogue means a smooth flow, such as the overall shape of a piece. So the digital is the points – the notation – and the analogue is how you move between the points. You can think about Western classical music as generally focusing on the notes, whereas for example certain practices in Indian classical music focus on the movement between the notes. For me that's the difference between digital or analogue.

ALGORITHMIC PATTERN

ALEX: I've become really interested in all kinds of patterns – I associate digital art with pattern, really. I think that's what it's all about. So if you perceive patterns in clog dancing, which I'm sure you do, then there's definitely some interesting work to be done in codifying that pattern, in code. I think once you codify this, you get to work with the structure in an interesting way. So once you write down the notation in a way that encodes the repetitions, like when you notate music you just write out the notes, but when you write out the patterns, like with my knitting pattern that I'm following at the moment (which I just bought in a craft shop) it has things like, repeat this eight times, but only if you're making it for a particular size, and so on. That's where you're kind of taking repetitions, and describing the repetition rather than just writing out the notes over and over again. You might then say on the fourth repetition, do something else instead. That's when you're starting to work with patterns on the level of composition. Once you're doing that, not to just notate a pattern but actually create a new one, I think that gives you a lot of possibilities because you're not working with individual steps or individual notes, you're working with lots of notes at the same time. So you get further away from the actual steps, but you sort of shift up on this upper level where you're working with the patterns. That's where I like to work, describing music in terms of pattern.

POWERS OF TWO AND ANTICIPATION

CAROLINE: Folk music and clog dances are very limited to groups of eight, aren't they? Like 8 bars, 16 bars, 32 bars. Many of them, such as Hornpipes and Reels, are in 4/4 and the steps generally break down into groups of 16 or 32s or 64, both within each bar and in the overall musical structure.

ALEX: That's really good for the audience, because they can anticipate when there's going to be a change.

CAROLINE: Yes it's very formulaic, you'd never vary from that unless you were some amazing contemporary clog dancer who breaks with every single convention, which, at some point, let's hope somebody does. You will always stick within that kind of 8 bar / 16 / 32 pattern. I'm not sure why, other than it's traditional and conventional, and that somebody like Steve Reich hasn't written for clogs. But there's no reason why you shouldn't break with that pattern, the only variation you get on that is triplets. But they still break down to 12s and 24s and 36s. So in terms of numbers, it will always be two, four, eight, sixteen, always.

ALEX: Yes, it's all about powers of two, isn't it? It's the same with the kind of music I make in general, you have to make a change after that eight or sixteenth, or 32nd repetition otherwise the music will just sound stale. Suddenly the repetition loses its magic. I think it's about anticipation – you're anticipating that change, and everything's moving towards that change, and if it doesn't happen.

CAROLINE: But why do you think it always divides into eight, sixteen, thirty-two? Because you know Quantz in the eighteenth century talks about basic beats as adhering to your heartbeat, which around that time was about sixty per minute. That all locks into all the ideas about time, the way it's all related to tides, and all that stuff. But you know often when you listen to music it's 60, or 120 bpm. I'm thinking, how does that relate to this 8, 16, 32 that's so prevalent within clog dance steps.

ALEX: I don't know, it's strange for me because when I was growing up I had an obsessive-compulsion to do everything in groups of four. Like if I touched something, I'd do it four times, or sixteen times.

CAROLINE: So you're a born clog dancer!

ALEX: It's something I really didn't like at the time, and it's not something I would talk to anyone about. It was a kind of this obsession which I felt I had to do, but I didn't know why – it was pretty horrible. But then after a while I just embraced it really, through listening to Techno music, which is always in these powers of two. It's not something that worries me anymore. But yes, it does feel like an obsession.

METRICAL STRUCTURE

CAROLINE: When you were talking earlier about it being an innate, felt, embodied knowledge, that is the way that I remember dances. You know when it's going to go into the next step because you've got that innate sense of what eight bars feel like. I know when the next step will come. I've got an appalling memory, but obviously a lot of it is from motor memory, from repetition, from learning the steps over and over and over again until they're fixed, until you are just remembering the movement. But what I'm listening out for is that change of eight bars. I'm not counting the bars, I just know when it happens.

So it's really important that we have an AABB structure – it will always be AABBAABB, always, you can feel it, you know when it's going to change. Our version of 'The Machinery' doesn't comply with an identifiable AABB structure because we created the composition from cotton machinery noises rather than using the traditional reel that Pat liked (Far From Home), which is perhaps why I find our version harder to dance.

ALEX: When you look into Indian classical music, there's a lot more variety in the metrical structure, with much longer form. But they have different ways of counting things out, and still being aware of a metrical structure or tala. They still know when the next start of the next cycle is starting, the next *sam* they call it, because they clap it out. When they're listening they're moving their hands to feel the metre.

CAROLINE: They do that with Irish dance as well which is really similar to clog dance, because it's step dancing. A lot of the steps that I do were brought over from Irish workers. In the potato famine they came over and worked in Liverpool and Lancashire. So one of the dances I do is the Lancashire Irish, which is a mix of Irish step-dancing and Lancashire clog dancing. But they do have a hand system.

MOUTH MUSIC AND WORKSONG

CAROLINE: Did you ever see that YouTube phenomenon that was a man and a woman (Suzanne Cleary and Peter Harding) doing this amazing Irish hand dancing? Kathak dancers and Indian musicians do a similar rhythmic speaking, what's it called?

ALEX: Konnakol or Bol syllables?

CAROLINE: Yes, when they count out rhythms, tabla players, they speak first, and then they play it. That's an Irish (lilting and diddling) and Scottish (*Puirt à beul*) tradition as well, There's a whole language. I don't know whether Lancashire clog dancers do it.

ALEX: Yes I read a thesis about non-lexical syllables (Chambers 1980), mainly about Canntaireachd, and other ways of using syllables to represent sounds. It's very interesting, and I suppose connecting back to weaving, it seems like a lot of this practice might come from worksong, not just from the mills but from people working in their homes and singing songs that help them remember the patterns that they're following. I saw a short film directed by Mehdi Aminian, of Iranian craftspeople making rugs and singing to each other, to communicate which threads they're picking and so on (Aminian 2019).

CAROLINE: I saw a video of Scottish weavers singing as they beat the cloth (waulking songs). There are loads of women's work songs associated with textile making. I tried to find written examples of clog dancing within the mills. I think what I need to do is go to actual mill archives, and see if there are any references to disciplinary action because someone was caught clog dancing while they were working or something! There isn't anything in general histories of mills. I did find a reference to psalm singing. A lot of those towns were very Methodist, and there seems to be a tradition of women singing Psalms very loudly over the noise of the machines while they worked. So that's the idea of what Marx talks about, about that need for social interaction and communication with other people in the workplace. That's a way that they can overcome the repetition and the dehumanisation of machine labour – by doing a communal activity like that. I think it's not just machines, but even just knitting, doing a complicated pattern is difficult work, and you have to do it over and over and over again. So even for artisan crafts, you still need to make music out of it to help the memory, but also stop yourself from just going crazy with the repetition of it.

ENDNOTES

1 See e.g., Collins, McLean, Rohrhuber, and Ward 2003.
2 A recording of a 2016 staging of 'The Machinery' at AlgoMech festival in Sheffield (organised by McLean) is available online: https://www.youtube.com/watch?v=pGEUhjWGQ2I.
3 Pat Tracey (1927–2008) was the clog dancer who taught Caroline Radcliffe the steps for 'The Machinery'.
4 'In drawing the difference between *artiste* and artisan, Diderot emphasised whether the art they practised required intelligence or not. There were arts that demanded only repetitive actions, while others benefited from 'genius', defined by an anonymous contributor to the *Encyclopédie* as "the fire and invention" that *artistes* put in their work' (Bertucci (2017: 9; with reference to *Encyclopédie* 7: 584).

REFERENCES

Aminian, M., '"The Woven Sounds": Demo documentary by Mehdi Aminian on pattern singing-Persian carpets', https://www.youtube.com/watch?v=vhgHJ6xiau8 [accessed 30 October 2023].

Bertucci, P., *Artisanal Enlightenment: Science and the Mechanical Arts in Old Regime France* (New Haven and London: Yale University Press, 2017).

Chambers, C., 'Non-Lexical Vocables in Scottish Traditional Music', (PhD Thesis, University of Edinburgh, 1980.

Cocker, E., 'Weaving Codes/Coding Weaves: Penelopean Mêtis and the Weaver-Coder's Kairos', *TEXTILE*, 15.2 (2017): 124–41. https://doi.org/10.1080/14759756.2017.1298233.

Collins, N., A. McLean, J. Rohrhuber, and A. Ward, 'Live Coding in Laptop Performance' *Organised Sound*, 8.3 (2003): 321–30. https://doi.org/10.1017/s135577180300030x.

Diderot, D. and J. d'Alembert, eds, *Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des metiers,* R. Morrissey and G. Roe, eds., University of Chicago: ARTFL Encyclopédie Project (Autumn 2017 Edition), http://encyclopedie.uchicago.edu/.

D'Ignazio, C. and L. F. Klein, *Data Feminism* (Cambridge, Massachusetts: MIT Press, 2020).

Harlizius-Klück, E., 'Weaving as Binary Art and the Algebra of Patterns', *TEXTILE,* 15.2 (2017): 176–96.

Hobsbawm, E., ed., *The Invention of Tradition*. Reissue edition (Cambridge Cambridgeshire: Cambridge University Press, 2012).

Ingold, T., *Being Alive: Essays on Movement, Knowledge and Description* (London and New York: Routledge, 2011).

McLean, A., 'Making Programming Languages to Dance to: Live Coding with Tidal', *Proceedings of the 2nd ACM SIGPLAN International Workshop on Functional Art, Music, Modelling and Design* (Gothenburg: ACM, 2014): 63–70. https://doi.org/10.1145/2633638.2633647.

McLean, A., E. Harlizius-Klück, and D. Griffiths, 'Digital Art: A Long History', 4th International Conference on Live Interfaces (ICLI 2018) (Porto, Portugal, 2018): 71–77. http://doi.org/10.5281/zenodo.2556604

Radcliffe, C., and S. Angliss, 'Revolution: Challenging the Automaton: Repetitive Labour and Dance in the Industrial Workspace', *Performance Research,* 17.6 (2012): 40–47. https://doi.org/10.1080/13528165.2013.775758.

14

BRAIDING AND DANCING: EMBODIED RHYTHM AND THE MATTER OF PATTERN

Victoria Mitchell

INTRODUCTION: FROM DANCING HANDS TO ROBOTIC MAYPOLES

FOR THE ANTHROPOLOGIST GREGORY BATESON, ALL ACTIONS WHICH ARE interlocking, directional, ever-changing, active, social and patterned, whether performative or material, are related to an 'almost universal linkage in aesthetics between skill and pattern' (Bateson 1972: 148). Following Bateson, this paper considers the actions, rhythms and patterns of braiding as an intertwining of physical and cognitive systems which pertain to relational interaction, not only between strands of material but also in social and cultural contexts.[1] Braiding is initially identified through the actions of fingers, hands, arms and neuromuscular rhythms in response to materials and cultural outcomes, as evidenced in basketry, textiles and hair styling. The embodied rhythm, patterned actions and 'physiological aesthetics' (Leroi-Gourhan 1993: 296) of braiding also lend themselves to whole-body kinaesthetic articulation, such that a parallel between braiding and dancing can be indicated. Reciprocity is thus established between the manipulation of materials, synchronised motions and social interaction; a 'universal linkage' of pattern and skill are inscribed in the braid, through braiding, and in dance, through dancing. Parallels between people braiding together through dance and fingers dancing as they braid may come to light.

The overt simplicity of braiding belies the hidden complexities of its reach. As Noémi Speiser indicates with reference to textiles, there are many braiding communities, each with techniques varying according to their context. For Jack Lenor Larsen, considering braiding in the context of interlacing, a 'universe of braid forms' can be identified (Larsen 1987: 119) while Heiko Hanmann, investigating emerging technologies for braid, considers its possibilities as 'almost infinite' (Hanmann 2018: 75). For students of the architect Lars Spuybroeck, designing a tower inspired by braiding, 'the simplicity of how braiding is defined might defy the complexity and abundance of its possible applications but it is precisely this vagueness of definition that allows for variation within the system'.[2] Even where the under-over actions of braiding are at their simplest, the effects can be complex. Variations, as articulated by Irene Emery, 'are effected by two basically simple devices: increasing the number of elements employed, and altering the order of the interlacing in one way or another', as in twill braiding. (Emery 1966: 62)

Elaborations as exemplified in hand loop, split-ply and *kumihimo* braiding patterns, together with seemingly unlimited colour combinations, further enrich the technical variation and complexity.[3]

Although a simple braid of three strands is ubiquitous and easily accomplished, proficiency in respect of the interweaving of separate strands into an elaborately ordered whole emerges through practice over time. Skill (from Old Norse *skil* and *skilja*, discernment, reasoning) includes establishing a sense of timing, combining various but often repeated actions with continuity and flow. Entrainment enables self-consciousness and reflection, facilitated by the discriminatory skills which are as much activated through the actions of the body as through the eyes that observe and modify the results. As in many forms of dancing, a succession of synchronised moves, figures, steps or units of action are acquired through trial and error or through imitation. Rush workers, braiding alongside one another, have noticed that the rhythm of their actions sometimes becomes synchronised[4] and Speiser, similarly, emphasises attention in braiding to phases of action that 'blend smoothly into each other' (Speiser 2018 (1988): 16).

The contexts of such fluidity of action might include meditation and religious observance but its sometimes mesmerising effects are also related to the industrial and economic exploitation of the body's ability to braid mechanistically, an unfortunate consequence of skill taken to an unhealthy extreme, as in plaiting for hat production, particularly in the nineteenth century (Robinson 2016).[5] Mind and body become mechanised, as if having a propensity to become robotic. Machine braiding may be an inevitable consequence. Since the nineteenth century, through mechanisation and the use of metals and synthetic materials, braiding techniques have multiplied, thus triaxial and three-dimensional braided fabric structures are now widely used in medical, aerospace and construction contexts, for example. The so-called Maypole braider, with clear reference to maypole and ribbon dance traditions (figures 14.1 and 14.2), is one of the oldest and now most technologically and digitally advanced machines for producing hollow circular braiding. Maypole ribbons become strands which move clockwise or anti-clockwise, alternating to the left or right to create the necessary interlace, with the tension and angle of the strands kept constant so that the pattern remains regular. Watching such a braider in action is uncannily reminiscent of watching the movement of people (as ribbon-holding bobbing bobbins) in a dance.

FIG. 14.1 Maypole dancing at a carnival in Llanfyllin, Wales, 1941; https://en.wikipedia.org/wiki/Maypole#/media/File:Llanfyllin_carnival_and_maypole_(7131389767)

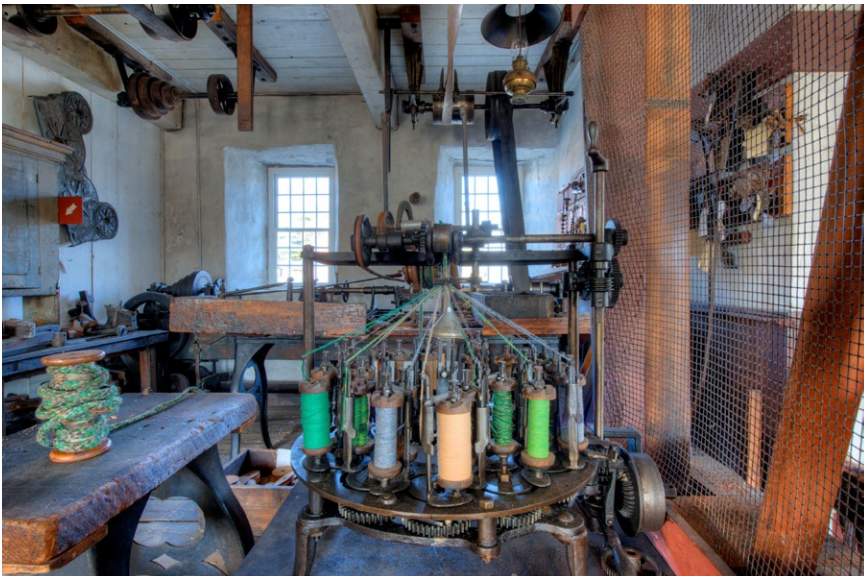


FIG. 14.2 Braiding machine, late nineteenth century, Wilkinson Machine Shop, Rhode Island; https://commons.wikimedia.org/wiki/File:Braiding_machine_in_Wilkinson_Machine_Shop.jpg

Inspired both by hand braiding and the Maypole braider, techniques of braiding have most recently been the subject of investigation by Flora Robotica, an EU-funded project (2015–19) for ‘Future and Emerging Technologies’ in which braid is understood as a ‘universal organizational structure’.[6] Although the Flora Robotica braid research is envisaged in terms of emerging future technology, traditional hand-braiding techniques form a crucial early stage of investigation, (figure 14.3) enabling connections between non-human fibres in plants and synthetic fibres to be cognitively generated and embodied. Having first been explored through manipulation, threads or filaments are then processed via algorithms, sensors, agents (and so on), to become autonomous and self-organising cognitive systems, functioning like artificial (robotically-generated) plants which not only support the biological plants but are in turn supported and controlled by the growth of the plants, such that plants and robots grow together. From simple beginnings braid emerges as having the potential to grow like a plant and to demonstrate discriminating behaviour.

Key advantages of braid in enabling robots and biological organisms to talk

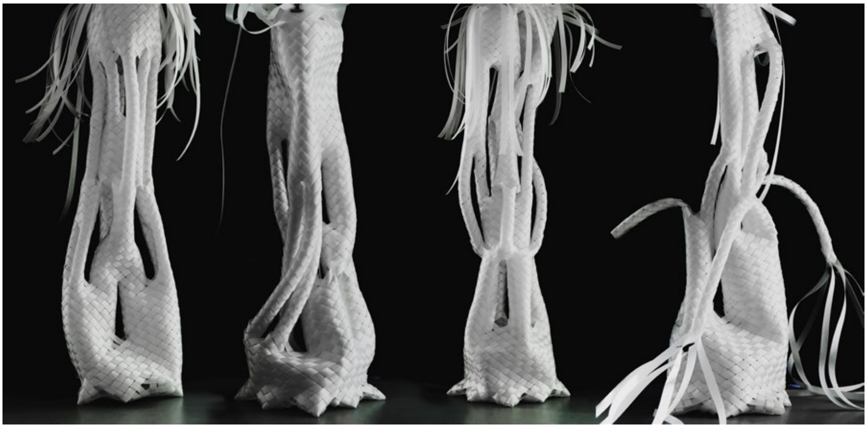


FIG. 14.3 Experiments to explore complexity of braid morphologies; *Flora Robotica*; Courtesy Phil Ayres, Centre for Information Technology and Architecture, The Royal Danish Academy of Fine Arts Schools of Architecture, Design and Conservation

to one another are noted in terms of a combination of flexure and stiffness and an ability to 'rotate at intersections', thus:

> Braid, as a typology, is a group of three or more continuous filaments interlacing so that they are functionally similar and span the length of the braid… The interlacing organization and continuity of filaments allows braided elements to be self-structuring if filaments are sufficiently stiff. Because individual filaments are not mechanically affixed to one another, they are also able to translate and rotate at intersections. They are mechanically flexible, able to contract and elongate without change to organization of filaments, and able to form a variety of complex shapes (Heinrich and others 2016: 154).

In one configuration, exemplifying swarm braiding, Thymio robots perform and form a maypole-type braid, influenced by a traditional maypole dance, in which '[r]obots braid, one strip each by a simple line-following behavior and a collision avoidance behaviour' (Hanmann 2018: 75). Braiding emerges through a reciprocity which enables strands to be held apart while also remaining together.

In 2017 Cathrine Hasse, a Danish anthropologist with an interest in robotic engineering, brought robotics engineers, including those working with Flora Robotica, together with Danish basketmakers, for a seminar on weaving robots and basketry. The objective was to see to what extent basketry skills can inform a shift in robot-making from hard materials to human-friendly soft materials, made for instance, of silicone or other bendable materials, together with wires necessary to conduct current. Hasse notes that '[b]asketry, knitting and weaving are embodied processes which often function without any conscious awareness by the human of all the bodily processes involved. When working with robots, humans have to learn to apply all the intuitive movements and at the same time become aware of their own embodied being by learning from robots' (Hasse and Treusch 2021). In the making of robots as cognitive, embodied systems we are thus led to reflect upon our own subconscious and intuitive braiding-type processes.

FROM HAND MOVEMENTS TO DANCING HANDS

Even within the futuristic ambitions of Flora Robotica, techniques originating in the body are understood as primary and instrumental in understanding the effective generation of braid. The body actively generates braiding motions which in turn generate technique, arguably through a bipedal more-or-less-symmetrical formation of interwoven or intersecting interior physiological structures and operational crossings from one side or one end of the body to the other and through interior-exterior interaction, especially through the hands in their manipulation of material. Techniques are not the preserve of individual bodies, however, but are also distributed within social and cultural contexts. For Marcel Mauss, 'techniques of the body' are coordinated bodily actions, learned or acquired, like those of a craft, so that they form part of a skill set for any given culture. They can be as seemingly innocuous as walking or perhaps more culturally marked, such as in dancing or caring for the body (Mauss 2006: 85–91). The braiding of hair may be one such technique of the body, an act of caring-for-one-another or grooming which has a relational role to play within the development of culture.

Hair is a textile medium, *of* the body at the same time as being an extension to it, which lends itself to braiding, activating the hands and fingers to work as combs, so that 'hair and hands work together' (Tarlo 2016: 149). Long hair, if it is not cared for, easily becomes dishevelled, but it is flexible and directional, easily divided into bundles of strands which can be shaped into an orderly pattern (figure 14.4). This serves not only practical but also aesthetic and symbolic ends. As increasingly suggested by the archaeological record, the patterning of hair braids in prehistoric contexts may be indicative of skill and enhanced status (Tomaž 2017: 355–56; Tassie 2009); in many cultures dishevelled or ungroomed hair (particularly of females) is or was associated with wanton behaviour, whereas braided hair denotes order and propriety (Barber 2014: 23). Perhaps coincidentally, braided hair is often worn by females in traditional social dance contexts; lively movement of the hair requires control and decorative effect is especially valued. In a way that is not dissimilar to loose strands of hair, the warp ends which are left when woven cloth is cut from the loom are sometimes tied and tidied through a braided fringe, thus mitigating against fraying and also adding a decorative element. In considering a crossover between hair braiding and braiding with other materials, an etymological crossover between hair braiding and rope may be indicative; thus the Greek word *trikhia* (τριχιά), meaning rope or tether, is derived from the word for hair *thrix* (θρίξ), with both combined in the Vulgar Latin cognate *trichia*, meaning both braid and rope. In contemporary Italian, braid is *treccia* and in French it is *tresse* (from which English derives 'tresses', to describe hair, especially when it is long).[7] The French word for knitting, *tricot*, is related, and more recently also used in English to describe a form of warp knitting in which the yarn zigzags vertically, following a single column or wale.

The reticulate patterning of braiding actions as formed through the manipulation of appropriate materials is characterised by branching and linking, dividing and uniting, opening and closing, interweaving or interlinking, all together forming a planar surface or a distinctively patterned length (figure 14.5). The quasi-geometrical patterns that typically result appear to be formed of small but dynamically poised squares, although each strand (or bundle of strands) can

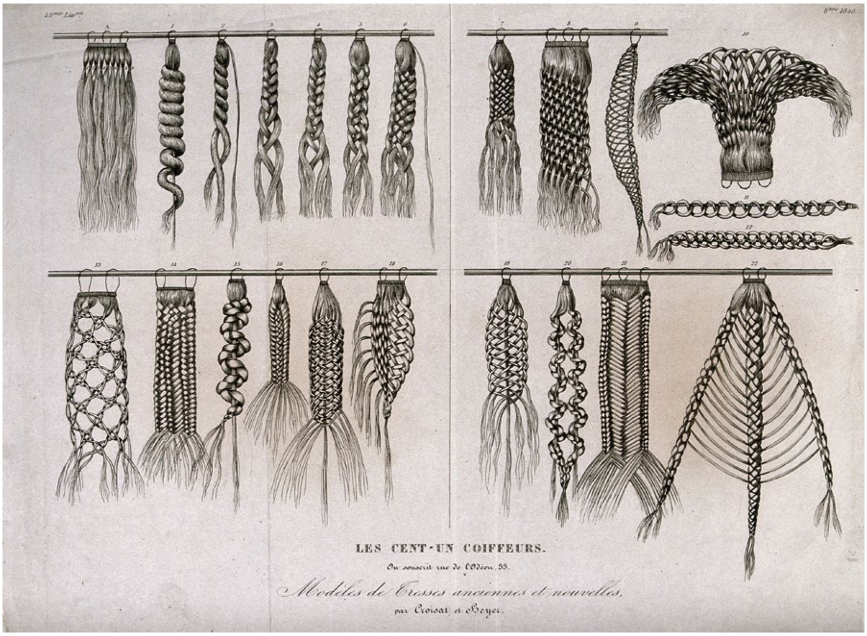


FIG. 14.4 Modèles de Tresses anciennes et nouvelles; twenty-two illustrations showing different plaited hair pieces. Etching. Croisat et Heyer, 1840. Wellcome Collection.

also be followed through with the eye, under and over other strands, criss-crossing and zigzagging from one end or side to the other. Each strand is 'active' in formation of the pattern, and there is typically an equivalence in the ordering of strands, with each strand alternating in being warp or weft as the braiding proceeds. In this 'active' capacity, braiding strands are distinct from the stronger-weaker effect of the fixed warp and active weft such as in weaving on a loom. Directional reciprocity is one of the salient characteristics of the alternating actions; thus, as the braid proceeds, one set of actions follows mimetically from another and the reticulation of the pattern is generated through mirroring, rotation, balance and repetition. Each strand has a role to play in forming an orderly, repeated arrangement. Pattern and skill form interweaving strands of action, as if always in close correspondence and 'in-forming' an intimate network.

The braider's hands are especially significant in this respect. Archaeologist Lambros Malafouris, considering the working processes of potters, remarks that 'their hands often have reasons of which their mind is not aware' (Malafouris 2008: 20). Within traditional textile and basketry contexts a well-made braid

FIG. 14.5 Felicity Irons, braiding with English freshwater bulrush, *scirpus lacustris* (photo courtesy of F. Irons)

depends on artful manipulation, with fingers and hands, separately and together, holding down, lifting, hooking up, tensioning, drawing together, teasing apart or disentangling, twisting, folding, smoothing and ensuring even density; The hands may perhaps also, as in the case of working with plant fibres, add more material of the appropriate dampness, density, pliability or colour. As braiding proceeds, strands are continuously and numerically divided by the fingers and (re)arranged according to the established order of the pattern-in-process. The two hands mirror each other yet are continually shifting, as if in rotation. In Noémi Speiser's explanation 'the distinct movements depend to a certain degree on the proportions of your hands, especially on the relative lengths of index, middle and ring fingers, which are particularly involved in these processes'. All the fingers are employed and 'a lazy finger must not be allowed to rest, it must on the contrary, be trained to participate' (Speiser 2014 (1988): 16).

In loop braiding (also known as finger-loop braiding) the strands are kept under tension by being looped around the fingers (figure 14.6), and sometimes the hands (Boutrop 2012: 52). Effectively, the fingers function as a mobile loom, forming an intrinsic relation with the braid. Globally widespread as well as historically extensive, even considered to be the technique used in an Iron Age braid from the Halstatt salt mine (Grömer, Kania, and Boutrup 2015), such braiding may have been the most common method of production for braided items such as laces during the later Middle Ages and Renaissance, and it was also the means to create *kumihimo* before use of the *Marudai*.[8] Ingrid Crickmore, a contemporary loop braider and historian of the art, describes how her hands and fingers activate the braiding and suggests a parallel to dancing in the way that the two hands interact with one another:

> All the fingers are constantly cooperating and reacting to each other's movements in passing the loops back and forth, without my really feeling that I am consciously controlling each separate movement. Of course, I am broadly in control, but not at the level of telling each finger what to do. It feels as if they all know what the overall goal is, and how to achieve it, and that they enjoy doing it smoothly, efficiently, and rhythmically. The two hands and all the fingers have to constantly cooperate and anticipate each other's movements, like pairs of dancers adjusting to each other, or jugglers throwing balls to each other. . . . The bundle of loops is integral to the hand movements – I am totally unable to reproduce or mime the confluence of movements in the absence of the loops and the resistance of the loop bundle attached to its fixed position.[9]

The hands and fingers might thus be said to be dancing as they work to engage the rhythms as indicated through the succession of actions; Crickmore notes also that braiding while music is playing can provoke an added sense of dance movement for the actions.[10] When two or more people braid together (enabling more loops to be worked) and the vibrancy and rhythm of actions are experienced socially, parallels with dance may be further accentuated. A three-person, seventeenth century, openwork 'Katheren Wheel' braid is even suggestive of processional paths that dancers might have taken at the time.[11]

Other examples of dancing hands have been noted. The braid techniques used by Miao women in Guizhou are described by Jacqui Carey as actions which flow together in a 'rhythmic hand dance' (Carey 2012: 11), while Stephen Lonsdale, discussing hand gestures in the dancing practices of fourth-century

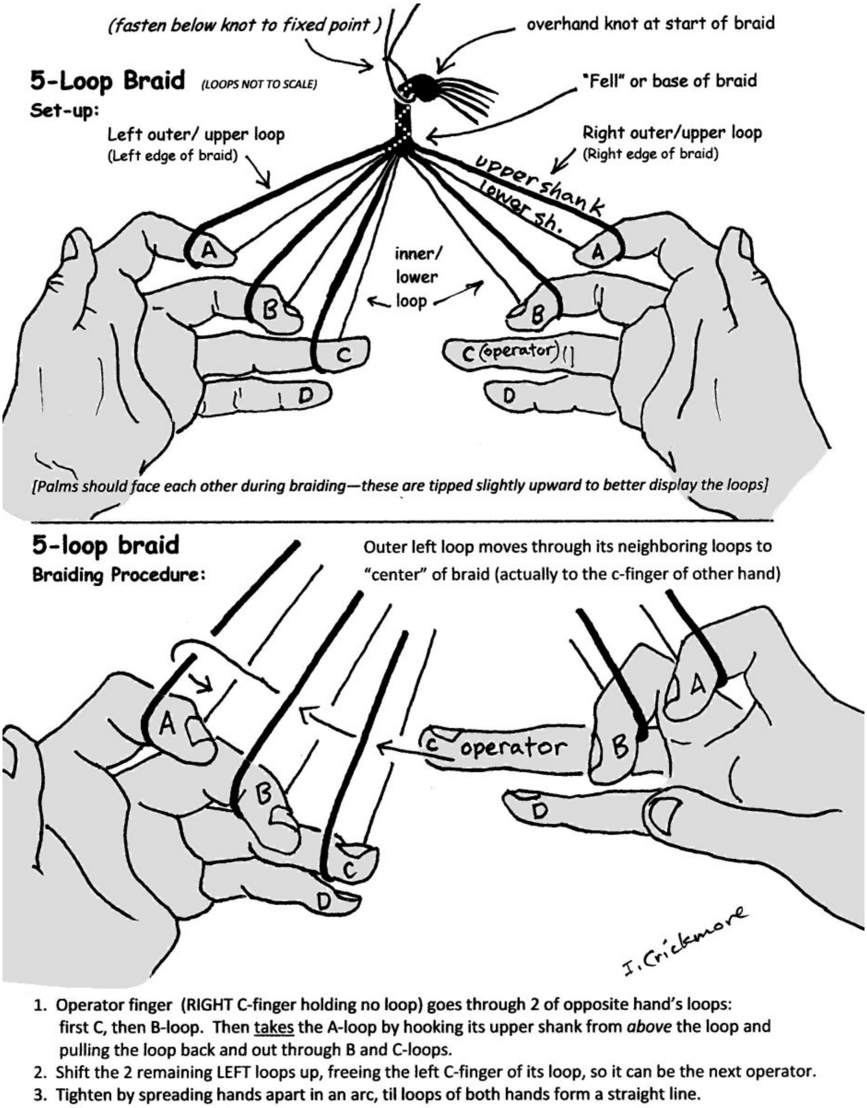


FIG. 14.6 Ingrid Crickmore, diagram to demonstrate the making of a 5-loop braid (Image courtesy of I. Crickmore)

BCE Greece, draws attention to *cheironomia* as denoting 'dancing with the hands', a widespread association at the time (Lonsdale 1993: 30). For the anthropologist Alfred Gell, 'the dancer-like nimbleness of the hands' is not only indicative of 'cognitive linkages' between dancing and drawing in the art of the Trobriand islanders, but 'even more, it indicates the synergy between art forms and modalities of expression which conventional aesthetics tries to deal with separately' (Gell 1998, 94–95).

When the fingers of one hand fit snugly between the fingers of the other hand there is already a suggestion of braided form. As they work to braid with materials, these fingers and hands form a relation with the rest of the body which imparts a sense of rhythm. In her comprehensive archaeological and ethno-archaeological analysis of Egyptian basketry, Willeke Wendrich identifies the 'body as instrument' and, as in Mauss' techniques of the body, she finds that each body depends upon and finds its own rhythm within the social context in which it is embedded (Wendrich 1999: 341–49). Wendrich notes that skilled basket-makers (including those making baskets of plaited coils) adopt 'a very steady working rhythm' dictated by the pattern of the actions, so that each technique results in a different rhythm (Wendrich 1999: 391). It is not just the fingers and the hands that are active, however; rather, it is the whole body that is engaged. The actions of braiding give rise to heightened awareness of bodily rhythm and of the body's capacity for and need to be attuned to rhythmic experience. Dance functions in a parallel way; indeed, Wendrich likens the making of the baskets to a kind of choreography for which the dance is the basket as a whole. It is not until watching the dance as a whole, she concludes 'that the meaning [*of the basket*] can be sensed' (Wendrich 1999: 389–91; Wendrich's italics).

BRAIDING PATTERNS OF THOUGHT

As well as being activated and articulated in the production and construction of a braided length of fibre, braiding's sequential reciprocity parallels an ordering propensity in respect of perception, conception and cognition. As Suzanne Küchler has suggested, patterns are 'good to think with' (Küchler and Were 2005: 172): they both reflect and are formative of patterns of thought. Coherence to the eye and heightened visual perception are conveyed as strands which begin as loose and separate become interlocked in conjunction with one another in a form that imparts and inspires order and coherence. Patterning can be perceived and operate as ontological as well as morphological action. It is something that happens to us *and* that we make happen in forming intelligible connectivity between matter and meaning. From the knowing action of the hands as they work the material(s) an inherently aesthetic length of braid gradually emerges, as if giving shape to the actions.

In theory at least, André Leroi-Gourhan's physiological aesthetics is at work here, as a satisfying operational rhythm effects the formation of an equally satisfying visual rhythm in the pattern that results. Reticulate braided patterns, and the braided lengths themselves, may have been absorbed through visual or tactile experience of something in the environment (such as snakes and their patterned scales) which conjoin with the symmetry and pattern inherent in the evolutionary physiology of the body and enable the articulation and externalisation of the movements and patterns of braiding. A parallel with dancing is clear. Such physiology is as if braided in itself, not only in the interconnectivity of muscles, tendons, joints and nervous system but also through the agency of bilateral symmetry and bipedal evolution. Within this physiological parabraiding, the senses, notably in the kinesthetic relationship between haptic and optic, are especially and acutely active in the coming-into-being of braided form. In return, the formation of the braid activates the coming-into-being of maker, or dancer, and also, through affordance, of the braid's beholder.

This braiding of optic-haptic twists and turns reflects Edmund Husserl's idea of 'intertwining' (*Verflechtung*), which Maurice Merleau-Ponty draws attention to with reference to the optic chiasma or chiasmus. This is the term used to denote the crossing point or intertwining (*entrelacs*) whereby, as if between the flesh of the body and the reflections of the mind, '[t]here is double and crossed situating of the visible in the tangible and of the tangible in the visible' (Merleau-Ponty 1969: 134). The partial crossing of nerve fibres or ligaments at the optic chiasma enables the left cerebral hemisphere to process the right hemispheric vision and vice versa, effecting a 'crucial' (cross-shaped) balance between the two sides of the body as well as between the senses and other cerebral processes. Ted Toedvine notes that chiasma is typically used in relation to anatomical structure whereas chiasmus references rhetoric, as when opposing phrases are used to convey the same thing. Toedvine further remarks that although each word has a distinct etymological root in Greek, *khiasma* and *khiasmos*, they share a common root, *khiazein*, to mark with an χ (*khı-*) (Toadvine 2011: 336). Merleau-Ponty elegantly effaces these differences in his haptic-optic mind-body cross-over, as if marking with a cross (χ) the reciprocity and balancing of the diagonal intertwining and distinctive patterns which are so typical of movements in braiding.

The materials also assume an aspect of the embodied action and reflection. The stuff from which we make objects informs how we operate and the way in which our lives become knowingly structured. Materials carry memory of their having come-into-being (Trewavas 2014: 222, 229) and can be considered as co-respondents in the making process through the mobility, structure and detail of the responses that they generate and stimulate. They are formative of the emerging braid, such that it is as if we are intra-actively both embodied and embraided in and through the intricate and sometimes irregular patterning of the material strands. Lars Spuybroeck has argued that the characteristics of braiding are shaped by the infinitesimal detail which structures both pattern and matter, and that braid is paradigmatic in its contribution to conceptual frameworks within consciousness (Spuybroeck 2016: 92). These characteristics are considered as embedded within materials, with technology 'acting on the inside of matter' and pattern being an effect of the 'self-crafting of matter' (Spuybroeck 2016: 102). Successive crisscrossing, whether of nerve-muscle fibres, material fibres or dancing feet, effects interaction and relational coherence. Patterning and rhythm, as active in braiding, or dancing, are intrinsic to the (bio)morphology of connectivity as it infiltrates tissues of knowing; for physicist Donna Haraway, 'the tissues of one's knowings' extend beyond the human and engage common biological ground, with weaving, string figures and interlacing as especially potent manifestations of the 'relational action' between human and nonhuman fibres and as formations through which kinship and behaviour are sustained (Haraway 2016: 91–93).

In a similar vein, but from the perspective of archaeology, Lambros Malafouris proposes 'a 'hylonoetic' (from the Greek *hyle* for matter and *nous* for mind) ontology of thinking *through* and *with* matter' (Malafouris 2013: 236 Malfouris' italics). In *How Things Shape the Mind* he traces the active or enactive coming-into-being of thought in tandem with the coming-into-being of objects, and while recognising that neural networks and DNA evolution are significant in this process he holds that cultural and environmental factors also affect the way in which brains are formed and thoughts are shaped. Above all, making and engaging with material is formative of cognition rather than a reflection of it, providing 'a scaffolding device that enabled human perception gradually to become aware of itself', enabling humans to think about thinking (Malafouris 2013: 204). Within a now well-established discourse detailing the embodiment of the cognitive apparatus,[12] Spuybroeck and Malafouris both emphasise ways in which knowing emerges through engagement with materials, thus considering materials as a primary conduit for the consequent forms. For braiding, therefore, pattern formation reflects and exhibits a continuously active and emergent phenomenon that is as much internally formed as it is externally fashioned.

DANCING AS BRAIDING

Braid and braiding carry notions of side-to-side movement but also an implied sense of conjoining, confluence and bringing together. Dancing can be paralleled, especially in effecting the mesmerising tempo of experienced braiding. Dances often convey or mimic movements associated with repetitive activities, as sometimes reflected in the names by which they are known. In the Orcadian 'Strip the Willow' line dance, for example, the movement conveys a loose figuring of willow being stripped while also enabling the turning-and-interlinking-with-one-another passage of the leading couple as they 'strip' along the lines from head to foot (or tip to butt) to the rhythm of musical accompaniment.

Establishing a conducive rhythm is fundamental to proficient braiding, and the origins of the English word braid indicate that rhythmic movement is intrinsic to its meaning. Rooted in the proto-Germanic **bregdanan* from which Old English and Old Saxon *bregdan*, middle English *breiden*, then braid, evolved, the term indicates darting, jerky, zigzag movements from side to side or off to one side (as in brandishing a sword), movements so nimble as to be associated with a cunning sleight of hand. It is not until the sixteenth century that the sense of braiding as a distinctive hither-thither action gives way to textile-related actions; the 'broid' of embroidery, perhaps drawing attention to the in-and-out of a needle, is noted as a borrowing from braid dating from this time. The Oxford English Dictionary also includes a 'transferred' meaning, noted in nineteenth century examples, of braid (v.) 'to 'thread the mazes' of the dance; to cross and recross', and definition of the adjective braided includes 'as a dance' in a figurative sense.

The word braid thus emerges as referring to patterns of movement and exchange which carry a pronounced sense of a vibrant action and which involves centred but sharp twists and/or turns. Perhaps it was in response to the dexterity, virtuoso speed and characteristic criss-crossing of skilled braiders, as outlying strands were turned and interwoven to form a reticular pattern, that the word shifted towards its now familiar use in textile and hair-braiding contexts. Braiding is the preferred nomenclature for this paper (rather than plaiting) in part because zigzagging references the body that produces the pattern as well as the pattern that is produced, whether as braid or dance.

When people interact with one another through dance, sharing the stimulus of rhythmic music, they form movements and patterns in negotiation with one another, as if each moving body is a strand, forming stronger strands through formation with others. Relationships (especially between partners) are articulated and can be fostered, braiding social coherence through the patterns and rhythms, perhaps even entwining as a prelude to 'tying the knot' in marriage. The concept of braiding is thus extended, here, to substantiate the premise that the patterned actions of braiding, whether identified through manipulation, mechanical agency or social dance, constitute an embodied semiosis (Violi 2008: 241–64), formative of individual and social cognition (and of the reciprocity between these). Braid, by this measure, is but a material form of social dancing, with both informed by the harmonious, repeating, criss-crossing, in-and-out, close-fitting togetherness of lines or figures and brought about through well-tuned actions. Elaborations of braided patterning (and the speed with which these can be accomplished) can capture the radiance and variegation (ποικιλία, *poikilía*) discussed by Giovanni Fanfani in the context of ancient Greek weaving and the chorality of song and dance (Fanfani 2018: 9).

We use our whole body to dance, and especially we work with our feet, embodying 'the rhythmic pattern of lived time and space' as Tim Ingold puts it

(Ingold 2004: 332). Through the familiar dynamics of waltzing, for example, Maxine Sheets-Johnstone suggests that the actions 'are woven into our bodies and played out along the lines of our bodies', so that we become attuned to the 'kinesthetic melodies' of bodily coordination (Sheets-Johnstone 2012: 390). The actions thus enable that which is inside the body and that which is exterior to the body to be understood as a continuum. For Sheets-Johnstone,

> [o]ur visual sensing of movement dynamics is grounded in our awareness that our own movement has an inside and an outside, not simply in terms of the fact that it is both personally experienced and publicly visible, but in terms of the fact that, through kinesthesia, we experience directly our ability both to *feel* and to *perceive* our own movement. (Sheets-Johnstone 2012: 396; Sheets-Johnstone's italics)

In Patricia Daugherty's consideration of the production of Turkish-Yörük flat-weaves, the weavers' sense of balancing inside and outside through centering, containing and separating invokes and expresses 'patterns of physical bodily experience' that are also evidenced in their dance (Daugherty 2004: 306). These patterns are reminiscent of braiding, at least in principle; thus one of the most distinctive patterns for the weavers is that of repeated diagonal squares or diamonds forming lines which are seen as separating (*ayirir*) and coming together (*kavuşur*) as they zigzag through the weave (and for which there is always a balancing mirror reflection which is central to their cultural aesthetic). That which is inside the lines is associated with the inside of the body, and the diamond opening which the lines create is considered as an interior-exterior point of entry and exit. Carrying this example over to braiding, the effect of bringing outlying, separate strands into a cohesive geometry reflects the internal workings of the body and its spatial awareness, indicating a form of patterning, also expressed through dance.

Although even the simplest braiding is not exactly mirror-symmetrical, symmetry is nevertheless a characteristic of the process and typical of resulting braids as a form of 'glide reflection' symmetry. Donald W. Crowe provides an image of walking feet (right foot ahead of left foot, left foot ahead of right, either side of a line indicating the centre of the body) to illustrate glide reflection; dancing figures could be substituted with similar effect (Crowe 2004: 6; figure 1.5). The feet also indicate a forward-moving trajectory, paralleling the generative direction of braiding as it extends outwards from the body as a kind of prosthesis. In eighteenth-century notation for dance, as illustrated in Raoul Auger Feuillet's dance notation for a Rigadoon (figure 14.7), lines for foot movements and arm gestures in the manner of braid-like glide reflection are described. The Rigadoon was a fast dance, requiring much practice to grasp the subtleties of movement.

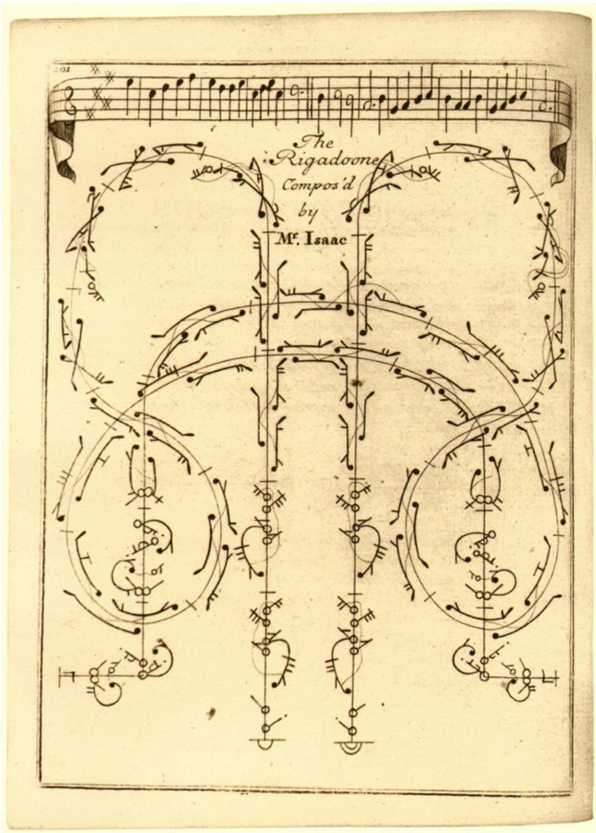


FIG. 14.7 Raoul Auger Feuillet's dance notation for a Rigadoon by Isaac, first published in *Orchesography or the Art of Dancing … an Exact and Just Translation from the French of Monsieur Feuillet*. By John Weaver, Dancing Master. Second edition. London, ca. 1721 (https://upload.wikimedia.org/wikipedia/commons/1/1e/Feuillet_notation.jpg)

Social dances such as country or folk dancing and processional dances such as were common in Renaissance Europe are particularly rich in actions akin to interlacing and braiding. This can be recognised in contemporary descriptions, as in the poem 'A Farewell to Town' of 1577 in which the poet Nicholas Breton evokes braiding through his poetic description of dancing, thus

> And to it then; with set, and turn about,
> Change sides, and cross, and mince it like a hawk;
> Backwards and Forwards, take hands then, in and out; ... (Baskerville 1929: 351)

In the Renaissance processional dance known as the *galliard* there was an enchaînement of five steps (the *cinquepace*) which corresponded to six musical beats; thus in four movements 'the dancer…raises one foot in front of or behind or across the other' then performs a leap (a *petit saulte* or cadence) with the foot that bears the weight, followed by a 'posture' (Baskerville 1929: 341). This was a set of units around which repetition and variation were possible, including more steps, leaps, spins and turns and on occasion the close holding of a partner. The final posture might be likened to the final pulling or easing into shape that ensures that the tension of a just-worked interwoven strand is in keeping with the braid form.

The relationship between process and processional – moving forward and transforming, in and through time – reflects the embodied agencies of making and pattern formation in shaping culture, as well as in shaping the body within social and cultural contexts. There is evidence of braiding not only in the movements of the dancing but also in the forming of social bonds; thus, depending on the social context, a succession of dances might begin with those that were relatively formal and become livelier and more inclusive as a dance event proceeded. Towards the end, the simplicity and familiarity of country dances, in which 'in a word, a group of dancers kaleidoscopically advance[e] and retreat[...], swinging each other about, crossing from one side to the other, moving up or down inside the lines or outside, weaving in and out, passing under an arch of hands…' might provide a fitting finale to an evening's entertainment.[13]

Scottish country dances were generically known as reels, perhaps from the whirling and turning associated with the reeling or unreeling of a spool. In the sixteenth century, 'reel' also had the meaning of a zigzag path, as if in the manner of 'hither and thither'.[14] The reel figure was also associated with a serpentine or 'round' country dance known as the 'hay' or 'heydegues', praised by William Hogarth in his Analysis of Beauty of 1753: 'One of the most pleasing movements in country dancing, and which answers to all the principles of varying at once, is what they call 'the hay': the figure of it, altogether, is a cypher of S's, or a number of serpentine lines interlacing or intervolving one another'.[15] While this raises complexities regarding the softness of a serpentine line of thread or movement in relation to the zigzag line, it's worth noting that 'hay' was also a term used to describe a net for catching fish, thus indicating a more pronounced geometrical reticulation. The 'intervolving' may be serpentine but the cross-over point is angular; the familiar phrase 'figure of eight' not only indicates the shape of the number 8 or describes a knot but also describes a motif in Scottish dancing in which one or more dancers follows the path of a figure of eight, moving around either standing figures or one-another, crossing one another's path and creating a figural, braid-like reticulation through succession. In Scottish dancing a set of repeated movements is known as a figure,[16] a word rooted in the Latin *figura*, meaning a form or shape, which was in turn a translation of the Greek *skhêma*, (σχῆμᾰ, schema), which referred not only to shape and form but also to dance. A 'figure' in dancing, conceived thus as a formation, or a shaping, creates a pattern of movements that are repeated.

For the contemporary British basketry artist Joanna Gilmour, who was a classical ballet dancer before she turned to the making of braided structures, the rhythms and symmetries of movement as experienced in dance are closely paralleled with braiding, as exemplified in practice work at the barre in which exercises on one side of the body would be repeated on the other side, with the body turned around. She suggests that 'maybe legs and feet in dance could be compared to arms and hands in basketry' and that in forming a figure of eight through the interlacing of two lines 'a group of dancers can make a whole, in a similar way that making a basket can bring many elements together'.[17]

CONCLUSION

As with so many textile-related actions, braiding lends itself to extension through association, across and between phenomena. These associations are conveyed as much by the conduit of the body's experience of the actions as by the way in which braid functions in relating one thing to another, as through metaphor, which can itself be perceived as braid-like, bringing together disparate strands of reference into a single concept while still distinguishing one from another. While the parallel between braiding and dancing which is outlined here began as an almost instinctive analogy, albeit with metaphorical reference, it is through attention to the patterned actions and motions of braiding, whether in the making of braids or social dancing, that a more substantial semblance between the two has been identified. As techniques of the body, shaped by patterns (both visible and invisible, external and internal), merge with skill, an element of performativity might be considered as appropriate to both.

Maypole dancing, although not considered in detail in this paper, is perhaps the most obvious example of braiding and social dancing in combination (Mitchell 2020: 250). However, an example such as that of multi-person finger loop braiding, where the strands are intricately manipulated to form detailed patterns, might be seen alongside a dance such as a Rigadoon or a Scottish reel in such a way as to suggest that as well as a close intertwining of braid and dance, there are further significant parallels to be drawn, or crossing points to be identified, the implications of which are instructive.

ENDNOTES

1 The subject of this paper was first outlined at the 2017 *Woven Communities* symposium, University of St. Andrews (UK). I am grateful to Dr Stephanie Bunn for her invitation.

2 Bishop and Neumann in Spuybroeck ed. 2011: 142.

3 Sprang is also sometimes considered in relation to braid (as well as to weave). Elizabeth J. W. Barber cites Elizabeth van Reesma (1926) in describing it as 'plaiting with stretched threads' but also likens it to cat's cradle. Barber 1991: 122.

4 Felicity Irons, *Rush Matters*, Bedfordshire, UK., in conversation with the author, 27.11.2018.

5 As a related example, Caroline Radcliffe, in 'The Machinery – Challenging the Automaton: Creative Resistance and the Nineteenth Century Cotton Worker' given at the HOMO TEXTOR conference, Munich, 2019, performed and described a heel-and-toe type clog dance (discussed also in chapter 13) which she traced back to Lancashire cotton mill machine loom contexts, where the loud and rhythmic sound of the machines provided a kind of musical backing.

6 Heinrich and others 2016: 154. *Flora Robotica* project, https://www.florarobotica.eu.

7 Barber 1991: 136–7. The example here given by Barber (dating from 3000 B.C., from Lüscherz, Switzerland) also incorporates supplementary weft threads. The same example is also discussed in Grömer, Kania, and Boutrup 2015.

8 Nutz 2014: 118; Crickmore, https://loopbraider.com/category/loop-braiding/history/.

9 Crickmore, email correspondence with the author, 22 April 2020. I am very grateful for Ingrid Crickmore's apposite responses, her encouraging consideration of historical examples and for allowing the use of her diagram demonstrating the making of a 5-loop braid (figure 14.4).

10 Crickmore, ibid.

11 Crickmore 2012: 59; Sibthorpe 2016: 234. The dance related suggestion is mine, the *pavane* for example, or the Rigadoon (for which see below, figure 14.5).

12 Varela, Thompson and Rosch 1991; Noland 2009; Malafouris 2013.

13 Baskerville 1929: 371 (with reference to John Playford's *The Dancing Master* of 1651).

14 Emmerson 1972: 151.

15 Hogarth 1753: 150. In the same volume Hogarth also discusses the braiding of hair, 'an artful way of preserving as much of intricacy, as is beautiful', 28–29.

16 Scottish Country Dancing Dictionary (online, n.p).

17 Gilmour 2019, (online, n.p).

REFERENCES

Barber, E. W., *Prehistoric Textiles* (Princeton, New Jersey: Princeton University Press, 1991).

Barber, E. W., *The Dancing Goddesses: Folklore, Archaeology and the Origins of European Dance* (New York: W. W. Norton and Company, 2014).

Barthes, R., *S/Z*. Trans. by Richard Miller (New York: Hill and Wang, 1974).

Baskerville C. R., *The Elizabethan Jig* (Chicago: University of Chicago Press, 1929).

Bateson, G., *Steps to an Ecology of Mind* (Chicago: University of Chicago Press, 1972).

Boivin, N., *Material Cultures, Material Minds* (Cambridge: Cambridge University Press, 2010).

Boutrop, J., 'Loop Manipulation Braiding', in S. Berlin and R. MacGregor, eds, *Threads That Move: Proceedings of the Second International Conference on Braiding* (The Braid Society, 2012), pp. 52–57.

Carey, J., 'Chinese Braid Embroidery', in S. Berlin and R. MacGregor, eds, *Threads That Move: Proceedings of the Second International Conference on Braiding* (The Braid Society, 2012), pp. 7–13.

Crickmore, I., 'Loop Braided "Double Braids"', in S. Berlin and R. MacGregor, eds., *Threads That Move: Proceedings of the Second International Conference on Braiding* (The Braid Society, 2012), pp. 57–71

Crickmore, I., https://loopbraider.com/category/loop-braiding/history/ (accessed 10 May 2020).

Crowe, D. W., 'Introduction to the Plane Symmetries', in D. K. Washburn and D. W. Crowe, eds, *Symmetry Comes of Age* (Seattle: University of Washington Press, 2004), pp. 3–17.

Daugherty, P., 'Cognitive Structures and Body Metaphors in the Aesthetic and Everyday Discourse of Turkish-Yörük Weavers', in D. K. Washburn and D. W. Crowe, eds, *Symmetry Comes of Age* (Seattle: University of Washington Press, 2004), pp. 304–46.

Emmerson, G. S., *A Social History of Scottish Dance* (Montreal: McGill-Queen's University Press, 1972).

Emery, I., *The Primary Structures of Fabrics* (Washington DC: The Textile Museum and Watson Guptill Publications, 1966).

Fanfani, G., 'Craftsmanship and Technology as Chorality: The Case of Weaving Imagery in Archaic and Classical Choral Lyric', *Dionysus ex machina*, IX (2018): 6–40.

Flora Robotica, https://www.florarobotica.eu (accessed 10 December 2019).

Gell, A., *Art and Agency: An Anthropological Theory* (Oxford: Clarendon Press, 1998).

Gerofsky, S., J. Forren, and E. Knoll, 'Dancing Rope and Braid into Being: Whole-Body Learning in Creating Mathematical/ Architectural Structures', *Bridges Conference Proceedings,* 2017. https://archive.bridgesmathart.org/2017/bridges2017-523.pdf (accessed 13 January 2022).

Gilmour, J., 'Symmetries of Movement, Symmetries of Making', extracts from a conversation for *Forces in Translation: Basketry, Maths, Anthropology*. https://forcesintranslation.org/conversation-with-joanna-gilmour/, 2019 (accessed 26 May 2023).

Grömer, K., K. Kania, and J. Boutrup, 'Iron Age Finger-Loop Braiding Finds from the Hallstatt Salt Mine', *Archaeological Textiles Review*, 57 (2015): 39–46.

Hamann, H., *Swarm Robotics: A Formal Approach* (New York: Springer, 2018).

Haraway, D. J., *Staying with the Trouble: Making Kin in the Chthulucene* (Durham: Duke University Press, 2016).

Hasse, C., and P. Treusch, 'Weaving Together: Human-Robot-Relations of Basketry and Knitting', in S. Bunn and V. Mitchell, eds, *The Material Culture of Basketry* (London: Bloomsbury, 2021), pp. 255–63.

Heinrich, M. K., M. Wahby, M. D. Soorati, D. N. Hofstadler, and others, 'Self-Organized Construction with Continuous Building Material: Higher Flexibility Based on Braided Structures', *IEEE 1st International Workshops on Foundations and Applications of Self Systems* (FASW), (Augsburg, Germany, IEEE 2016): 154–59. https://doi.org/10.1109/FAS-W.2016.43 [accessed 15 November 2023].

Hogarth, W., *The Analysis of Beauty* (London: Printed by J. Reeves for the Author, 1753).

Ingold, T., *The Perception of the Environment* (London: Routledge, 2000).

Ingold, T., 'Culture on the Ground: The World Perceived Through the Feet', *Journal of Material Culture* 9(3), (2004): 319–40.

Küchler, S., and G. Were, *Pacific Pattern* (London: Thames and Hudson, 2005).

Larsen, J. L., *Interlacing: The Elemental Fabric* (New York: Kodansha USA Inc., 1987).

Leroi-Gourhan, A., *Gesture and Speech* (Cambridge, Massachusetts: Massachusetts Institute of Technology, 1993).

Lonsdale, S. H., *Dance and Ritual Play in Greek Religion* (Baltimore: Johns Hopkins University Press, 1993).

Malafouris, L., 'At the Potter's Wheel: An Argument for Material Agency', in C. Knappett and L. Malafouris, eds, *Material Agency: Towards a Non-Anthropocentric Approach* (Boston, MA: Springer, 2008), pp. 19–36.

Malafouris, L., *How Things Shape the Mind: A Theory of Material Engagement* (Cambridge Massachusetts: Massachusetts Institute of Technology, 2013).

Mauss, M., 'Techniques of the Body', 1935, in N. Schlanger, ed., *Techniques, Technology and Civilization* (Oxford, New York: Berghahn Books, 2006), pp. 77–97.

Merleau-Ponty, M., 'The Intertwining – The Chiasm', in M. Merleau-Ponty and A. Lingis, eds, *The Visible and the Invisible* (Evanston, Illinois: Northwestern University Press, 1969), pp. 130–55.

Mitchell, V., 'Braiding and Dancing: Rhythmic Interlacing and Patterns of Interaction', in S. Bunn and V. Mitchell, eds, *The Material Culture of Basketry* (London: Bloomsbury, 2020), pp. 245–53.

Noland, C., *Agency & Embodiment: Performing Gestures / Producing Culture* (Cambridge, MA: Harvard University Press, 2009).

Nutz, B., 'Drgens sn wir vs nvt schame – No Shame in Braiding: 15th Century Fingerloop Braids from Lengberg Castle', *Estonian Journal of Archaeology*, 18.2 (2014): 116–34.

OED online. Oxford University Press: http://www.oed.com (accessed 10 December 2019).

Robinson, C., 'Imports, Mechanisation and the Decline of the English Plaiting Industry: The View from the Hatters' Gazette, Luton 1873–1900', MA Thesis, University of Hertfordshire, 2016. https://uhra.herts.ac.uk/handle/2299/17623?show=full (accessed April 2020).

Scottish Country Dancing Dictionary. https://www.scottish-country-dancing-dictionary.com (accessed 10 December 2019).

Sheets-Johnstone, M., 'Movement and Mirror Neurons: A Challenging and Choice Conversation', *Phenomenology and the Cognitive Sciences*, 11.3 (2012): 385–401.

Sibthorpe, J., 'Manuscript Directions for Weaving Braids', in C. Richardson, T. Hamling, and D. Gaimster, eds, *The Routledge Handbook of Material Culture in Early Modern Europe* (Abingdon: Routledge, 2016), pp. 234–35.

Spencer, P., *Society and the Dance* (Cambridge: Cambridge University Press. 1986).

Speiser, N., *A Manual of Braiding* (Bern: Haupt Verlag, 1988, reprinted 2018).

Spuybroeck, L., ed., *Textile Tectonics* (Rotterdam: NAi Publishers, 2011).

Spuybroeck, L., *The Sympathy of Things: Ruskin and the Ecology of Design* (London: Bloomsbury, 2016).

Tarlo, E., *Entanglement: The Secret Lives of Hair* (London: Bloomsbury, 2016).

Tassie, G. J., 'The Hairstyles Represented on the Salakhana Stelae', in T. DuQuesne with S. Abdel Razak, E. S. Meltzer, J. M. Johnstone, and G. J. Tassie, eds, *The Salakhana Trove: Votive Stelae and Other Objects from Asyut* (London: Oxfordshire Publications in Egyptology 7, 2009), pp. 459–536.

Toadvine, T., 'The Chiasm', in S. Luft and S. Overgaard, eds, *The Routledge Companion to Phenomenology* (Abingdon: Routledge, 2011), pp. 336–47.

Tomaž, A., 'Depiction of Hairstyle, Reflection of Identity: Some Considerations Concerning Neolithic Depictions of Hairstyles in the Anzabegovo – Vršnik and Velušina – Porodin Cultural Milieu', *Documenta Praehistorica* XLIV (2017): 346–58.

Trewavas, A., *Plant Behaviour and Intelligence* (Oxford: Oxford University Press, 2014).

Varela, F. J., E. Thompson, and E. Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge Massachusetts: Massachusetts Institute of Technology, 1991).

Violi, P., 'Beyond the Body: Towards a Full Embodied Semiosis', in R. Frank, R. Dirven, T. Ziemke, and E. Bernardez, eds, *Body, Language and Mind,* Vol. 2 (Berlin: Mouton de Gruyter, 2008), pp. 241–64.

Wendrich, W., *The World According to Basketry: An Ethnoarcheological Interpretation of Basketry Production in Egypt*, CNWS publications no. 83 (University of Leiden: Research School of Asian, African and Amerindian Studies, 1999).

15

UNTANGLING KNOWLEDGE WORK BY MAYPOLE WEAVING WITH A PENELOPEAN ROBOT SWARM

David Griffiths

INTRODUCTION

THE PENELOPE PROJECT IS CONCERNED WITH UNTANGLING RELATIONSHIPS between the weaver's thought process while weaving, traces of this thought remaining within the textile, and the wider society in which this all takes place. When we study these relationships in the context of the ancient world, we are able to gain new perspectives on the hidden peculiarities of our own, contemporary culture.

When attempting to understand weaving in society, we need to confront assumptions of textile production and the roles involved. A weaver observed by an audience runs the risk of being misunderstood as an automaton; the repetition of actions used to manipulate symbolic information in threads (Harlizius-Klück 2015 and 2017) is easily read as a kind of absence of thought – 'mindlessly' following someone else's rules, at the lower levels of an imagined power structure. A computer programmer meanwhile, repetitively operating a keyboard in order to process symbols represented as glyphs on a screen – is the epitome of our society's current view of well paid and important 'knowledge work'. Such a worker is seen as a master of the world, highly trained in arcane arts.

Robots have a unique role in our culture: they are automata that follow someone else's rules – and yet we can all too easily assign agency to the simplest robots. We see them as an inescapable part of our future, and yet we are also wary of what they might do. Interventions involving robotics can take advantage of these cultural attributes to expose our social/technological assumptions in a unique way. A principle of the PENELOPE project is to design performances and artworks which present the weaver and weaving, and the programmer and code, in a way that asks questions about work, gender, technology and control.

The first instances of robotics in history are as artworks for performance. In the third-century BCE text *Liezi*, we find an account of Zhōu Mù Wáng, the fifth king of the Zhou dynasty of China, who was presented with a singing and dancing robot:

> As the performance was drawing to an end, the automaton winked his eye and made sundry advances to the ladies in attendance on the King. This, however, threw the King into a passion, and he would have put Yen Shih to death on the spot had not the latter, in mortal terror, instantly pulled the automaton to pieces to let him see what it really was. And lo! it turned out to be merely a conglomeration of leather, wood, glue and paint, variously coloured white, black, red and blue (Liezi 5.34, after Giles 1912: 91).

Robots have always provoked and challenged our understandings of agency: in the modern era, bomb disposal robots used in the military arena provide a stark example of how strongly we can relate to robots in our working life:

> Every time he was working, nothing bad ever happened. He always got the job done. He took a couple of detonations in front of his face and didn't stop working. One time, he actually did break down in a mission, and we sent another robot in and it got blown to pieces. It's like he shut down because he knew something bad would happen (Garreau 2007).

Our connections with automata do not seem to be reliant on their sophistication or similarity to living organisms such as ourselves: if anything, as with the bomb disposal robot above, the more utilitarian the robot, the more likely a sense of connection. Kacie Kinzer's small cardboard Tweenbots (Kinzer 2021) navigate Washington Square Park in New York by the use of a small flag that displays their destination. These vulnerable robots rely on the good will of passers-by to successfully reach the goal, by pointing them in the right direction or helping them when they become stuck under a park bench or drain.

This paper describes the use of robots to perform weaving – not as mechanical looms to be judged by the quality of the textile they produce, but as alien beings inserted between the weaver's mind and the act of traditional textile production.

PRACTICAL METHODS AND NOTATIONS OF WOVEN ROBOTICS

In this description we pay particular attention to the notation systems used in the design process, and use these notations to highlight the 'discontinuities' (Latour 2013: 41) in both the working process and the final systems. In doing so we aim to describe technology as a 'seamful' (rather than seamless) material.[1] This is common in weaving practice, where various levels of notation systems are required to describe, reason about and communicate a multi-layered technology.

PENELOPEan dancing robots are woven automata designed for choral dancing and maypole weaving. They are constructed using low cost materials and accessible techniques, including a tablet-woven structure to provide them with an overall form which is robust, flexible and soft. Critically, the woven form presents a very different technological narrative to more standard plastic 3D printing or aluminium extrusion. These robots can be programmed remotely by radio communication (either individually or broadcast to the whole 'swarm') and their dancing can be synchronised to musical beats for performances.[2]

INITIAL ROBOTICS WORKSHOP IN THE PENELOPE LABORATORY

We began this investigation with a workshop, with the help of Christian Faubel in our PENELOPE Laboratory (Harlizius-Klück 2019). Here, members of the research team constructed various different forms of robots, using custom electronics and off the shelf standard parts (Lego Mindstorms), both digital and analogue, (Faubel 2016) control circuitry and a variety of different locomotion methods.

At the end of the workshop, we set up a small maypole during the opening hours of the Museum for Casts of Classical Sculptures where the lab is situated. We attached the robots to the pole with ribbons, to allow them to interact and tangle 'weaves' together. We then observed participants watching the resulting dance, and found that our legged robot prototypes elicited stronger reactions of empathy and attachment than our wheeled ones. There was a tendency for observers to intervene and 'help out' legged robots that was absent from those that 'looked a bit like cars'. Walking robots are more challenging to construct, but as our objective is to question attitudes to agency, these responses are important to explore.

THE SHOPPING LIST

The role of Then Try This[3] in the PENELOPE project is to facilitate technological investigations by designing and building artefacts that can be used to carry our experiments and artistic interventions. PENELOPEan robots have 3 pairs of legs, each able to rotate on one axis. Their basic components comprise cheap, easily obtainable components:

- Tablet-woven flexible structure holding everything together (see below)
- 3 SG92R micro servos to drive the legs
- 3.7v li-ion battery
- NRF24L01 radio module for remote control/programming
- GY91 accelerometer/gyro/compass sensor module
- Custom Atmega328 main PCB
- Radio, sensor and servo breakout secondary PCB
- 3 laser-cut ply leg pairs
- 2mm diameter wire to provide rigidity
- Extra yarn to stitch everything together

A NOTATION FOR TABLET WEAVING

PENELOPEan robots are constructed using tablet-weaving (Collingwood 2015), an ancient technology dating back to at least the sixth century BCE and probably earlier (Priest-Dorman 1999). Tablet looms are simple to set up, and consist of a stack of easily constructed square cards with holes punched in the corners, through which the warp yarn passes.

Usually, tablet-weaving produces a strong braid. For the robot structures a technique known as 'Icelandic double weave' is used (Collingwood 2015: 158), where the cards are rotated at 45 degrees and use two wefts at the same time. This allows us to split the weave into doublecloth, to create more complex three-dimensional forms that we can use to support all the components for our robot.

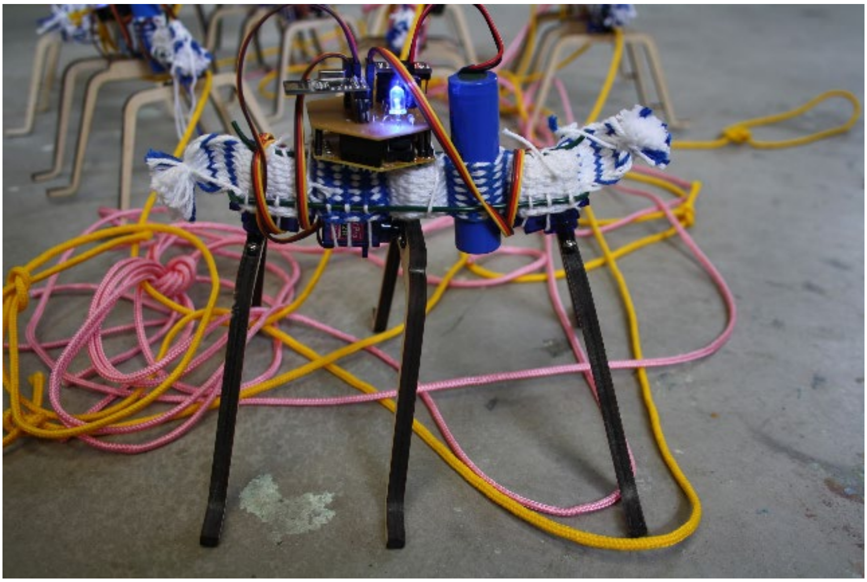


FIG. 15.1 Final robot form (photo by David Griffiths in 2019)

We used 100% cotton yarn and measured out roughly ten wefts to hold the SG92R micro servo and eight wefts for the 18mm diameter cylindrical battery. In order to record and notate the weaving process required, we used the following notation:

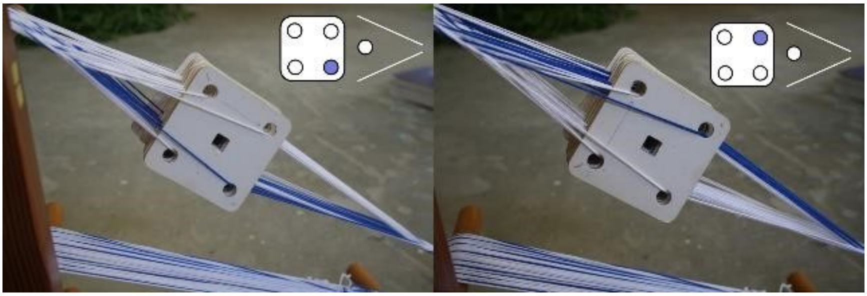


FIG. 15.2 Symbols used to describe these two tablet orientations. The blue warp thread is used as an indicator (photo and graphics by David Griffiths in 2019)

This describes the tablets, warp and weft threads, seen from the side – the tablet is set up so a single colour indicator warp yarn is threaded through one corner of the tablet, which enables us to keep track of the rotation at each step. The weft is repeatedly inserted after each 90° rotation.

So far, this can be described by traditional tablet-weaving notation; however, in order to describe Icelandic double weave we need to allow for two wefts and a 45° offset rotation. Between each (double) weft, we still rotate the tablets 90 degrees, but only once back and once forward – the creates the two separate fabrics:

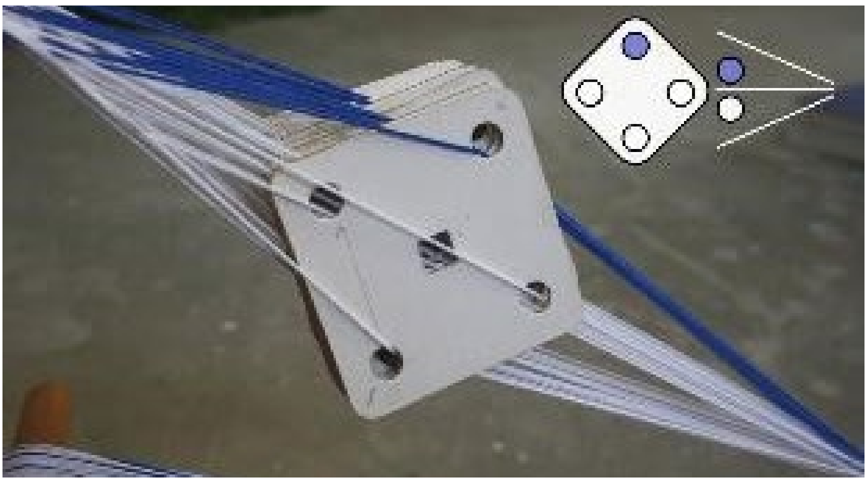


FIG. 15.3 Symbol used to describe tablets in an Icelandic double weave orientation, where we can use two wefts in the two sheds provided in the warp (photo and graphics by David Griffiths in 2019)

If we keep turning two more times and then repeat the split weave, we can pass one side of the double weave through the textile and 'weave' the structure through itself to create separate sections.

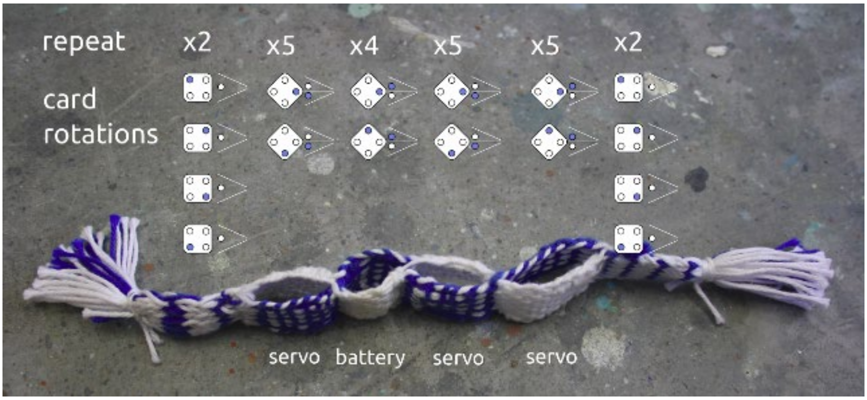


FIG. 15.4 Full notation for a PENELOPEan robot (see text) (photo and graphics by David Griffiths in 2019)

Given this notation system, we can record the steps required for a PENELOPEan robot in full. We begin with a supporting weave, using normal single weft weaving for 8 wefts (two times four 90° card rotations), and then start splitting to hold the 3 servos and a battery, along with a supporting spacer to make the legs equidistant, which is needed to improve walking performance (4 or 5 wefts each). We finish with a final supporting weave of 8 wefts at the end.

As the structure is woven into the fabric rather than being stitched afterwards, it is extremely strong and able to cope with the forces involved. This turned out to be important during events when the robots were handled by lots of children. The final stage is to stitch the components into the structure to hold them in place, and add some thick wire to give the legs something to push against.

A NOTATION FOR WALKING

The robot's front and back legs move in the 'yaw' axis, while the central legs move in the 'roll' axis with respect to the robot. Broadly, this arrangement allows the front and back legs to be used to drive the motion, while the central legs are used to select which feet on either side are touching the ground at any time as they sweep backwards and forwards. By changing the phase of the central legs, it is possible to change the direction the robot is walking in. The central legs can be used to more precisely control the friction of the feet with the floor, to rotate it gradually for turning or more quickly for on-the-spot turns.

In order to describe and experiment with all the different motion types possible, each servo is controlled via a 'movement pattern sequencer' which interprets symbols that represent angles of rotation. This is partly designed to simplify synchronisation with music and movement across the entire swarm.

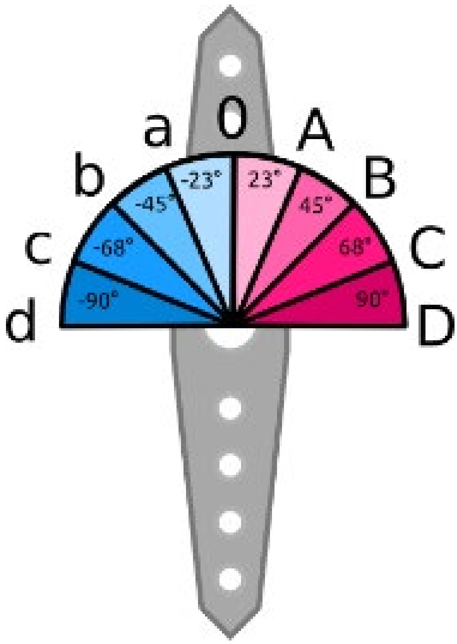


FIG. 15.5 180° servo rotation represented as symbols (graphics by David Griffiths)

Each pattern consists of 12 symbols, split into three patterns of four symbols for each of the three servos (front, middle and back). This seems to be the minimum we need to describe the range of motions required. The full servo range is 180 degrees, and we use 'A', 'B', 'C' and 'D' to refer to clockwise rotation up to 90 degrees from the servo's central position (so 23, 45, 68 and 90 degrees) while 'a', 'b', 'c' and 'd' symbols refer to the same angles in the counterclockwise direction. '0' sends the servo back to its central position.

Various patterns (found mostly via experimentation) are predefined for convenience:

front middle back

walk-stop: "0000 0000 0000"
walk-forward: "AAaa AaaA AAaa"
walk-backward: "AAaa aAAa AAaa"
turn-left: "AAaa 0CC0 aaAA"
turn-right: "AAaa C00C aaAA"
turn-left-fast: "AAaa 0DD0 aaAA"
turn-right-fast: "AAaa D00D aaAA"
silly: "AaAa AaAa AaAa"

Turning on the spot is a more complex sequence where momentum is built up by the 'driving' legs and controlled by the central one to swing the robot around. As this procedure is dependent on many variables we cannot control (for example, the texture of the floor) we can use a magnetometer sensor as a compass to accurately keep track of the rotation achieved by each step.

A NOTATION FOR DESCRIBING ROBOT BEHAVIOUR

One of the challenges of working with a robot swarm is to update and distribute code changes to them. We use 'Yarn', a new live coding language and system made for the PENELOPE project, where compiled bytecode (Bovermann and others 2014) can be broadcast over radio in small packets and written directly to each robot's memory. This bytecode can be halted, reset or run via separate radio messages and is isolated from the robots' other processes, which need to take care of polling the radio for incoming data, controlling the servos and reading sensors. This means we can program, debug and experiment with multiple robots easily, by sending them messages over the air.

The bytecode is compiled from a variant of the Lisp language family providing typical constructs for conditionals, looping and a full function call stack with local argument variables. It is designed to be implemented on the very small processors we are using on-board the robots.

The Yarn language provides access to a set of registers that describe and control the current state of the robot. These include the servo movement sequencer above, and incoming sensor information. Registers can be altered in order to change the current walking pattern or light up their indicator LED.

One of the important registers is 'next-pattern' which selects the walking pattern from the list above, for example to trigger a forward walking movement is very simple:

```
(set! next-pattern walk-forward)
```

or to stop the robot moving:

```
(set! next-pattern walk-stop)
```

All servo movement timing is decoupled from the code so it can be synchronised externally across all the robots, so we include a 'step count' register to keep track of what is going on. This can be reset via another register, so we can, for example, wait for a number of steps to be carried out before resetting and continuing. This program moves the robot 5 steps forward, then moves it 5 steps backwards and then repeats:

```
(forever
(set! step-count-reset 1)
(while (< step-count 5)
(set! next-pattern walk-forward))
(set! step-count-reset 1)
(while (< step-count 5)
(set! next-pattern walk-backward)))
```

Similar registers are provided so angular rotation or accelerometer movement values can be checked and used to trigger different actions or behaviours. Various servo parameters such as speed or movement smoothing can be modified too.

One of the most complex behaviours to model is at the higher choreographic level – for example, setting up two groups of dancers walking in opposite directions (see figure 15.6), where one group needs to politely wait for the other to finish before they can continue.

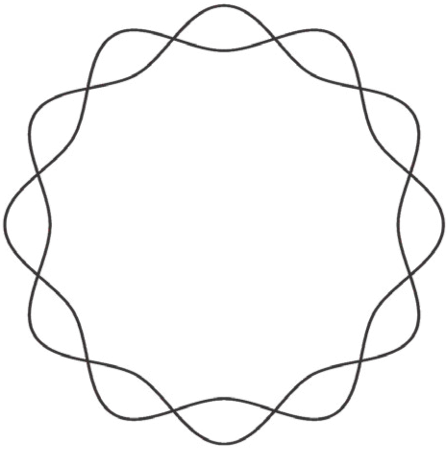


FIG. 15.6 Track for 12 pairs of maypole dancers (graphics by Viktoria Lubomski in 2010)

We model this by using a register as a 'ready' semaphore that is used both to trigger the robots to start walking in a group, as well as to signal that they have reached their destination:

```
(forever
(while (not ready-semaphore) ;; wait for external signal
(set! led 1))
;; now we can start walking
(set! led 0)
(set! step-count-reset 1)
(set! next-pattern walk-forward)
```

(while (< step-count 8)) ;; wait for 8 steps
(set! next-pattern walk-stop) ;; stop walking
(set! ready-semaphore 0)) ;; signal that we have finished

A NOTATION FOR DANCING TOGETHER IN A PANDEMIC

During the year 2020, a new extension to the Yarn programming language was developed to make the robot language more accessible, and allow the robots to be live coded online using a visual 'block based' language. This was a reaction to the coronavirus pandemic, which interrupted our plans for performances with physically present audiences (more on this below). Each participant could be paired with their own robot, which could be viewed as part of a larger collaborative dance via online video streaming.

To achieve this, Google's Blockly system (Seraj and others 2019) was adapted to generate Yarn lisp code. A Raspberry Pi fitted with the NRF24L01 radio module served a web-based application for participants using standard web browsers to remotely create robot programs. Using this interface, participants could choose an individual robot and click on a 'Transmit' button to send the

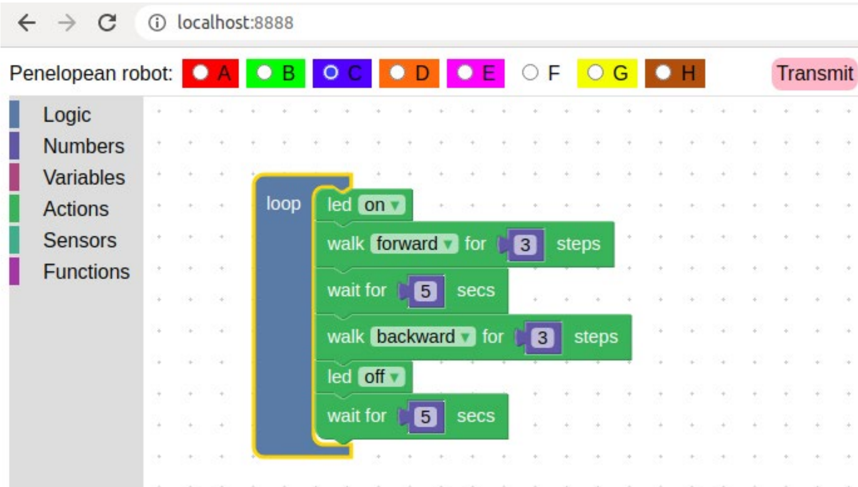


FIG. 15.7 Remote robot programming interface to be used alongside video conferencing so you can see your robot respond to your code changes (screenshot by David Griffiths)

compiled code to it. We attached markers to the robots so they could be picked out on the video feed by colour and letter. The interface provided rapid feedback on failure, such as a robot being out of radio range. With everything running on a single Raspberry Pi, we were able to reduce the network message-compile-transmit-acknowledge loop to under a second, even with eight people using it at the same time.

An advantage of this kind of block-based visual programming is that it is impossible to create syntactically incorrect code. This is why they are commonly used in educational settings (Maloney and others 2010) and are fully featured languages in their own right. We could use the blocks to encapsulate common behaviours that made it more convenient for people to sequence their robot's actions.

We could use Yarn blocks to easily expose all the features in the robots' registers, including their walk speed and individual servo controls. These turned out to be important so participants could learn to fine-tune their programs for their individual robots using trial and error. Here is a more complex example using one of the robot's motion sensors as input – checking the current magnetometer compass heading to create a program which will gradually adjust its aim to walk in a southerly direction:

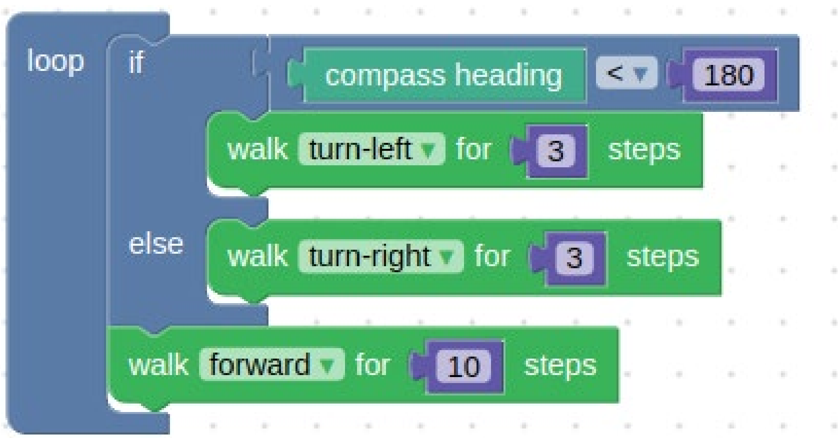


FIG. 15.8 A code example including the use of a magnetometer sensor for orientation detection (screenshot by David Griffiths)

RESULTS

A series of performances was undertaken where the robots (acting as reimagined choral dancers from Greek antiquity) were presented alongside a recitation of Classical Greek poetry by Giovanni Fanfani and a live coded music (Collins and others 2003) performance by Alex McLean. For Giovanni's poetry recital we use two pieces: Homer, *Iliad* 18.590–603, and Sophocles, *Oedipus the King* 883–910. The Sophocles passage presents a specific form of metrical transformation known as *epiplokē* (McLean and others 2018), which we rhythmically blend with the live coded music inspired by contemporary musical instruments and sounds. We also used the robots in installation form over a longer duration, facilitating audience interaction with them. To aid in this endeavour, in later performances the robots were programmed to move sporadically, with two groups taking turns as explained above – this created pauses during which the robots fell still, giving people an opportunity to pick them up and adjust their positions, as a form of audience-lead choreography. A third form of performance was created under pandemic lockdown conditions, where a maypole was constructed for remote participation, with the robots individually live coded by the participants via an online interface. This was designed both as an educational introduction to programming, and a chance to 'dance together' in the same space while remaining socially distant.

PERFORMANCES IN THE MUSEUM FOR CASTS OF CLASSICAL SCULPTURES

The debut appearance of the PENELOPEan robots occurred during Sandra De Berduccy's opening event for 'AWAY | TAKIY – Raise the Curtain for Weaving' at the Museum for Casts of Classical Sculptures, Munich.[4] The audience consisted of students, researchers and museum visitors in the context of a comparative display of ancient Greek and pre-Columbian Andean weaving. The improvised musical live coding was based around rhythms matched with the poetry recital. The robots were synchronised together, but not directly with the music; their movements were controlled using a 'pattern matrix', a tangible interface where

12 tokens represented the simple and lowest level servo movement notation explained above. Six robots were arranged in a circle and were instructed to move synchronised together, gradually at first – slowly building up to a walking pattern which disrupted their initial circular configuration until they wandered among the audience for some time after the performance had finished.

FIG. 15.9 Opening performance for 'AWAY | TAKIY – Raise the Curtain for Weaving' at the Museum for Casts of Classical Sculptures, Munich (photo by Giovanni Fanfani in 2018)

A second performance took place in the same location with a private audience consisting of students from a local university. The poetry recital and live coding improvisation was similar to the first performance, but the robots' activity was simpler in that they were given an initial walking movement and left to wander unaided among the audience during and after the performance.

ALGOMECH MAYPOLE PERFORMANCES

The third and fourth performances occurred during the 2019 AlgoMech festival.[5] Here we used a maypole to include a form of tangling or braiding into the results of the robots' movement, incorporating all the elements of poetry, dance and weave inherent in ancient Greek performances. The location was the Sheffield Winter Garden – a covered public garden in the city centre, and the performing lasted over the course of two days. The audience on both days consisted of a mix of engaged festival participants and groups who happened to be passing by, from young families to pensioners. The maypole was approximately 3 metres high, with each robot attached with ribbon and arranged in two opposing circular formations. The music, poetry and robotic movements in these performances were all synchronised.

Before and after the performances, the robots were left slowing weaving and unweaving for several hours. During this time passers-by, mostly children, parents and people interested in technology interacted and played with the robots. As we found previously, they found that they could help by guiding them – repositioning them when they became tangled or fell over, and also by changing their direction in order to alter the patterns on the maypole. The tangles and twists left behind represented a record of the movements and choices of previous

FIG. 15.10 Maypole performance at Algomech 2019, Wintergarden of Millenium Gallery, Sheffield (photo by Giovanni Fanfani in 2019)

participants. The robots took approximately half an hour to fill the maypole up, and the same to un-weave back to their starting positions. At some points, up to 12 people were interacting with the installation together, while others sat patiently watching the progress of the weaving[2] for several weave/unweaves.

DANCING TOGETHER SAFELY AROUND A MAYPOLE

Having worked extensively to make the most of tangible and tactile forms of technology, we found in 2020 that we had to re-evaluate our approaches during the coronavirus pandemic. The necessity of social distancing and new acceptance of online streaming gave us an opportunity to adapt the maypole performance with the development of 'Yarn blocks' and work on a far more accessible and direct form of interaction with the robots' underlying code.

This activity took the form of a lecture for Masters students covering the historical and critical underpinnings of the PENELOPE project, followed by a maypole workshop. The students, who had no previous experience of programming, were split into two groups of 8 and 7 people, so we could assign individual robots to everyone. These two sessions lasted 90 minutes, and participants could start by sending code to flash the LED on their robot to make sure they were looking at the right one. They progressed from simple remote control of their walking behaviour to coordinated and timed actions in conjunction with the other participants. At the end we could inspect the tangle/weave that resulted. Due to the greater complexity and therefore freedom of movement of the robots, all behaving differently, these tended to be more complicated (and take longer to unwind) than the previous single direction twisting.

Feedback from the students included the desire to have individual camera views for their robots, multiple camera angles and many more robots and participants.

CONCLUSION

Several practical observations can be made for the use of PENELOPEan robots in the context of historically embedded live coding performance. The woven

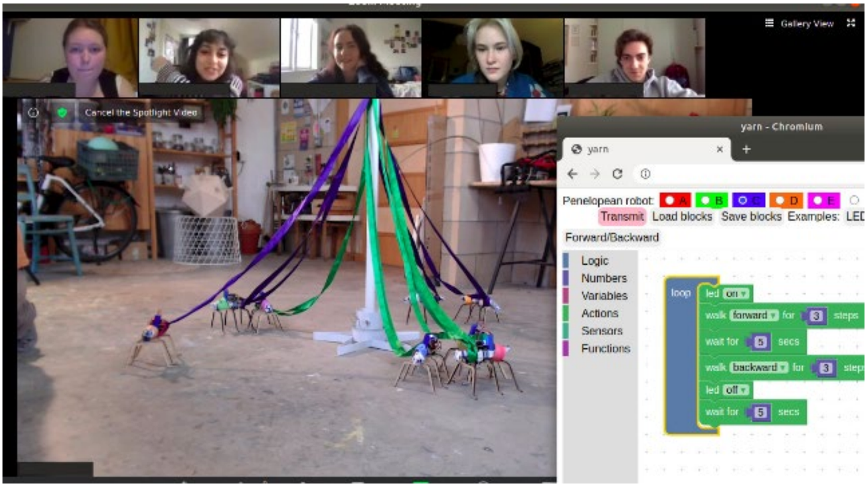


FIG. 15.11 Remote maypole coding-dancing as part of a lecture on weaving and code (screenshot by David Griffiths in 2021)

structure and electronics survived hours of play and interaction with small children – the flexibility of their tablet-woven construction meant they could cope with the dangers of a public space including being occasionally trodden on or knocked over. The batteries lasted for the entire duration of the installation and could be recharged overnight.

More importantly, both the performance and installation worked as a kind of public intervention to encourage discussion – particularly amongst the less 'already engaged' passers-by who were not expecting to see such a spectacle during their normal daily routine.

Discussions often began with the nature of the robots themselves, a comparison with more 'scary' depiction of robots presented on film or used in military research. Topics cropping up in discussion included whether these robots contained artificial intelligent algorithms, and what the meaning or expectations of that really was. Importantly, the woven technique could be recognised by people with a background in textiles, and the familiarity of material in general meant that people were likely to pluck up the courage to pick the robots up for closer inspection. There seemed to be a general feeling that they 'could probably make them if they wanted to' – which represents an important and distinct response compared to most contemporary technological devices.

Longer discussions were had on the nature of work, the history of technology and its disruption, particularly in Sheffield which has an industrial history of significant technological change well within living memory. The ancient Greek topics were surprisingly present in many discussions with the younger audience, relating it to their school education.

The development of the remote maypole weaving, although an adaptation made necessary by the pandemic, represented an important step, as for the first time we could provide participatory live coding of a robot to create a weave.

. . .

Our maypole robots provide a way to present weaving as a complex technological feat, one where the weaver's role becomes one of managing a collection of robots that seem barely up to the job – to the extent that they even require additional human assistance to occasionally help them out. The 'automata' are now in clear view, not to be confused with the humans, who are still very much required. The 'weaving' itself, can barely be called that: it is more a collection of tangles. While it would be possible to design more complex choreographies, capable of weaving more consistent braids, this seems less important than the overall message.

We know very little about the choral dances of Greek antiquity. Only tantalising hints from ceramic vase painting and frieze sculptures remain, alongside incomplete texts (Fanfani 2018). These robotic performances can also be seen as a type of experimental archaeology, where we try to fill in some of the gaps in our knowledge with contemporary technology, designed with much care – but representing a clear and humble admission of a lack of knowledge. This allows us to invite our audience to suspend their disbelief, which leads to further considerations. One of the most important of these is that, by incorporating dance, textile production and music of the ancient world, we are continuing a tradition of transdisciplinary life. In some ways this is the most challenging and even jarring aspect for us to understand and accept today – that in the past, people inhabited a world where intimate knowledge of the materials and techniques needed for their civilisation, textiles included, was diffused throughout society (Öhrman, 2018). This meant that their technology could form a central role in their philosophical framework, with weaving specifically expressing the notion of 'cosmos' via the interlacing of warp and weft (Harlizius-Klück and Fanfani 2016). This compares with the rather fragile system of specialist technological knowledge that exists today (Guzdial 2019), and the challenges we face with its uneven distribution that can be problematic for social cohesion (Wylie, 2020).

ENDNOTES

1 In an interview with Sam Hart, critical engineer Julian Oliver argues that we should look for seams in technology: 'The ideology of seamlessness associated with "cloud" technologies, these children's book metaphors (I would argue patronizing metaphors), are intrinsically disempowering and are designed as such. So if you can actually produce the seams that tie these technologies together, then you are being culturally, socially, and critically productive.' http://avant.org/artifact/julian-oliver/.
2 Fanfani and others 2020; see also McLean's chapter 13 'Algorithmic Patterns' in the present publication.
3 Then Try This replaced the name FoAm Kernow under which we began our cooperation with the PENELOPE project.
4 In September 2018, the Bolivian weaver and media artist Sandra De Berduccy worked in the PENELOPE laboratory to produce an interactive textile installation while the project team explored the algo-rhythmic and arithmetic properties of ancient pattern weaving and choral lyric. The final exhibition, entitled 'AWAY | TAKIY – Raise the Curtain for Weaving' presented her artwork as well as an experimental interactive performance with the pattern-matrix-controlled PENELOPE robots dancing to the algo-rhythm of ancient Greek poetry. The exhibition functioned as a pre-opening to RODEO Munich, a dance festival supporting our collaboration. In addition, the visit of De Berduccy was funded by a residency at the Ebenböckhaus of the city of Munich, and by the Goethe Institute Bolivia.
5 The third AlgoMech Festival on Algorithmic and Mechanical Movement took place in Sheffield, 17–19 May 2019, see https://algomech.com/2019/.

REFERENCES

Bovermann, T., and D. Griffiths, 'Computation as Material in Live Coding', *Computer Music Journal*, 38.1 (2014): 40–53.

Collingwood, P., *The Techniques of Tablet Weaving* (Brattleboro, VT: Echo Point Books & Media, 2015).

Collins, N., A. McLean, J. Rohrhuber, and A. Ward, 'Live Coding in Laptop Performance', *Organised Sound*, 8.3 (2003): 321–30. https://doi.org/10.1017/S135577180300030X.

Fanfani, G., 'Craftsmanship and Technology as Chorality: The Case of Weaving Imagery in Archaic and Classical Choral Lyric', *Dionysus Ex Machina*, 1.9 (2018): 6–40. https://doi.org/10.5281/zenodo.2553430.

Fanfani, G., D. Griffiths, E. Harlizius-Klück, A. Mamidipudi, and A. McLean, '(Micro-)Performing Ancient Weaving in the PENELOPE Project', *Performance Research*, 25.3(2020): 123–30. https://doi.org/10.1080/13528165.2020.1807772.

Faubel, C., 'Machine-Machine Communication without Hierarchies and Protocols', *Proceedings of the Fourth Conference on Computation, Communication, Aesthetics and X*, (Bergamo, 2016): 201–10.

Garreau, J., 'Bots on The Ground', 6 May 2007. http://www.washingtonpost.com/wp-dyn/content/article/2007/05/05/AR2007050501009.html.

Guzdial, M., 'Computing Education as a Foundation for 21st Century Literacy', *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, 502–3. SIGCSE '19. New York, NY, USA: Association for Computing Machinery, 2019. https://doi.org/10.1145/3287324.3290953.

Harlizius-Klück, E., 'Against All Odds: Pure Science and Ancient Weaving', in K. Grömer and F. Pritchard, eds, *Aspects of the Design, Production and Use of Textiles and Clothing from the Bronze Age to the Early Modern Era: Nesat XII. the North European … in Hallstatt, Austria*, Bilingual edition (Budapest: Archaeolingua, 2015): 271–77.

Harlizius-Klück, E., 'Weaving as Binary Art and the Algebra of Patterns', *TEXTILE*, 15.2 (2017): 176–97. https://doi.org/10.1080/14759756.2017.1298239.

Harlizius-Klück, E,. and Fanfani, F., '(B)orders in Ancient Weaving and Archaic Greek Poetry', in G. Fanfani, M. Harlow and M.-L. Nosch, eds, *Spinning Fates and the Song of the Loom. The Use of Textiles, Clothing and Cloth Production as Metaphor, Symbol and Narrative Device in Greek and Latin Literature* (Oxford: Oxbow, 2016), pp. 61–99. https://zenodo.org/record/840005.

Harlizius-Klück, E., 'Das PENELOPE-Labor', in A. Schmölder-Veit and N. Schröder-Griebel, eds, *Lebendiger Gips: 150 Jahre Museum Für Abgüsse Klassischer Bildwerke München*, (Munich: Propylaeum, 2019), pp. 166–71. https://doi.org/10.11588/PROPYLAEUM.549.

Kinzer, K., 'Tweenbots'. http://www.tweenbots.com/ (accessed 30 April 2021).

Latour, B., *An Inquiry into Modes of Existence: An Anthropology of the Moderns* (Cambridge, Massachusetts: Harvard University Press, 2013).

Giles, L., *Taoist Teachings from the Book of Lieh Tzŭ* (London: Murray 1912).

Maloney, J., M. Resnick, N. Rusk, B. Silverman, and E. Eastmond, 'The Scratch Programming Language and Environment', *ACM Transactions on Computing Education*, 10.4 (2010): 16:1–16:15. https://doi.org/10.1145/1868358.1868363.

McLean, A., G. Fanfani, and E. Harlizius-Klück,'Cyclic Patterns of Movement Across Weaving, Epiplokē and Live Coding' *Dancecult. Journal of Electronic Music Dance Culture*, 10.1 (2018): 5–30. https://doi.org/10.12801/1947-5403.2018.10.01.01.

Öhrman, M., 'The Singing Loom: The Importance of Textile Production in the Roman Domestic Soundscape', *Archaeoacoustics Lll: Proceedings of the Third International Multidisciplinary Conference*, 3 (OTS Foundation, 2018): 143–50. http://www.otsf.org/contact.html.

Priest-Dorman, C., 'Scutulis Dividere Gallia: Weaving on Tablets in Western Europe', *Creating Textiles: Makers, Methods, Markets. Proceedings of the Sixth Biennial Symposium of the Textile Society of America, New York 1998* (Earleville MAD: Textile Society of America, 1999): 51–60.

Seraj, M., E._S. Katterfeldt, K. Bub, S. Autexier, and R. Drechsler, 'Scratch and Google Blockly: How Girls' Programming Skills and Attitudes Are Influenced', *Proceedings of the 19th International Conference on Computing Education Research*, Koli Calling '19 (New York: Association for Computing Machinery, 2019): 1–10. https://doi.org/10.1145/3364510.3364515.

Wylie, C., *Mindf*ck: Cambridge Analytica and the Plot to Break America* (New York: Random House, 2019).

MATTERING PRESS TITLES

Technoscientific Globalisation from Below
EDITED BY MATHIEU QUET, KOICHI KAMEDA, JESSICA POURRAZ AND YVES-MARIE RAULT-CHODANKAR

The Ethnographic Case: Second Edition
EDITED BY EMILY YATES-DOERR AND CHRISTINE LABUSKI

Democratic Situations
EDITED BY ANDREAS BIRKBAK AND IRINA PAPAZU

Concealing for Freedom: The Making of Encryption, Secure Messaging and Digital Liberties
KSENIA ERMOSHINA AND FRANCESCA MUSIANI

Engineering the Climate: Science Politics, and Visions of Control
JULIA SCHUBERT

Environmental Alterities
EDITED BY CRISTÓBAL BONELLI AND ANTONIA WALFORD

With Microbes
EDITED BY CHARLOTTE BRIVES, MATTHÄUS REST AND SALLA SARIOLA

Energy Worlds in Experiment
EDITED BY JAMES MAGUIRE, LAURA WATTS, AND BRITT ROSS WINTHEREIK

Boxes: A Field Guide
EDITED BY SUSANNE BAUER, MARTINA SCHLÜNDER AND MARIA RENTETZI

An Anthropology of Common Ground: Awkward Encounters in Heritage Work
NATHALIA SOFIE BRICHET

Ghost-Managed Medicine: Big Pharma's Invisible Hands
SERGIO SISMONDO

Inventing the Social
EDITED BY NOORTJE MARRES, MICHAEL GUGGENHEIM AND ALEX WILKIE

Energy Babble
ANDY BOUCHER, BILL GAVER, TOBIE KERRIDGE, MIKE MICHAEL, LILIANA OVALLE, MATTHEW PLUMMER-FERNANDEZ, AND ALEX WILKIE

The Ethnographic Case
EDITED BY EMILY YATES-DOERR AND CHRISTINE LABUSKI

On Curiosity: The Art of Market Seduction
FRANCK COCHOY

Practising Comparison: Logics, Relations, Collaborations
EDITED BY JOE DEVILLE, MICHAEL GUGGENHEIM, AND ZUZANA HRDLIČKOVÁ

Modes of Knowing: Resources from the Baroque
EDITED BY JOHN LAW AND EVELYN RUPPERT

Imagining Classrooms: Stories of Children, Teaching and Ethnography
VICKI MACKNIGHT